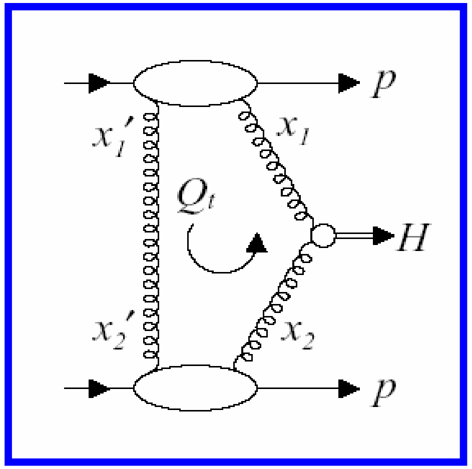
Forward Physics at the LHC
The High Luminosity part



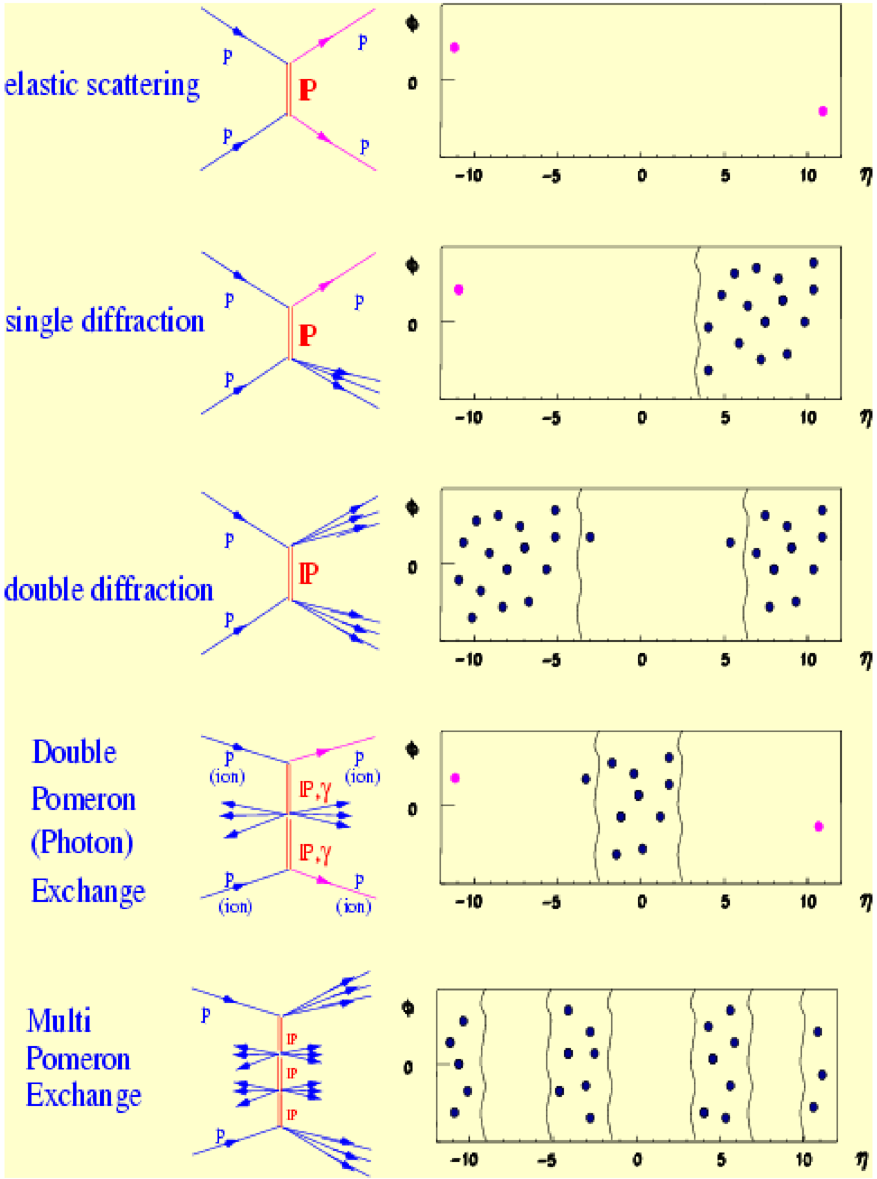
Albert De Roeck (CERN)

QCD at the Highest Energies

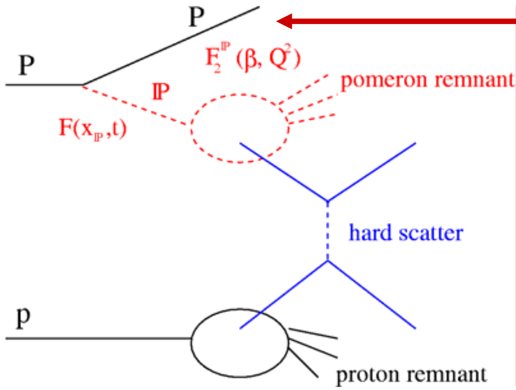
Skopelos, Greece

September 2005

Diffraction at LHC:



- PP scattering at highest energy
- Soft & Hard Diffraction



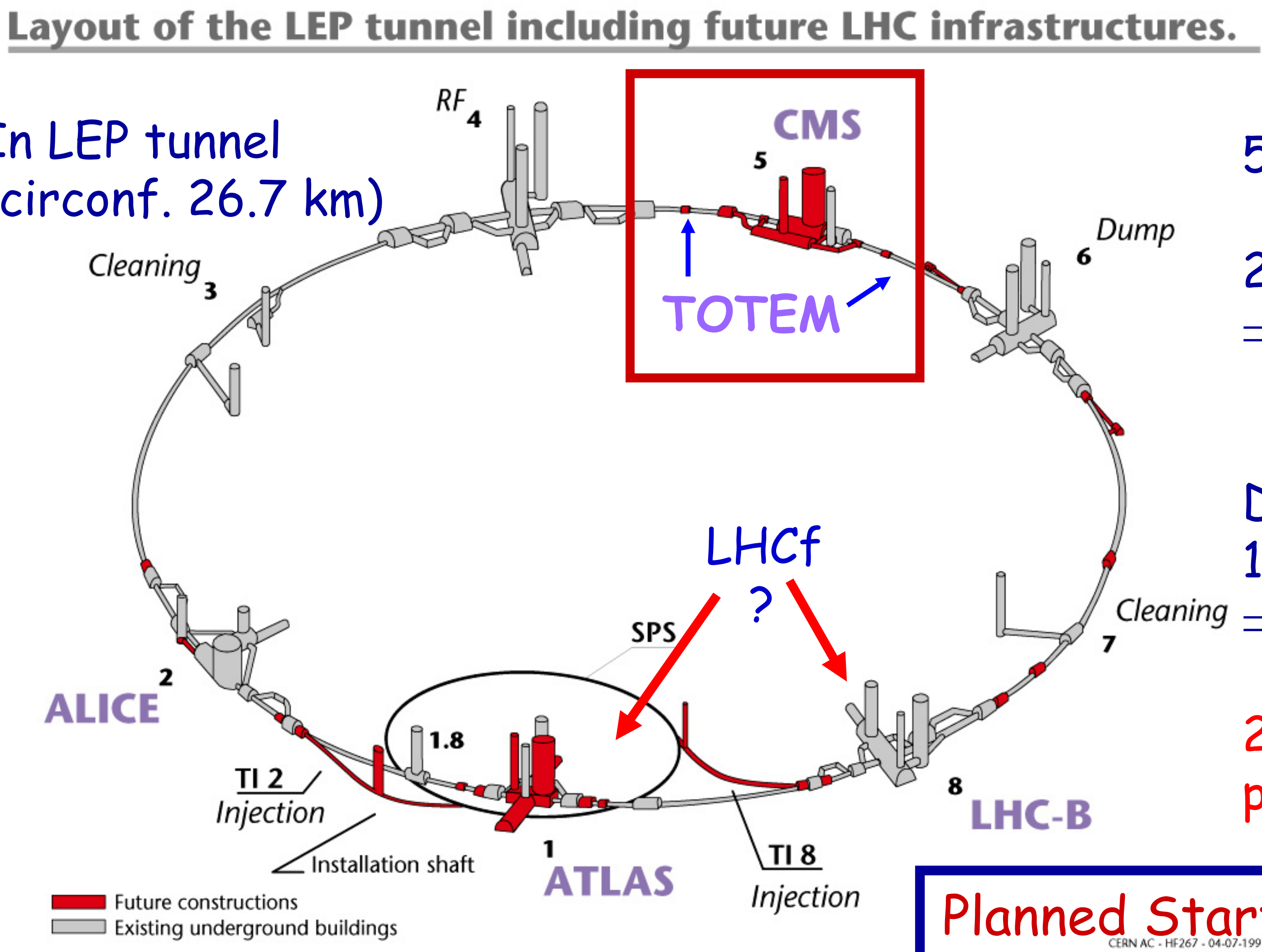
ξ = proton momentum loss
Reconstruct ξ with roman pots

ξ < 0.1 $\Rightarrow$ O(1) TeV "Pomeron beams"
E.g. Structure of the Pomeron $F(\beta,Q^2)$
β down to ~ 10^{-3} & Q^2 ~10^4 GeV^2
Diffraction dynamics?
Exclusive final states ?

- Gap dynamics in pp presently not fully understood!

The Large Hadron Collider (LHC)

In LEP tunnel
(circonf. 26.7 km)



PP collisions at
$\sqrt{s}$ = 14 TeV

5 experiments

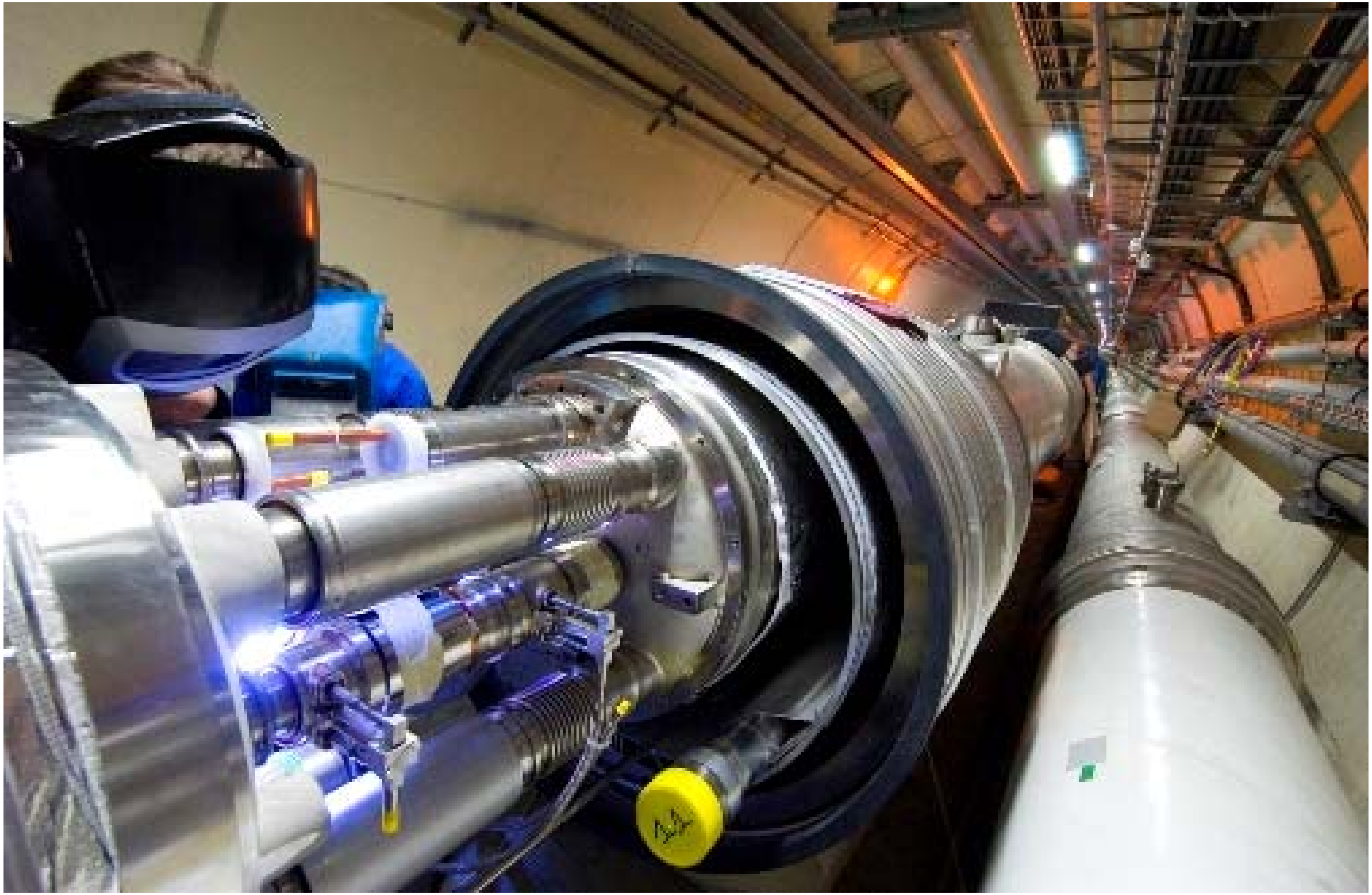
25 ns bunch spacing
$\Rightarrow$ 2835 bunches
10^{11} p/bunch

Design Luminosity:
$10^{33}cm^{-2}s^{-1}$ - $10^{34}cm^{-2}s^{-1}$
$\Rightarrow$100 fb^{-1}/year

23 inelastic events
per bunch crossing

Planned Startup: Summer 2007

The LHC is Coming!



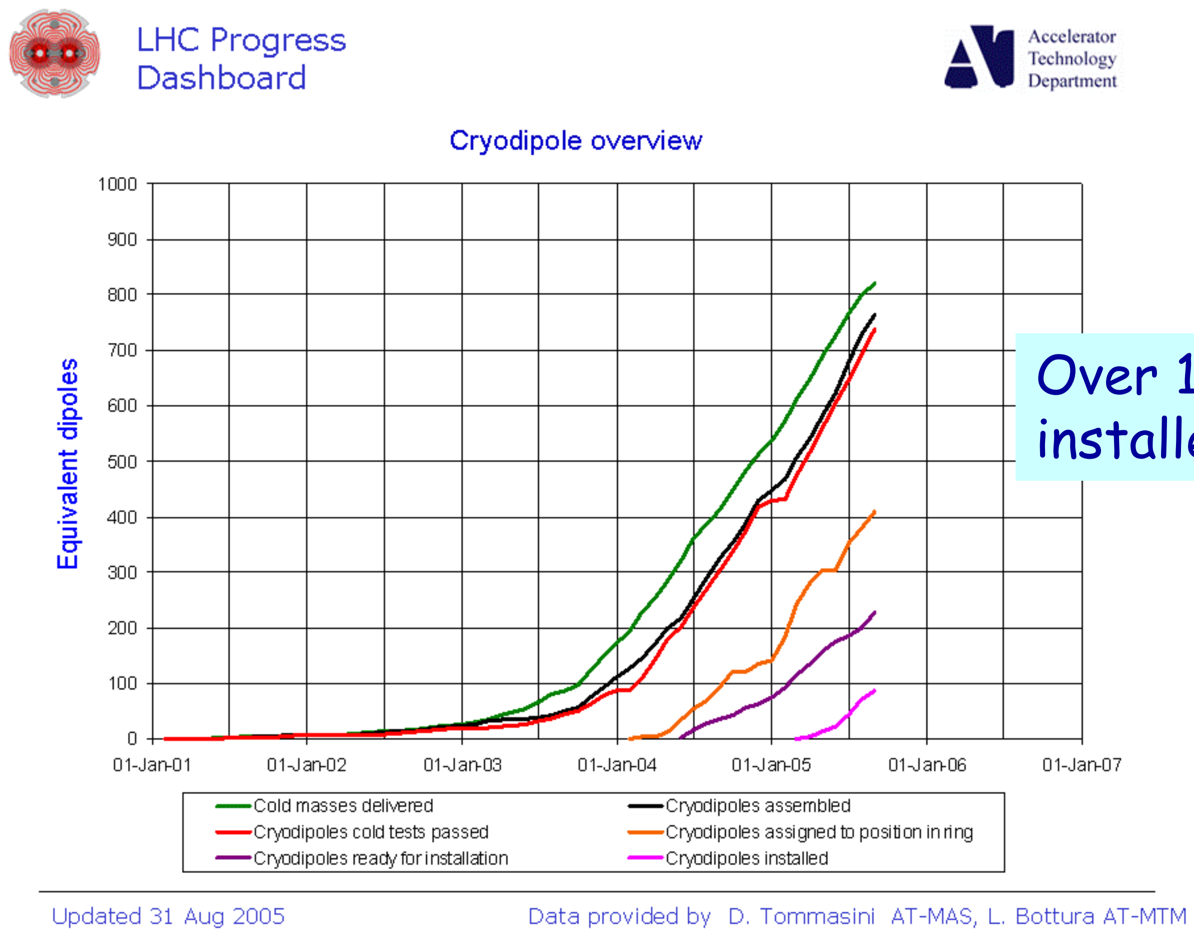
Dipoles: Waiting to be lowered after QRL repair

Transport in the tunnel

7th of March 2005
Lowering of the first dipole

Installing the dipole

The LHC Progress

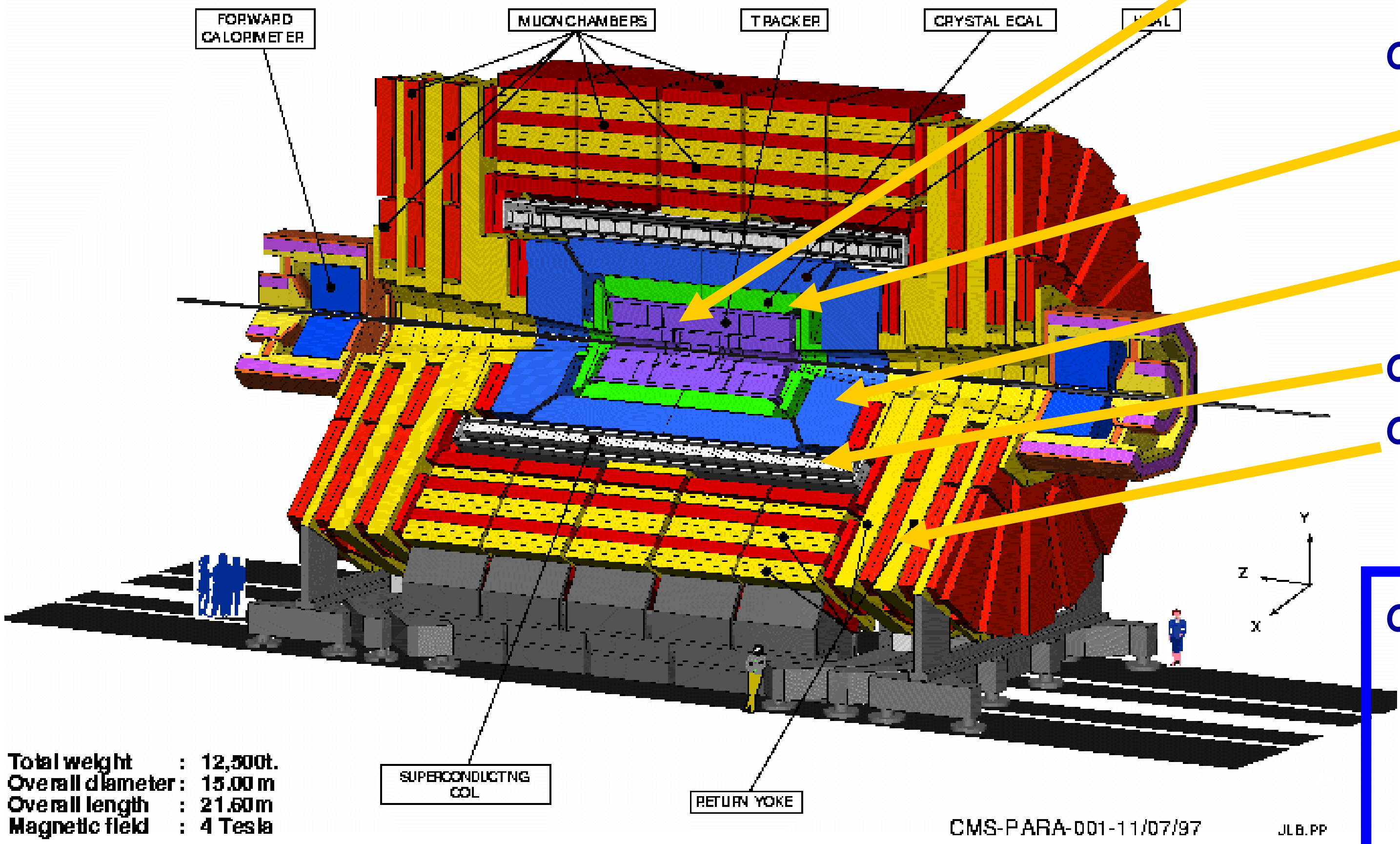


Over 100 dipoles installed by now

Crucial part: 1232 superconducting dipoles
Can follow progress on the CERN web page (dashboard)
http://lhc-new-homepage.web.cern.ch/lhc-new-homepage/

The CMS experiment

A Huge enterprise !



- Tracking
  - Silicon pixels
  - Silicon strips
- Calorimeters
  - PbW04 crystals for Electro-magn.
  - Scintillator/steel for hadronic part
- 4T solenoid
- Instrumented iron for muon detection

- Coverage
  - Tracking
    $0 < |\eta| < 3$
  - Calorimetry
    $0 < |\eta| < 5$

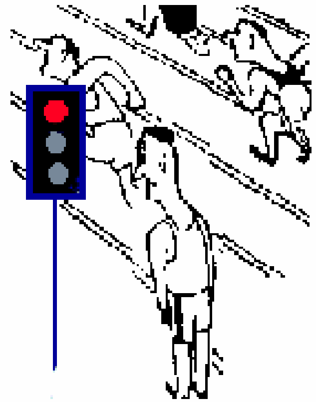
Main program: EWSB, Beyond SM physics…

Detectors at Start-up

❷ Which detectors the first year ?

RPC over $|\eta|<1.6$ (instead of $|\eta|< 2.1$)
4^{th} layer of end-cap chambers missing

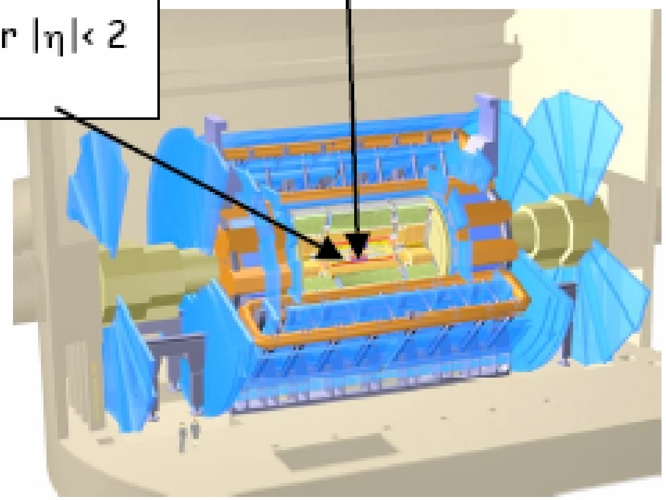
Pixels and end-cap ECAL
installed during first shut-down



2 pixel layers/disks instead of 3 ?

Detectors will be fairly complete at start-up

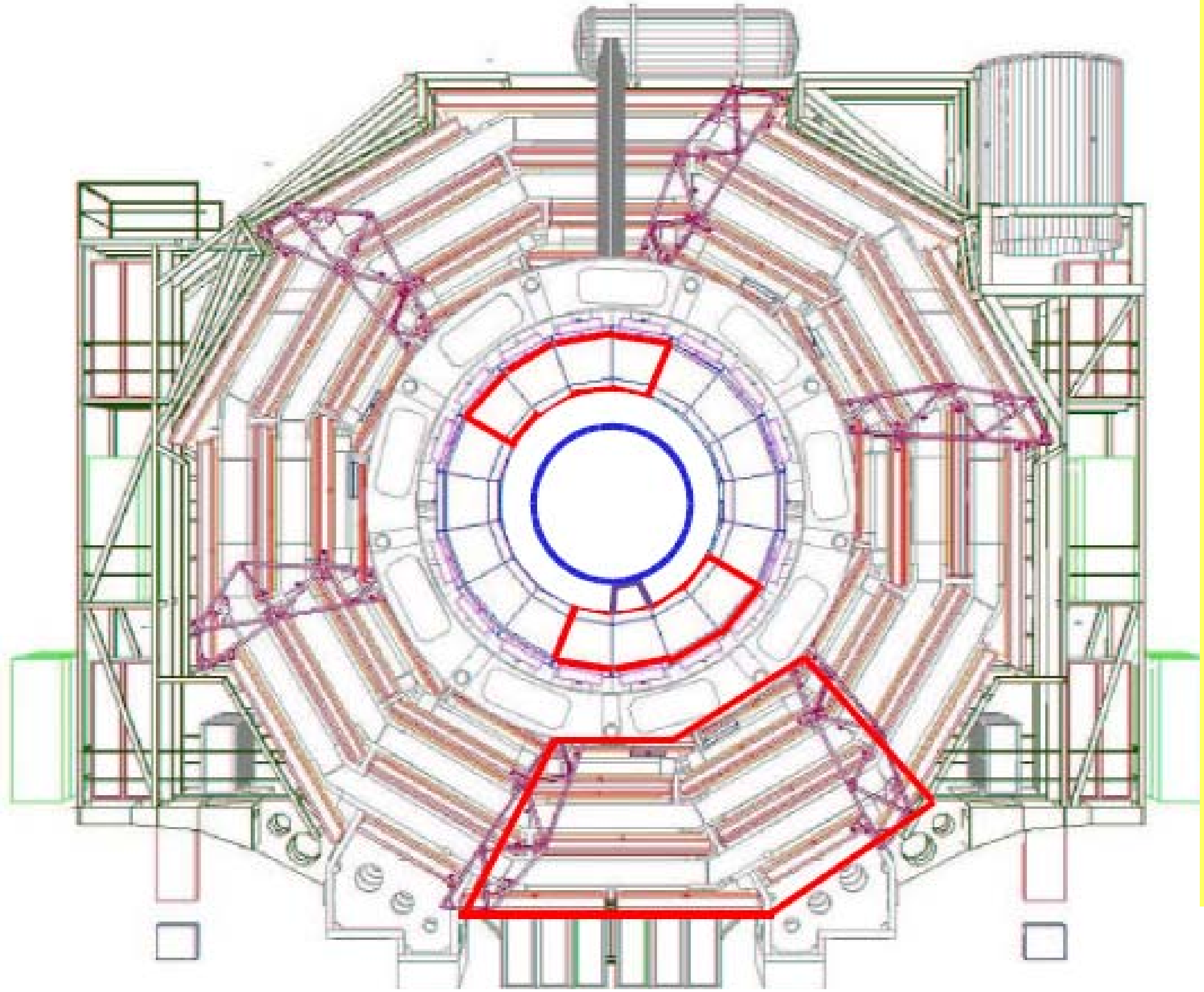
TRT acceptance over $|\eta|< 2$
(instead of $|\eta|< 2.4$)



Both experiments:
deferrals of high-level Trigger/DAQ processors
→ LVL1 output rate limited to
~ 50 kHz CMS (instead of 100 kHz)
~ 40 kHz ATLAS (instead of 75 kHz)

Impact on physics visible but acceptable
Main loss : B-physics programme strongly reduced (single μ threshold p_T> 14-20 GeV)

2006: Cosmic Data Challenge



Detector readiness preparation: Important milestone for 2006⇒

The cosmic data challenge

Combined operation of the subdetector systems

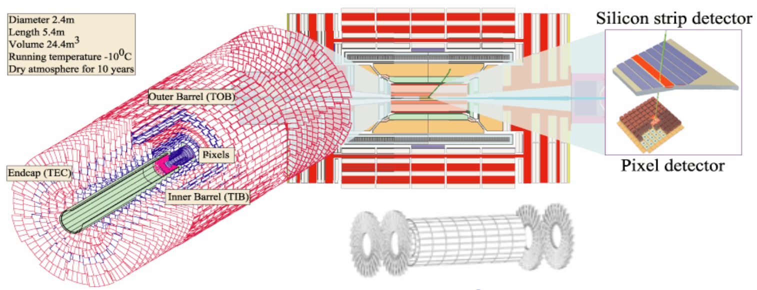
Similar to the combined beamtest of ATLAS in 2004 (a lot of sweat!!)

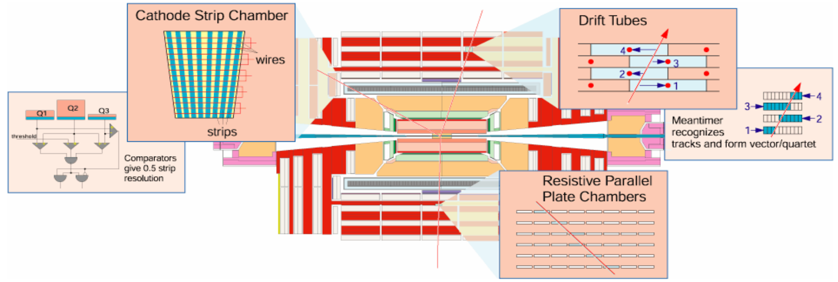
Include experience in Vol2.1 of Physics TDR

Major Commissioning Challenges

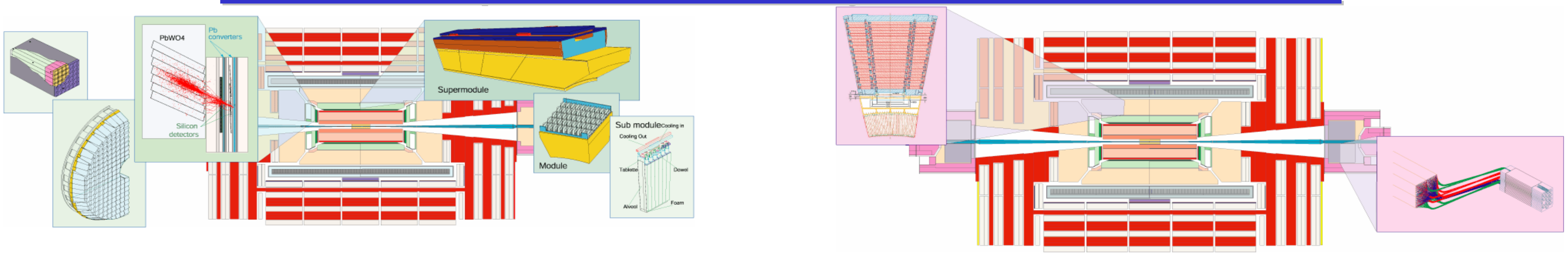
Efficient operation of Trigger (Level1/HLT) and DAQ System

Alignment of the tracking devices Tracker(PIXEL,Strip) and Muon System





Calibration of the Calorimeter Systems ECAL and HCAL

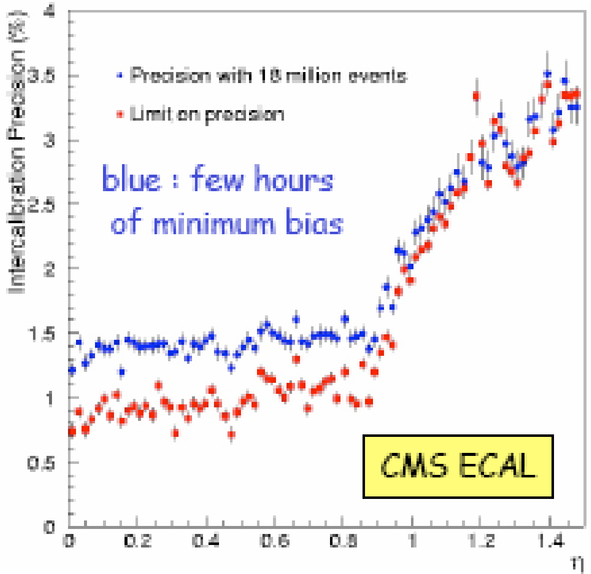


→form the base for the "commissioning of physics tools" like b and τ tagging, jets, missing E_T …

Detectors at Start-up for Physics

Which detector performance on day one ?

A few examples and educated guesses
based on test-beam results and simulation studies



Gianotti, Mangano hep-ph/0504221

	Expected performance day 1	Physics samples to improve (examples)
ECAL uniformity e/γ scale	~ 1% (ATLAS), 4% (CMS) 1-2 % ?	Minimum-bias, Z→ ee Z → ee
HCAL uniformity Jet scale	2-3 % < 10%	Single pions, QCD jets Z (→ ll) +1j, W → jj in tt events
Tracking alignment	20-500 μm in Rφ ?	Generic tracks, isolated μ , Z → μμ

Ultimate statistical precision achievable after few days of operation. Then face systematics ....
E.g. : tracker alignment : 100 μm (1 month) → 20μm (4 months) → 5 μm (1 year) ?

First Measurments

A quote I like…

The only place where you will find **success** before **work** is in the dictionary

May B. Smith

We will have to take this at heart in the next 3(+) years!

Diffraction and Forward Physics at LHC

TOTEM:

- Approved July 2004 (TDR of TOTEM web page http://totem.web.cern.ch/Totem/)
- TOTEM stand alone
  - Elastic scattering, Total pp cross section and soft diffraction.

CMS:

- EOI submitted in January 2004: /afs/cern.ch/user/d/deroeck/public/eoi_cms_diff.pdf
  - Diffraction with TOTEM Roman Pots and/or rapidity gaps
- Technical Proposal in preparation for new forward detectors (CASTOR, ZDC,+…)
  - Diffractive and low-x physics part of CMS physics program (low + high β)

CMS+TOTEM:

- Prepare common LOI due in November 2005 (K. Eggert/ADR organizing)
  - Full diffractive program with central activity. TOTEM will be included as a subdetector in CMS (trigger/data stream)

ATLAS:

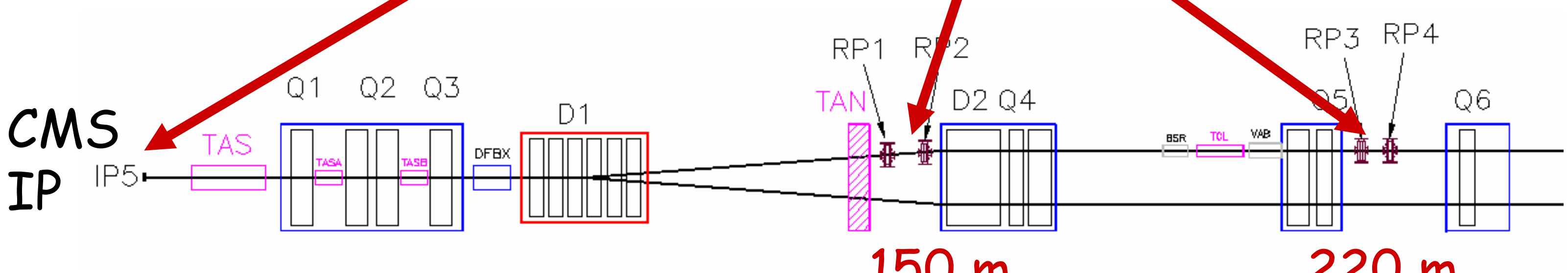
- LOI submitted (March 04) for RP detectors to measure elastic scattering/ total cross sections/luminosity. Diffraction will be looked at later

ALICE, LHCb: no direct forward projects plans but keeping eyes open.

FP420: Collaboration for R&D and feasibility study for detectors at 420 m

Roman Pot Detectors (TOTEM)

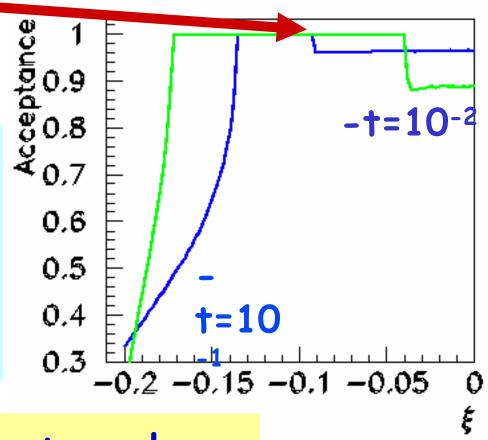
TOTEM physics program: total pp, elastic & diffractive cross sections
Apparatus: Inelastic Detectors & Roman Pots (2 stations)



High β* (1540m): Lumi 10^{28}-10^{31} $cm^{-2}s^{-1}$ (few days or weeks)

>90% of all diffractive protons are seen in the Roman Pots.

Proton momentum measured with a resolution ~10^{-3}



Low β*: (0.5m): Lumi 10^{33}-10^{34} $cm^{-2}s^{-1}$

220m: $0.02 < \xi < 0.2$

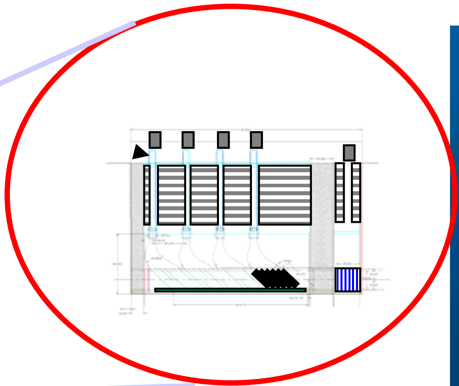
300/400m: $0.002 < \xi < 0.02$ (RPs in the cold region/ under discussion in CMS/ATLAS)

ξ = proton momentum loss

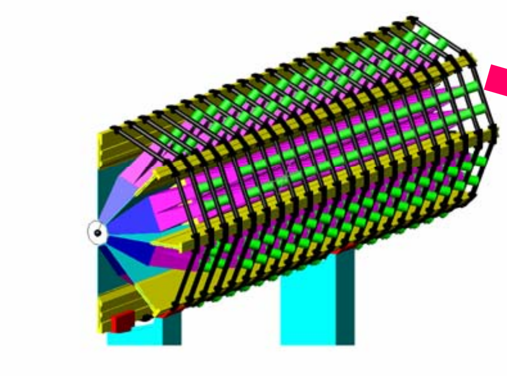
Forward Detectors

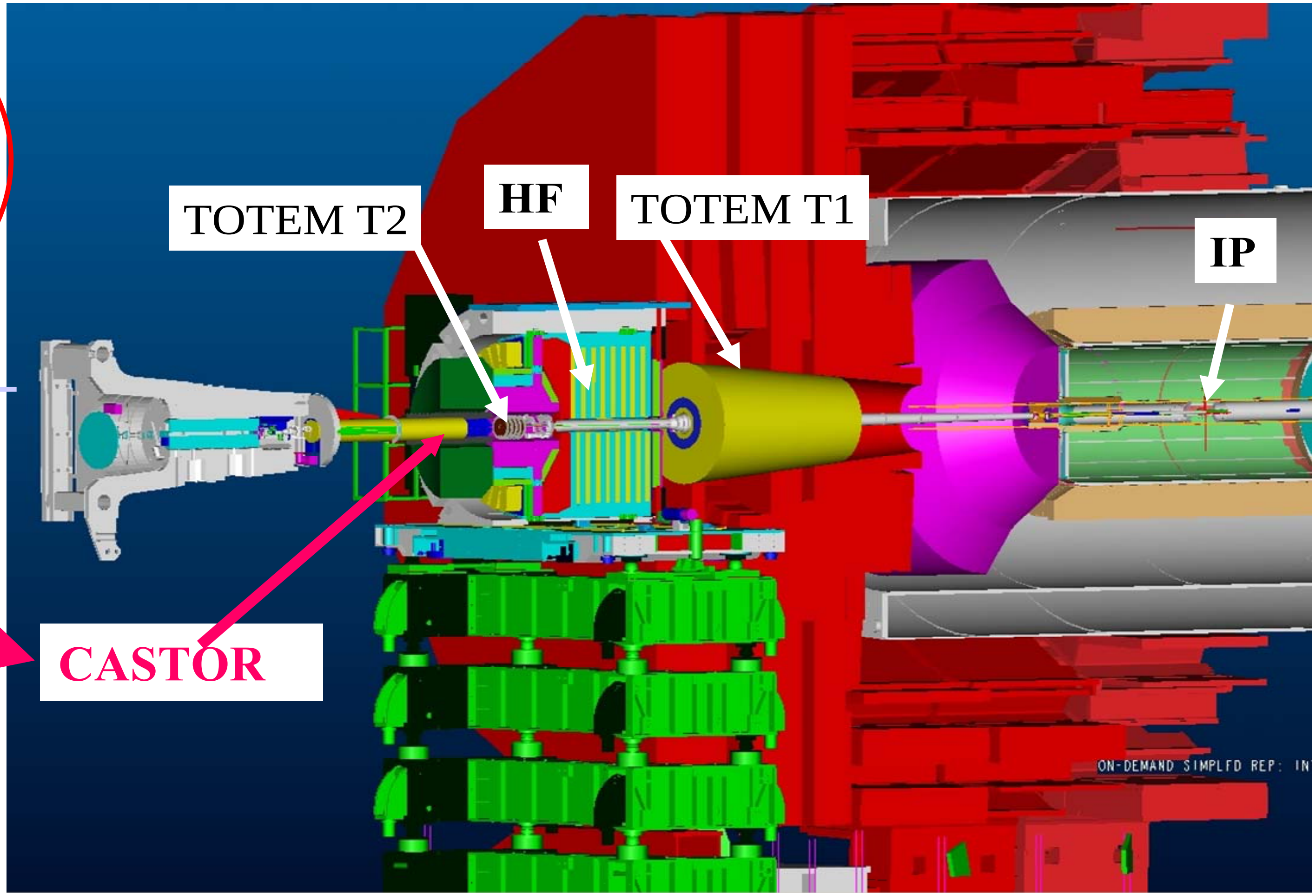
T1 3.1< η <4.7
T2 5.3<η <6.7
Castor 5.25<η <6.5

Extend the reach in η from |η|<5
to |η| <6.7
+ neutral energy at zero degrees

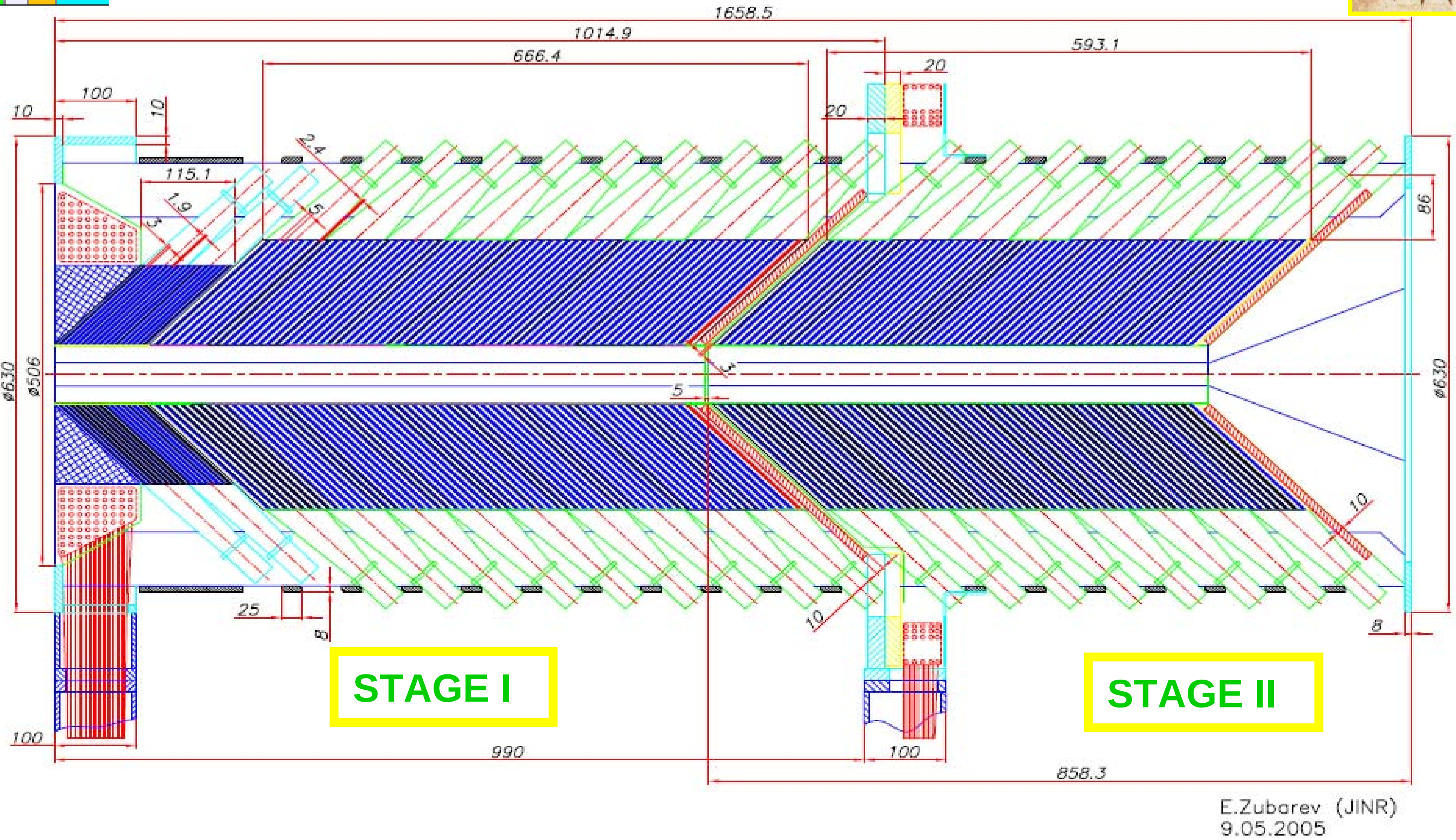


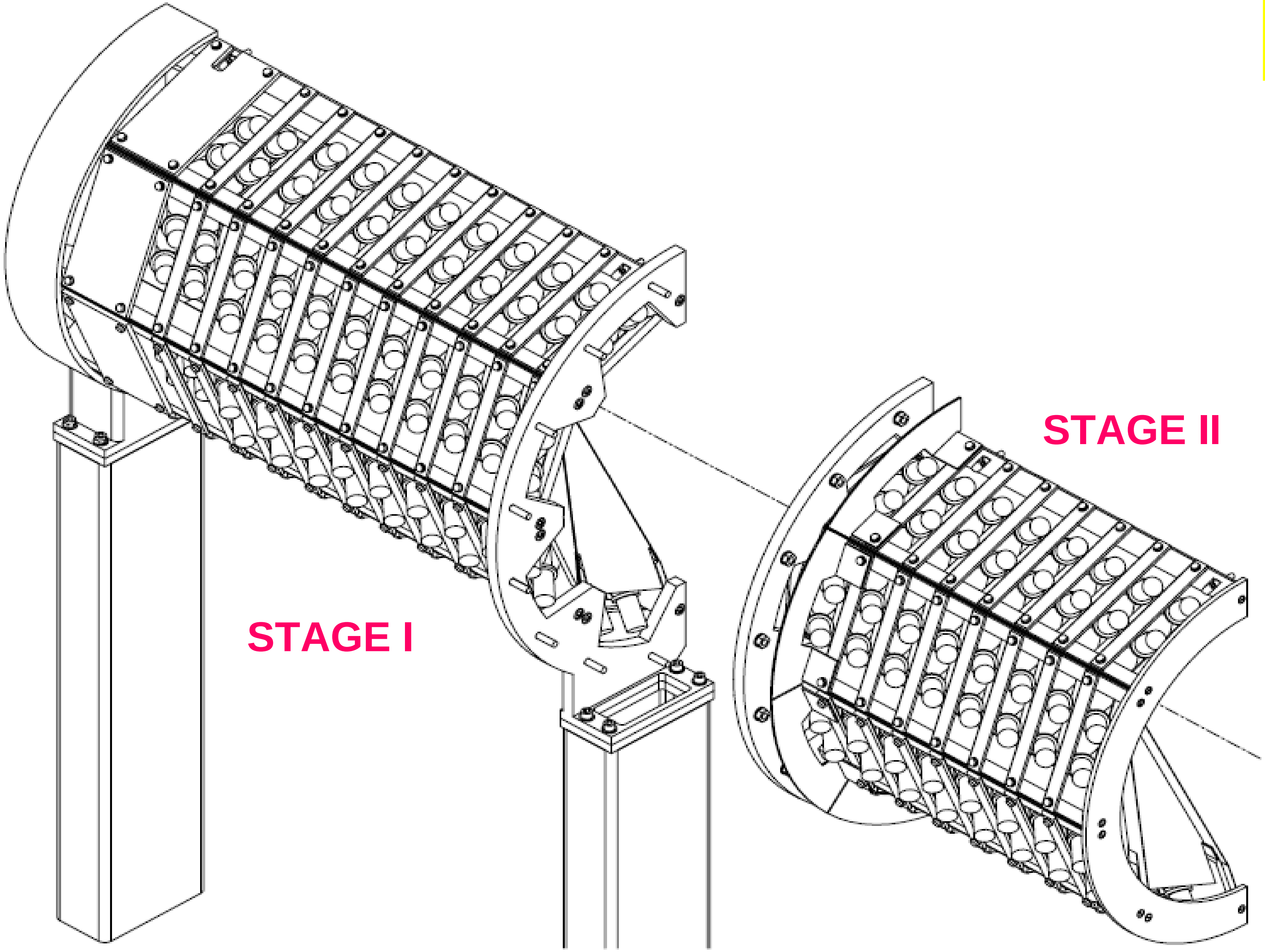
ZDC @ 140 m





Two Stage Construction & Implimentation




STAGE II
STAGE I

Full Calorimeter:

1 EM-RU + 10 H-RU = 1328 mm = 0.87 + 9.5 λ_I = 10.37 λ_I

Total air-gap length ~ 28 mm (~ 2%)

➡ **Total Number of Channels = 16 + 10x16 = 176**

STAGES OF CALORIMETER CONSTRUCTION AND IMPLEMENTATION

➡ **STAGE I (pp-Physics):**

EM(1) + H(6) = 7 RUs = 0.871 λ_I + 5.7 λ_I = **6.57 λ_I**
= 7x16 = **112 channels**

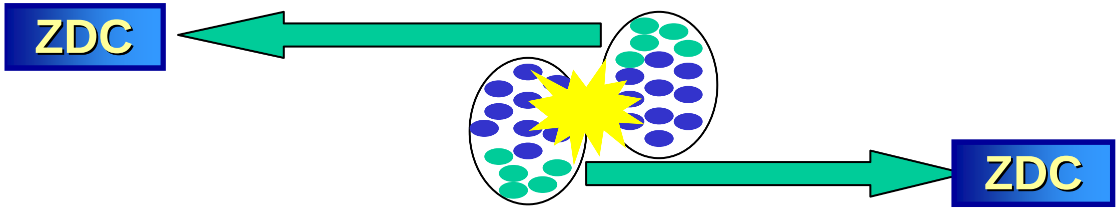
➡ **STAGE II (HI-Physics):**

H(4) = 4x16 = **64 channels**

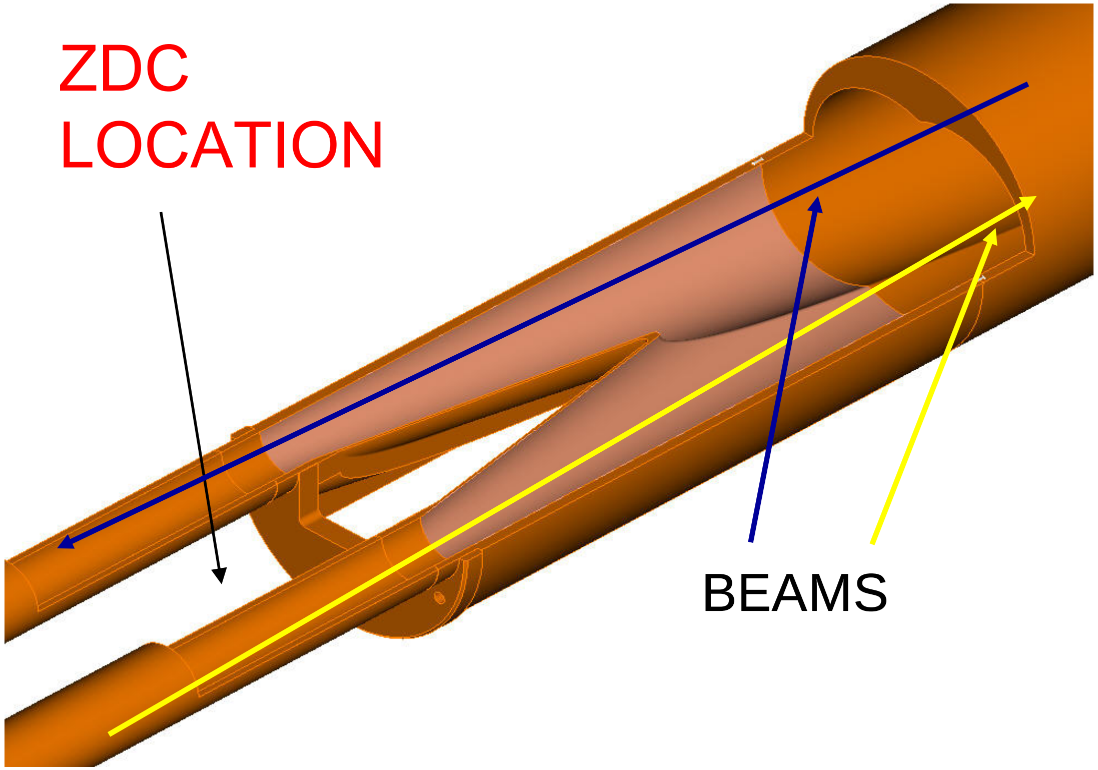
➡ **Prototype (½ calorimeter of Stage I):** **B.T. October 2006**

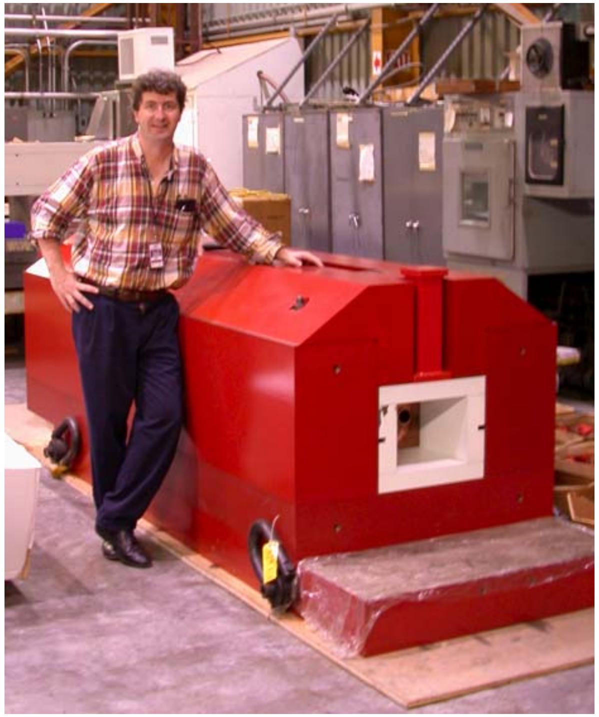
EM(1) + H(6) = 7x8 = **56 channels**

ZDC: zero degree calorimeter (CMS)



Beam pipe splits 140m from IR



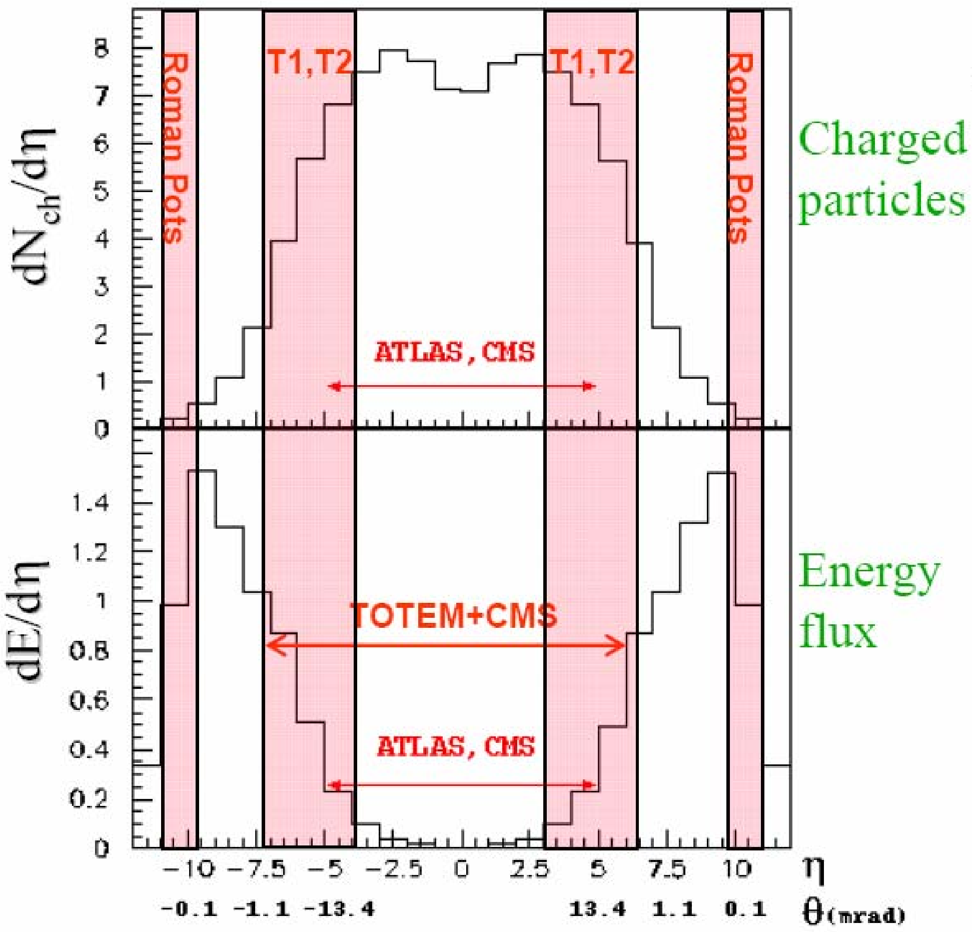


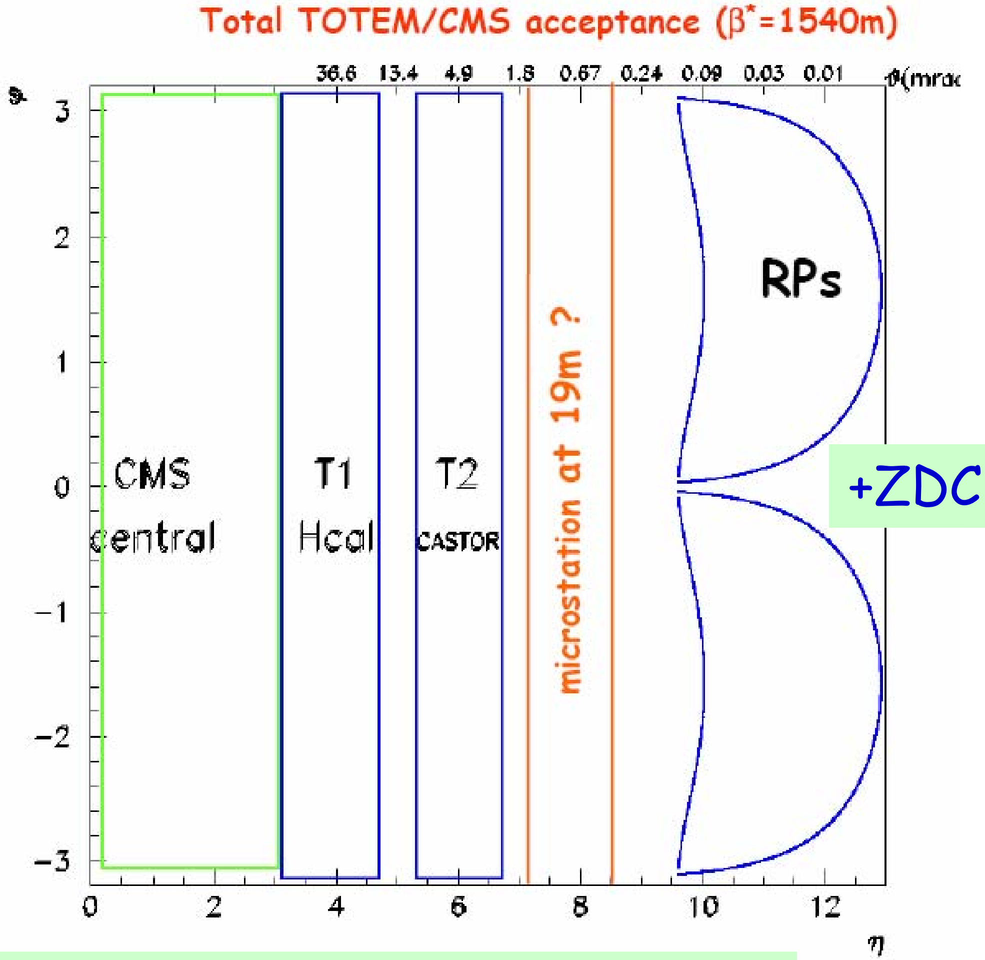
Tungsten/ quartz fiber or
PPAC calorimeter
EM and HAD section

Funding pending in DOE

CMS/TOTEM: a "complete" LHC detector

CMS/TOTEM will be the largest acceptance detector ever built at a hadron collider





+ZDC

K. Eggert

Still studying other regions (19m, 25m, 50m…)

Further Forward Detector Opportunities

V.Andreev, A.Bunatyan, H.Jung, M.Kapishin, L.Lytkine (DESY)

Requirement: study LHC forward beam line to find detector position / type to measure energy / particle flow in the range η=7-10

Possible solutions:

- 2 Horizontal Roman Pots (micro-stations) at 85 and 95m behind dipole magnet system D1

  Energy flow in the range: 2 TeV - 7TeV

- hadronic calorimeter at 135m in front of TAN absorber

  Energy flow in the range: 2 TeV - 5.5 TeV

- 2 micro-stations at 19m in front of TAS absorber

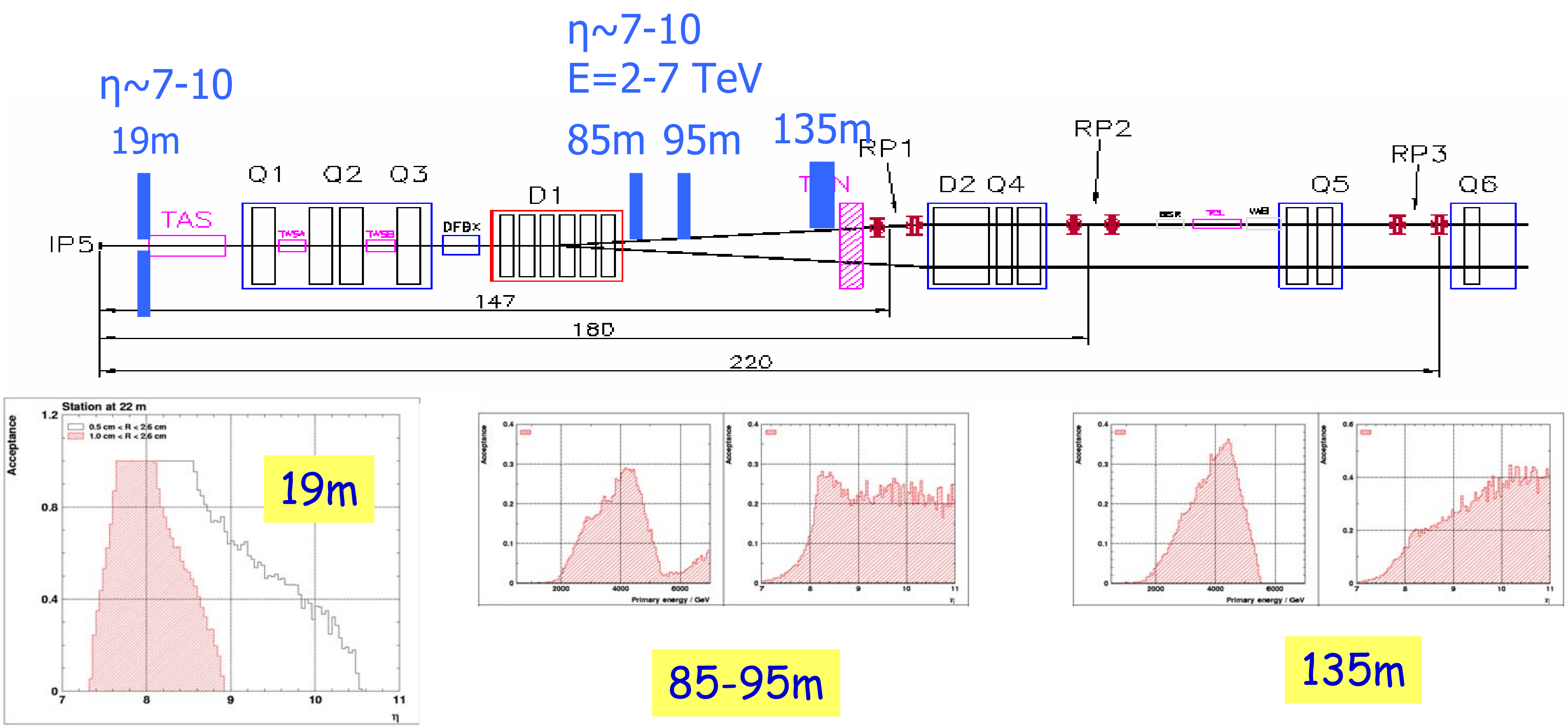
  Charge particle flow integrated over energy up to ~7 TeV

Open points resolution on E / η, pile-up events, background

Study in context of the HERA/LHC workshop/ Not used in physics study

Possible Detector Positions

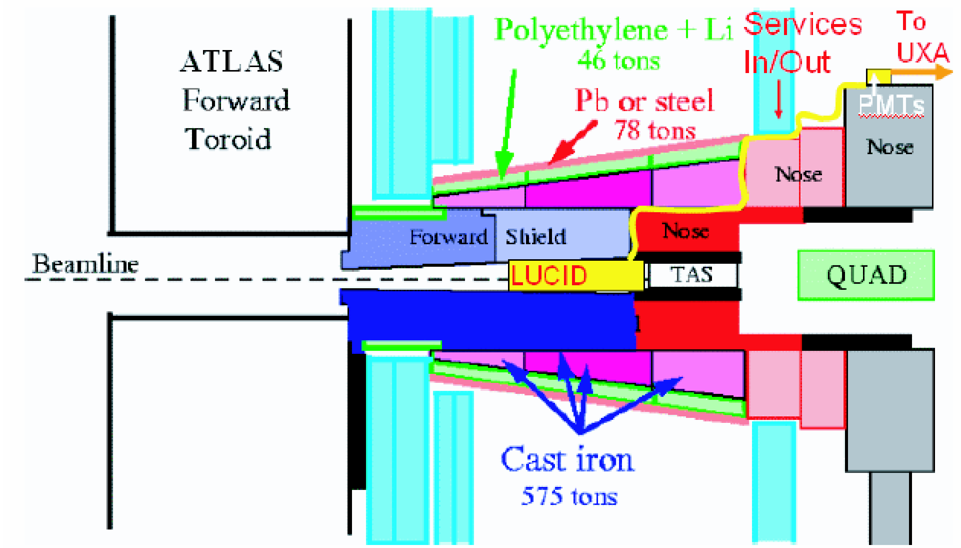
Positions of the detectors and acceptances
GEANT3 tracking through beamline elements

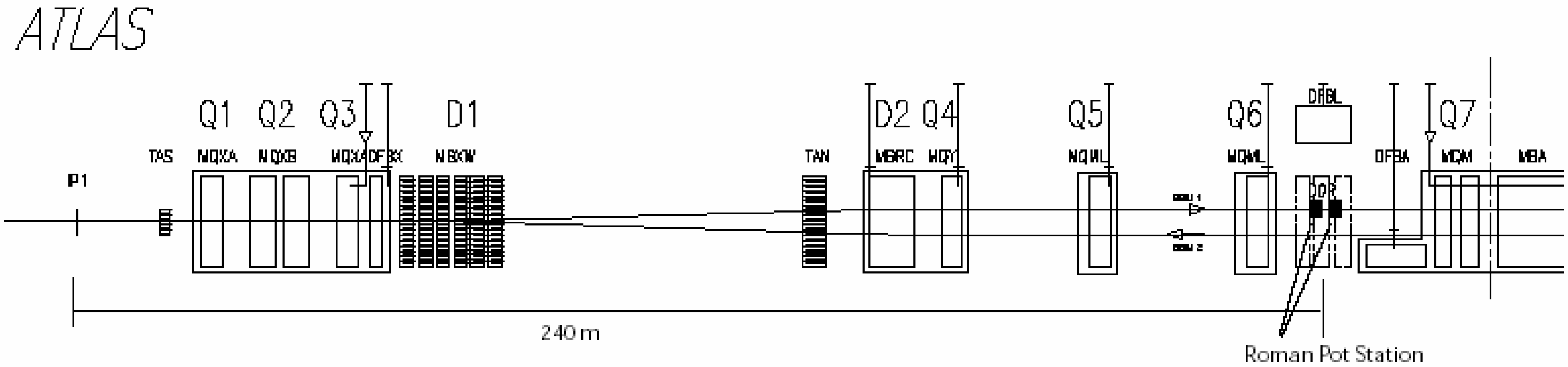


ATLAS LOI for forward detectors

ATLAS submitted a LOI on forward detectors for luminosity measurement and monitoring (May '04)

Roman Pots at 240 m
Cerenkov Counter (LUCID) $5.4 < \eta < 6.1$





Forward Physics Program (CMS/TOTEM LOI)

- Soft & Hard diffraction
  - Total cross section and elastic scattering (TOTEM, precision of O(1)%)
  - Gap survival dynamics, multi-gap events, proton light cone ($pp \rightarrow 3jets+p$), odderon
  - Diffractive structure: Production of jets, W, J/ψ, b, t, hard photons
  - Double Pomeron exchange events as a gluon factory (anomalous W,Z production?)
  - Diffractive Higgs production, (diffractive Radion production?), exclusive SPE??
  - SUSY & other (low mass) exotics & exclusive processes
- Low-x Dynamics
  - Parton saturation, BFKL/CCFM dynamics, proton structure, multi-parton scattering…
- New Forward Physics phenomena
  - New phenomena such as DCCs, incoherent pion emission, Centauro's
- Strong interest from cosmic rays community
  - Forward energy and particle flows/minimum bias event structure
- Two-photon interactions and peripheral collisions
- Forward physics in pA and AA collisions
- Use QED processes to determine the luminosity to 1% ($pp \rightarrow ppee$, $pp \rightarrow pp\mu\mu$)

Many of these topics are of direct interest for the HE QCD

Diffraction at LHC

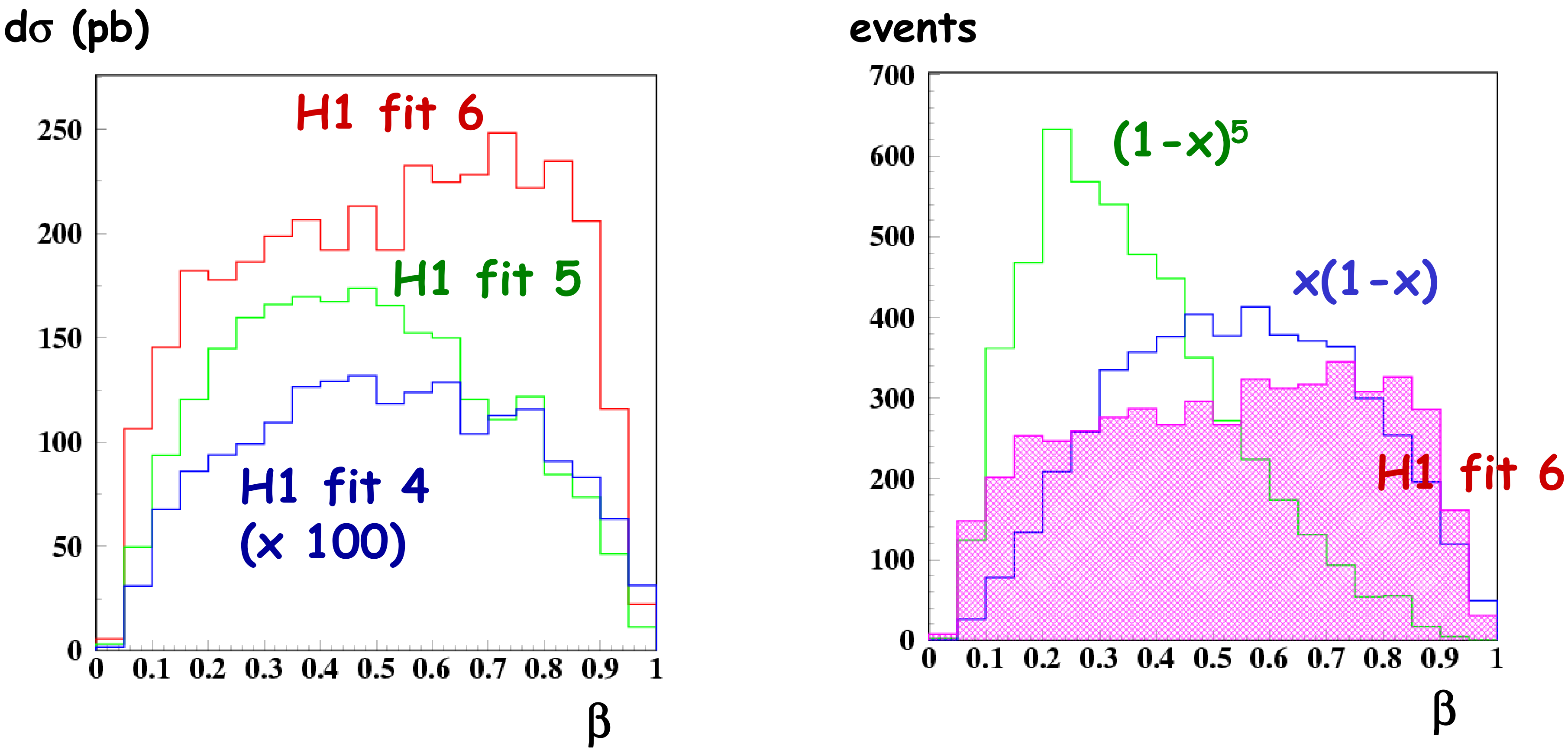
Plan to use both rapidity gap and proton tagging techniques

- Rapidity gaps based on the central detector
  - Used extensively at HERA and the Tevatron
  - Uses correlation between the η_{max} and ξ, the momentum loss of the proton
  - Once detector/readout stable, can be lead first results quickly. Many significant HERA papers, like F_2^D, are still with rapgaps
  - Only usable if pile up small and can be controled
  - Cannot distinguish between outgoing proton or low mass system
  - Need Monte Carlo based corrections
- Tagging protons based on detectors along the beamline
  - Clean measurement for non-dissociative final protons, kinematics!
  - Need to understand positioning, alignment, acceptance corrections… This can take some time (HERA & Tevatron experience)
  - May have reduced luminosity: can insert RPs only when beams/background low and stable

Experience from both HERA and Tevatron vital

DPE: β from Di-jet events

P_t>100 GeV/c for different structure functions



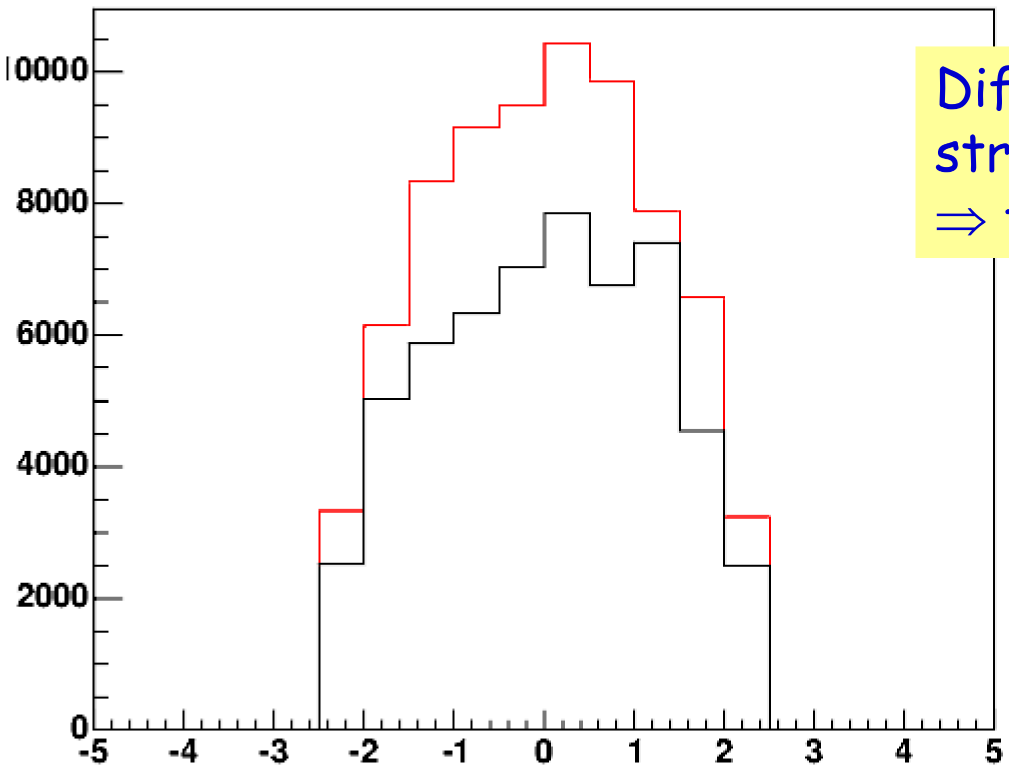
$\beta=\Sigma_{jets} E_T e^{-\eta}/(\sqrt{s}\,\xi)$; ξ from Roman Pots; E_T and η from CMS

High β region probed/ clear differences between different SFs

Diffractive W production

Pseudorapidity spectrum of the muons from diffractive W's after acceptance cuts, trigger condition and fast simulation

A. Loginov



Different H1 diffractive structure functions
⇒ fit 5 and fit 6

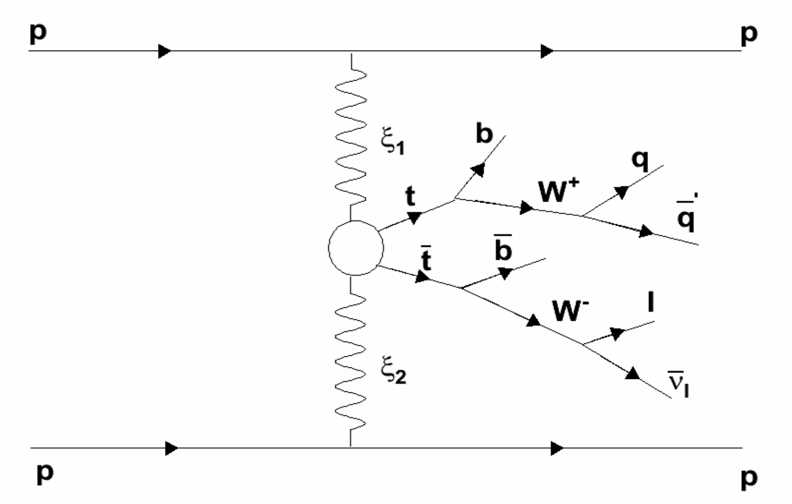
Cross section $W \rightarrow \mu\nu$
(not corrected for survival probability)

17-25 pb

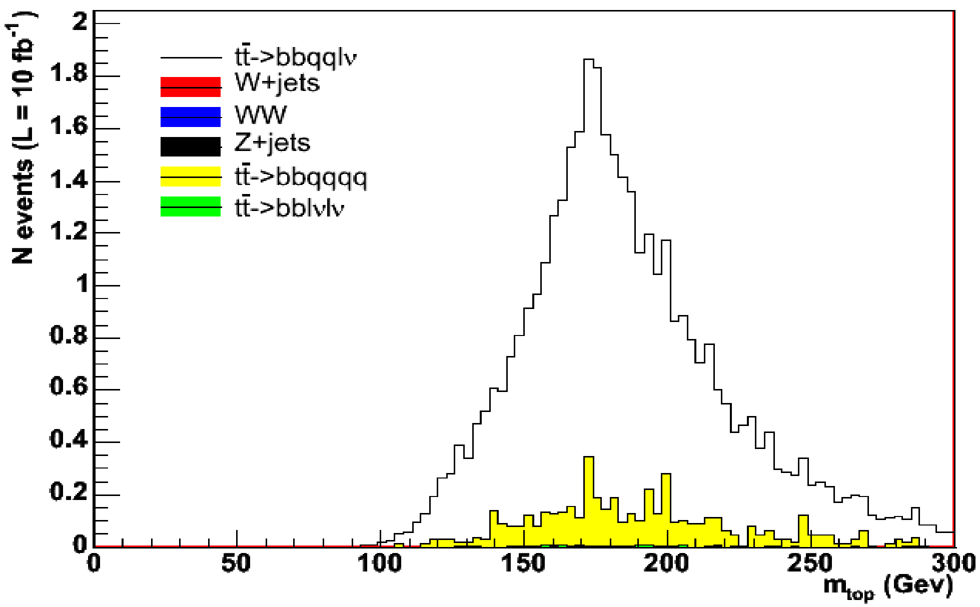
Novel channels: eg diffractive top

Decay Channel

A. Vilela



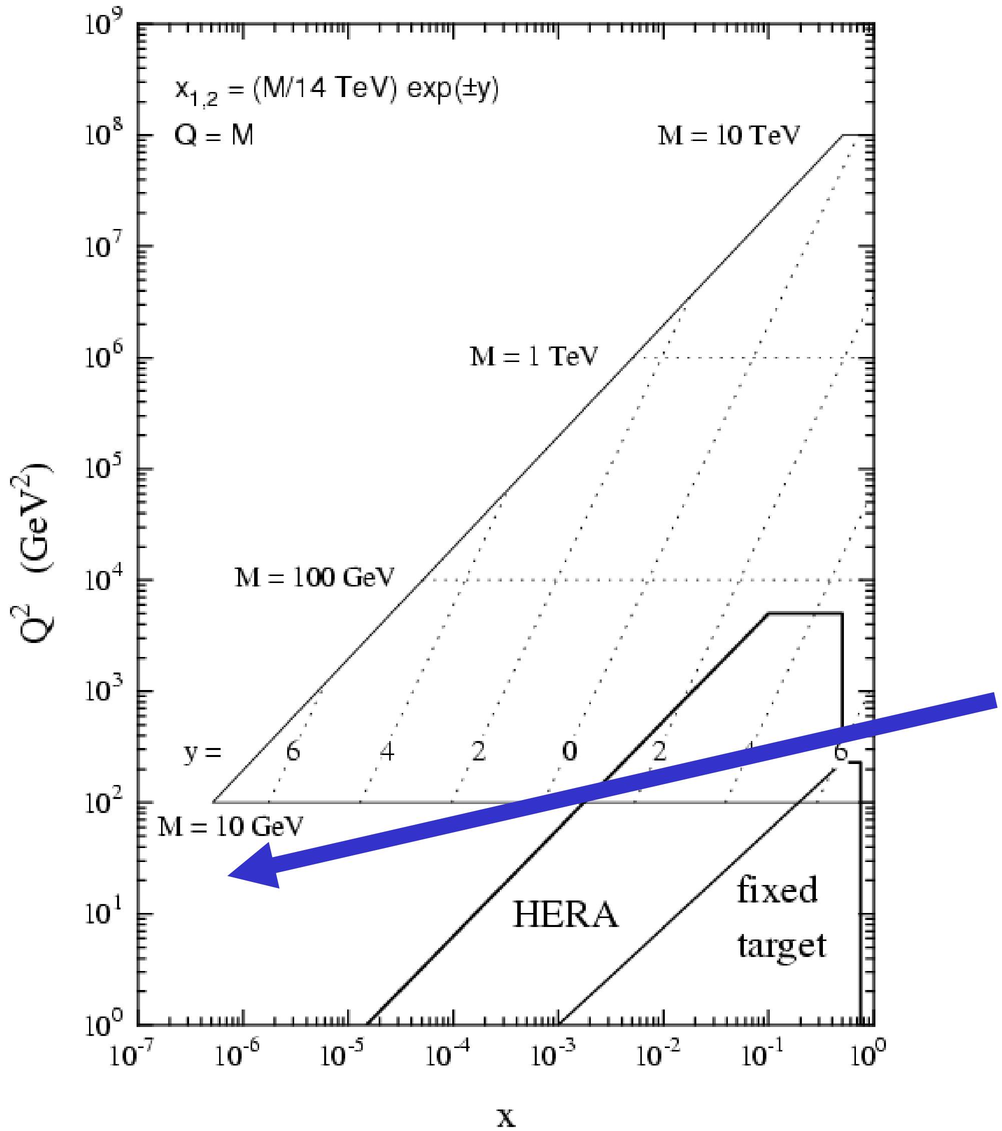
Top mass peak
Efficiency still to be increased



- $pp \rightarrow p + (t\bar{t}) + X + p$
- $t\bar{t} \rightarrow b\bar{b}\,l\,\bar{\nu}_l\,q\bar{q}'\,(l = e, \mu)$

With low Etjet cuts O(100) events/10 pb^{-1}

Low-x at the LHC



LHC: due to the high energy can reach small values of Bjorken-x in structure of the proton $F(x,Q^2)$

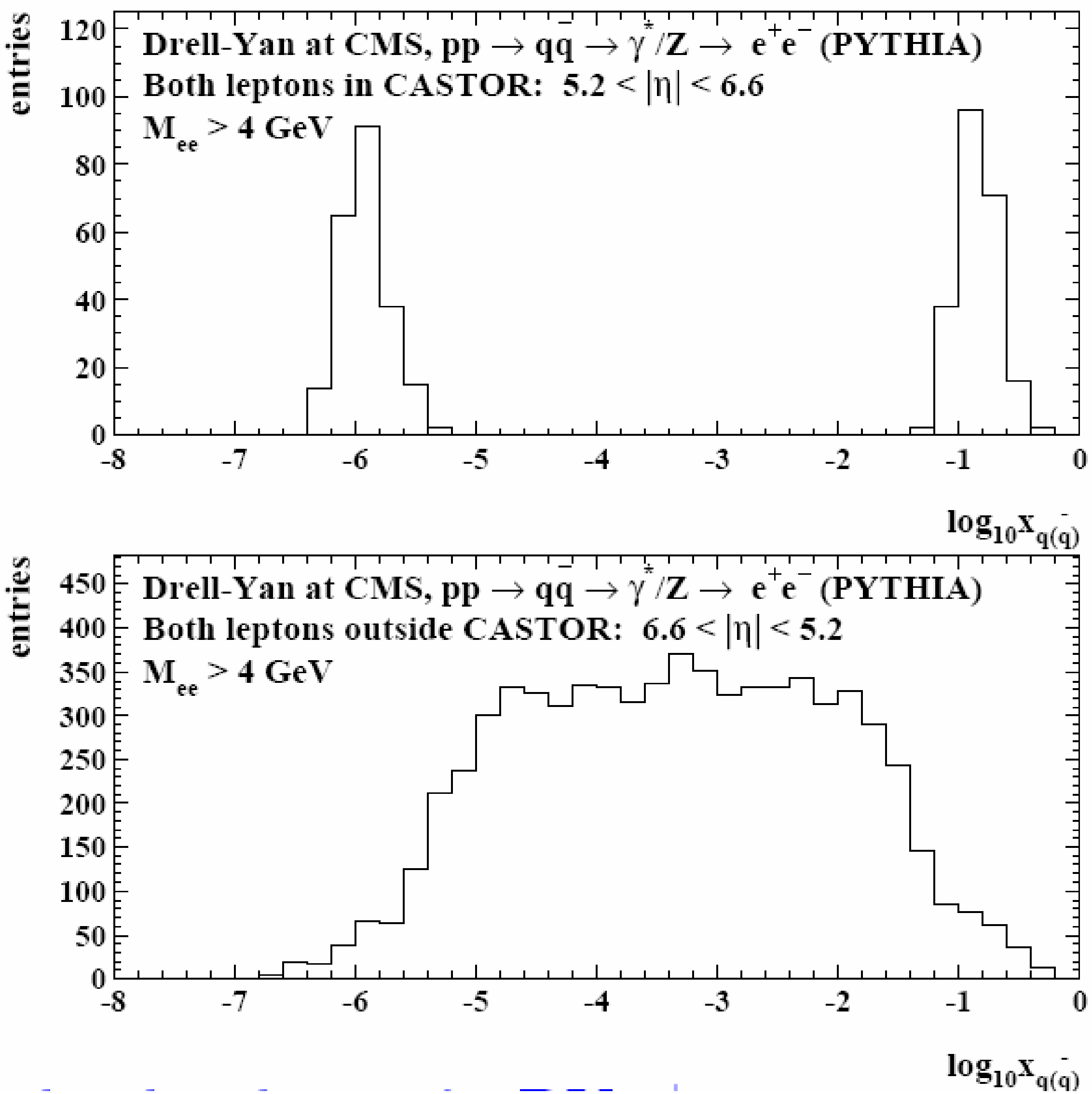
Processes:

- Drell-Yan
- Prompt photon production
- Jet production
- W production

If rapidities below 5 and masses below 10 GeV can be covered ⇒ x down to 10^{-6}-10^{-7}
Possible with T2 upgrade in TOTEM (calorimeter, tracker) $5<\eta< 6.7$!

Proton structure at low-x !!
Parton saturation effects?

Drell-Yan production



E. Sarkisyan

Drell-Yan into electrons

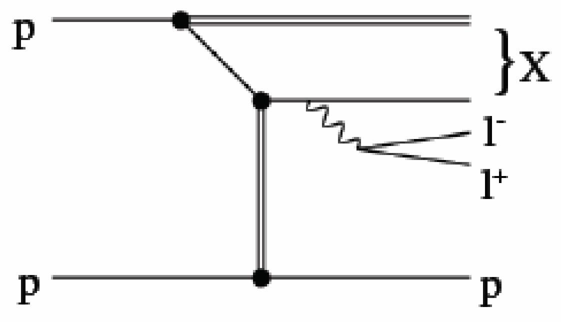
Includes (fast) CASTOR simulation

Large rapidity needed for low-x reach

Drell Yan with Tagged Protons

Diffractive production of Drell-Yan pairs

The process: $pp \to p\, l^+ l^- X$



CMS+CASTOR+TOTEM acceptance:
(study by K. Sedlak)

$$0.02 < \xi < 0.2$$
$$5.30 < \eta_{l\pm} < 6.46$$

leads to 900-9000 events/year, assuming

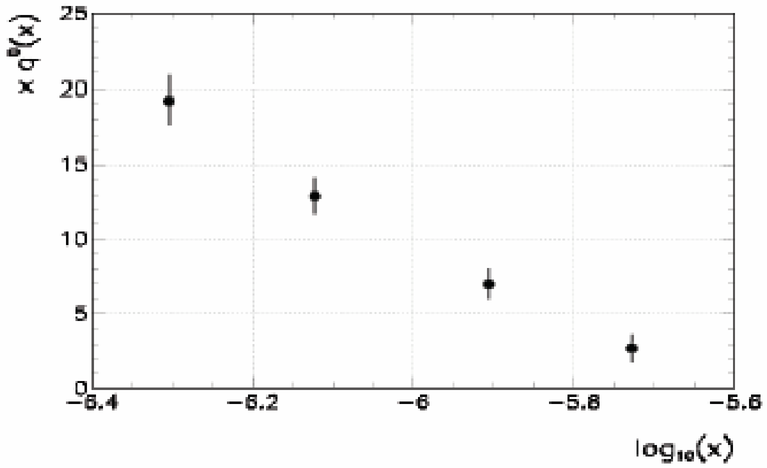
$$L_{int} = 200 - 2000\ \text{pb}^{-1}/\text{year}$$

with 1 interaction/bunch crossing

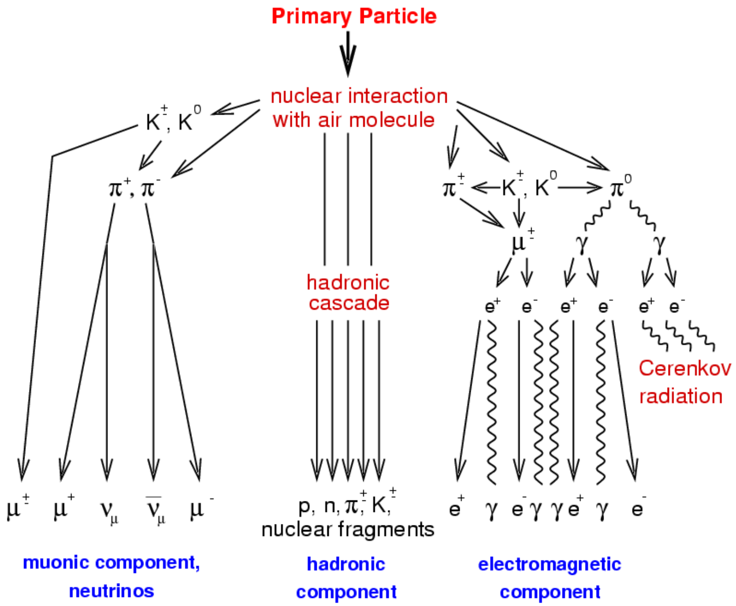
Physics interest:

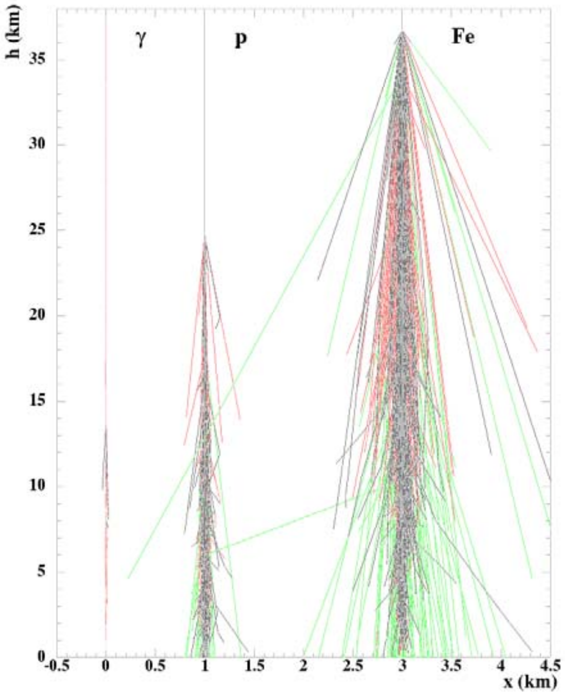
- Continuation of the study of diffractive structure
- Saturation at low x
- Test of factorisation
- ...

Example measurement:



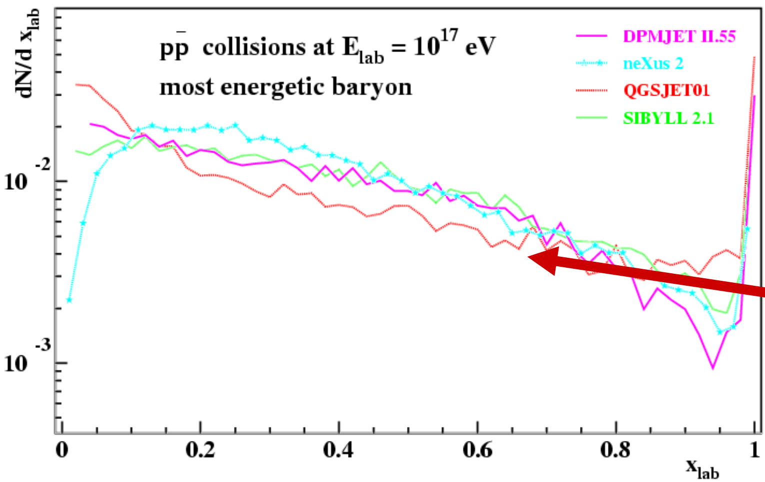
High Energy Cosmic Rays





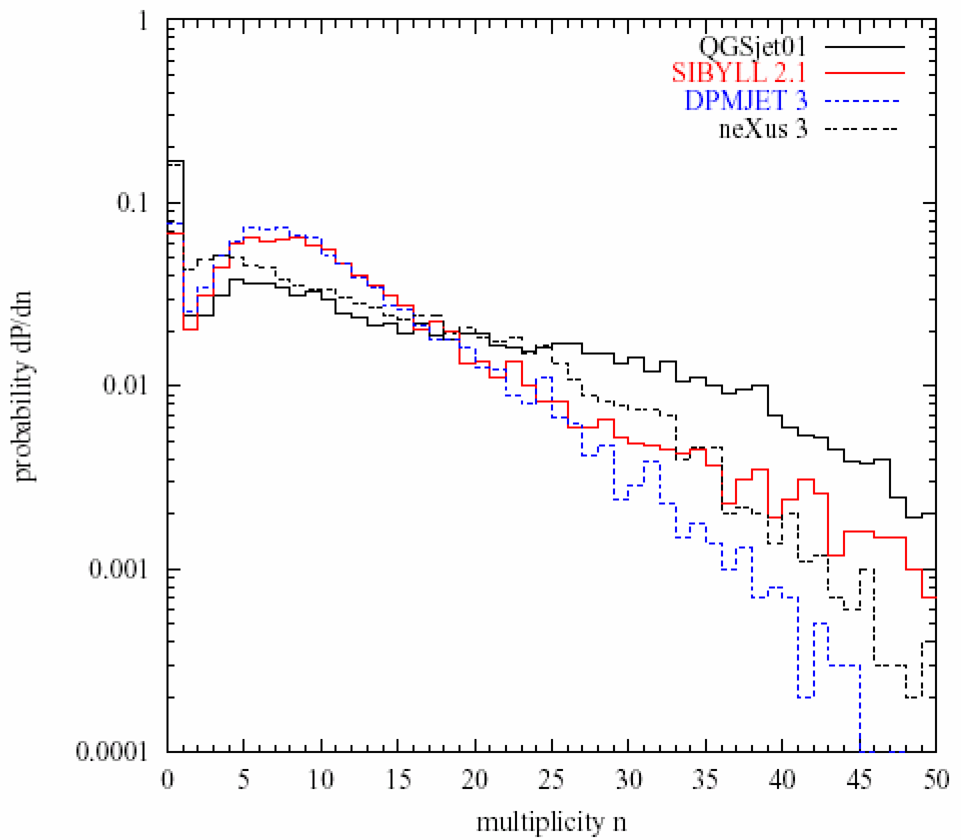
Cosmic ray showers: Dynamics of the high energy particle spectrum is crucial

Karlsruhe, La Plata



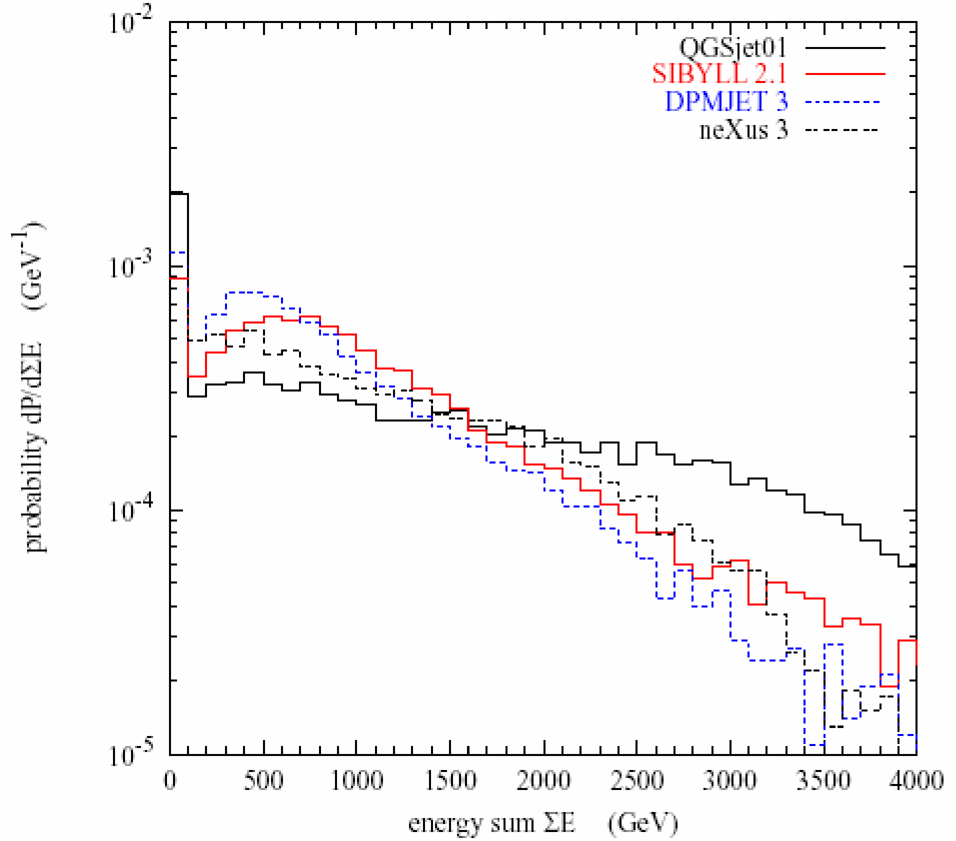
Interpreting cosmic ray data depends on hadronic simulation programs
Forward region poorly know/constrained
Models differ by factor 2 or more
Need forward particle/energy measurements
e.g. $dE/d\eta$...

Model Predictions: proton-proton at the LHC



total multiplicity in forward detector

$(5 \leq \eta \leq 7)$



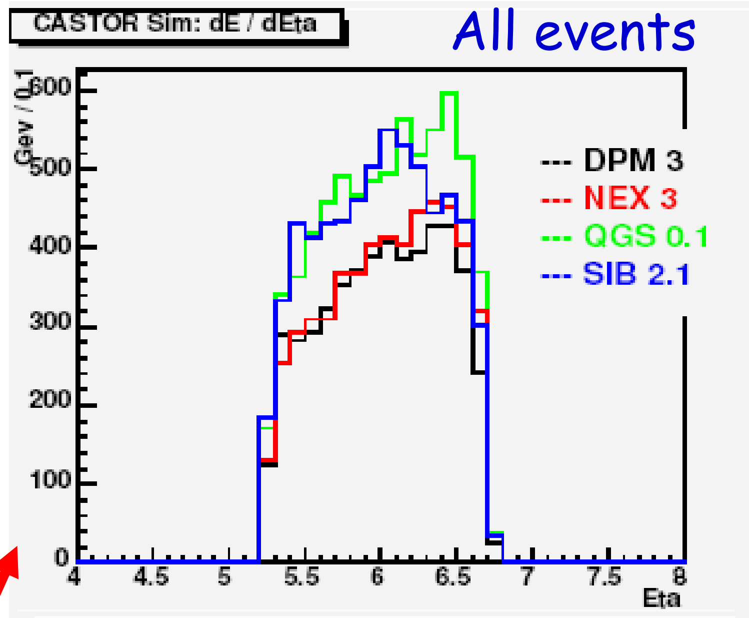
total energy in forward detector

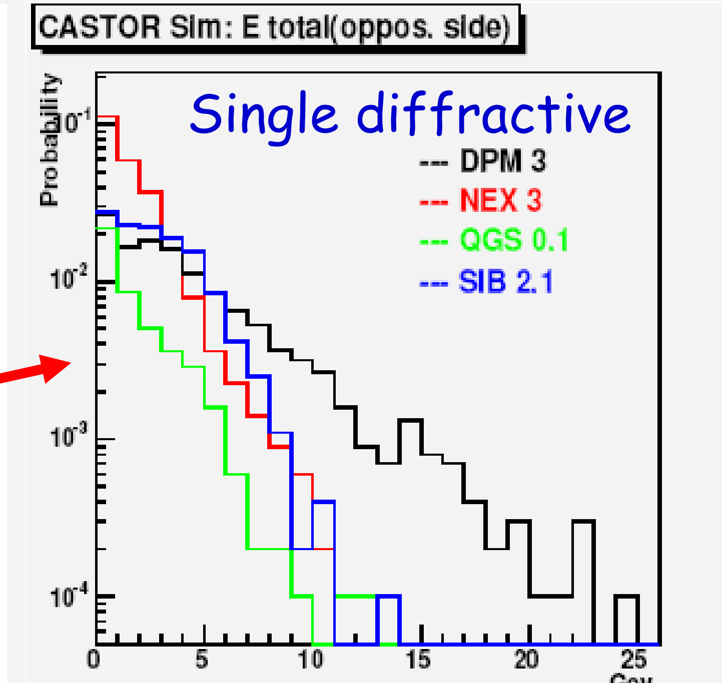
$(5 \leq \eta \leq 7)$

Predictions in the forward region within the CMS/TOTEM acceptance

Possible Forward Measurements

- Energy flow at high pseudorapidity (~ 6.7)
- Transverse energy (limited)
- Total/inelastic cross sections
- Fraction of diffractive dissociation
- Particle multiplicities
- Electrons, photons, hadrons
- Jets more limited (accpetance)
- (muons maybe in limited region with additional detectors, see H. Jung et al HERA/LHC workshop)





Full simulation

V. Popov, R. Engel, T. Dova

FP420

CERN-LHCC-2005-025
LHCC-I-015

FP420 : An R&D Proposal to Investigate the Feasibility of Installing Proton Tagging Detectors in the 420m Region at LHC

M. G. Albrow, T. Anthonis, M. Arneodo, R. Barlow, W. Beaumont, A. Brandt, P. Bussey, C. Buttar, M. Capua, J. E. Cole, B. E. Cox,*, C. DaVià, A. DeRoeck,*, E. A. De Wolf, J. R. Forshaw, J. Freeman, P. Grafstrom,+, J. Gronberg, M. Grothe , J. Hasi, G. P. Heath, V. Hedberg,+, B. W. Kennedy, C. Kenney, V. A. Khoze, H. Kowalski, J. Lamsa, D. Lange, V. Lemaitre, F. K. Loebinger, A. Mastroberardino, O. Militaru, D. M. Newbold, R. Orava1, V. O'Shea, K. Osterberg, S. Parker, P. Petroff, J. Pinfold, K. Piotrzkowski, M. Rijssenbeek, J. Rohlf, L. Rurua, M. Ruspa, M. G. Ryskin, D. H. Saxon, P. Schlein, G. Snow, A. Sobol, A. Solano, W. J. Stirling, M. Tasevsky, E. Tassi, P. Van Mechelen, S. J. Watts, T. Wengler, S. White, D. Wright

58 authors
29 institutes

LOI submitted to the LHCC end of June

FP420 plans

- Feasibility study for the development of detectors to measure protons at 420 m from the IP, during low β optics at the LHC
  - Main physics aim $pp \rightarrow p + X + p$
    - Higgs, New physics
    - QCD studies
    - Photon induced interactions
- First meeting at FNAL April 26 2005
  - Green light for the UK funds
  - Decide to submit a LOI to the LHCC
- Further meetings/collaboration web page

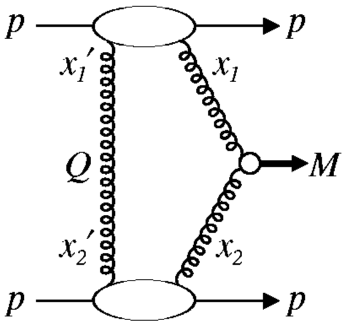
  http://www.fp420.com
- Next meeting 11 October at CERN

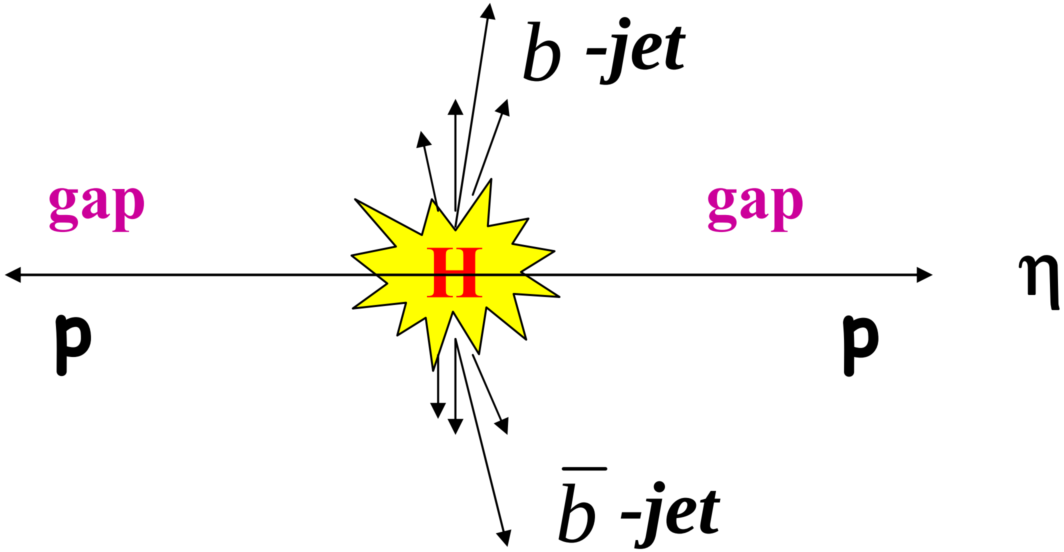
  Note: this is an open (proto-)collaboration

Contacts: B. Cox (Manchester), A. De Roeck (CERN)

Diffractive Higgs Production

Exclusive diffractive Higgs production pp$\rightarrow$ p H p : 3-10 fb
Inclusive diffractive Higgs production pp $\rightarrow$ p+X+H+Y+p : 50-200 fb

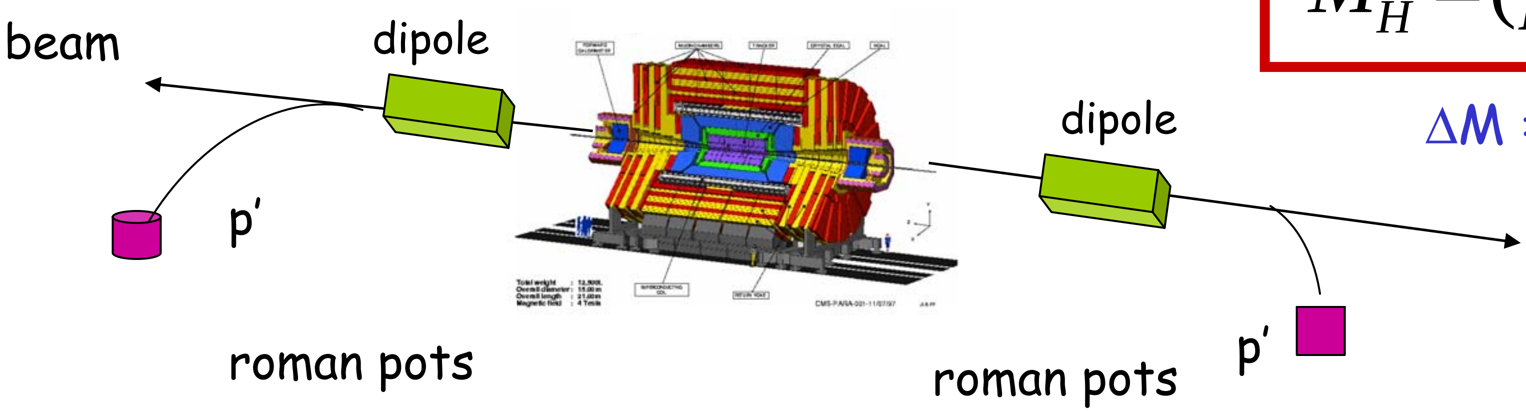




E.g. V. Khoze et al
M. Boonekamp et al
B. Cox et al.
V. Petrov et al…
Levin et al…

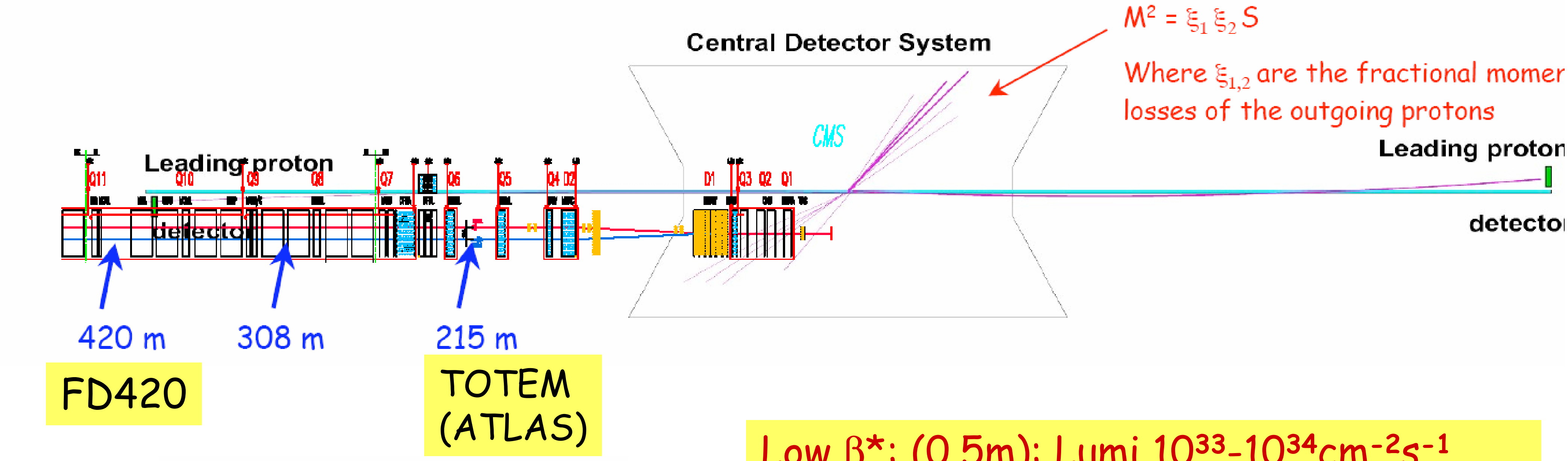
$$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$$

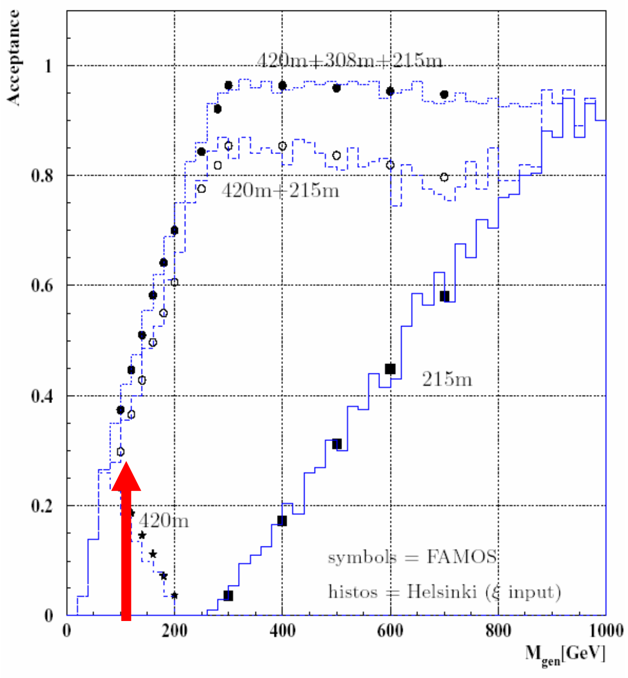
ΔM = O(1.0 - 2.0) GeV



Note: P. Lanshoff still believes the cross section could be larger

Roman pot acceptances





Low β*: (0.5m): Lumi 10^{33}-10^{34}cm^{-2}s^{-1}

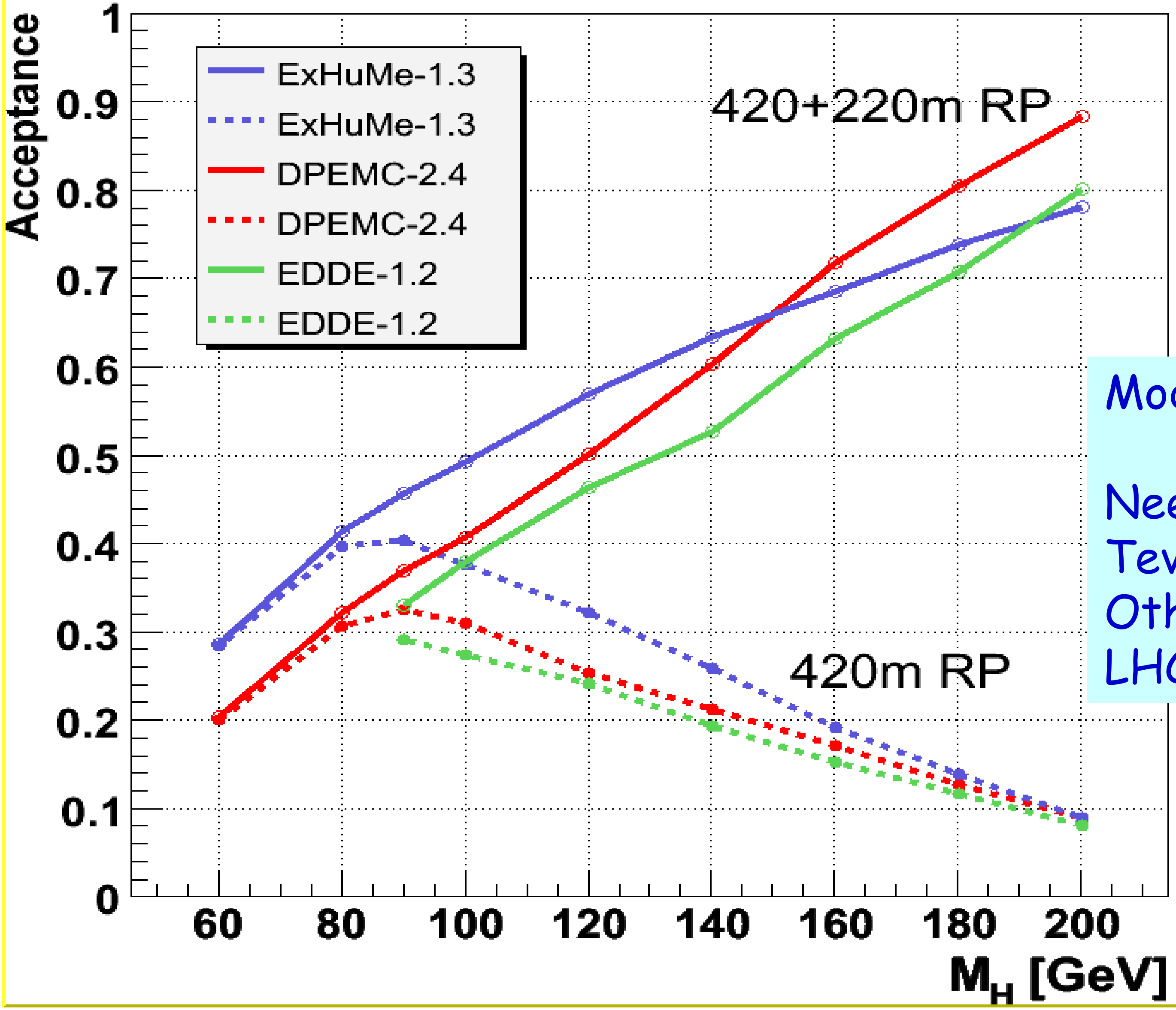
220m: $0.02 < \xi < 0.2$

300/400m: $0.002 < \xi < 0.02$

RPs in the cold region/FP420 are needed to access the low ξ values

- Problem: 420m to late for CMS/ATLAS L1 trigger. Trigger on central activity
- Addressed by common CMS+TOTEM study

M_H Acceptance



Helsniki Group
TOTEM study
FP420 study

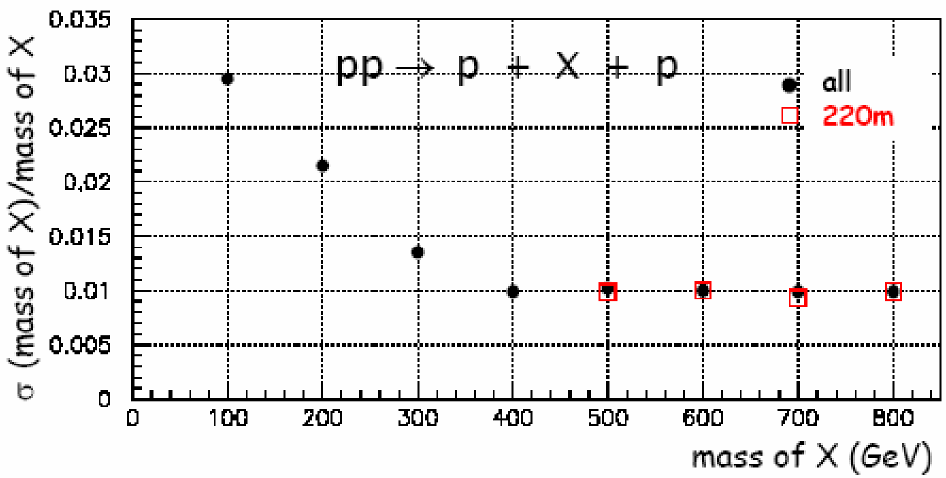
Model Dependence

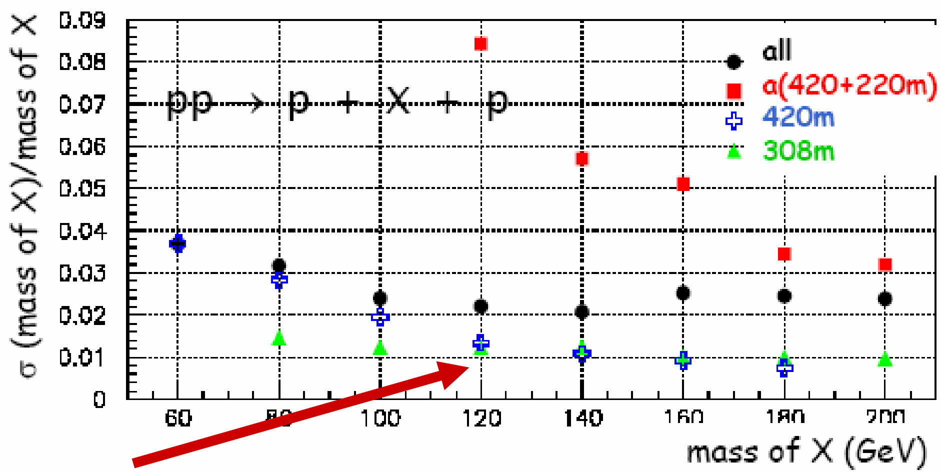
Need HERA and/or
Tevatron to referee
Otherwhise wait for
LHC data

Mass Resolution

Mass resolution of central system

Helsinki group





Resolutions for separate locations and all combination ("naive" combination)

- resolution ranges from ~ 4 % at low masses to ~ 1 % at high mass
- optimal resolution ~ 1 % for symmetric pairs (i.e. $\xi_1 \approx \xi_2$)

NB! a(420+215m) = $\xi_1 >> \xi_2$ or $\xi_1 << \xi_2$

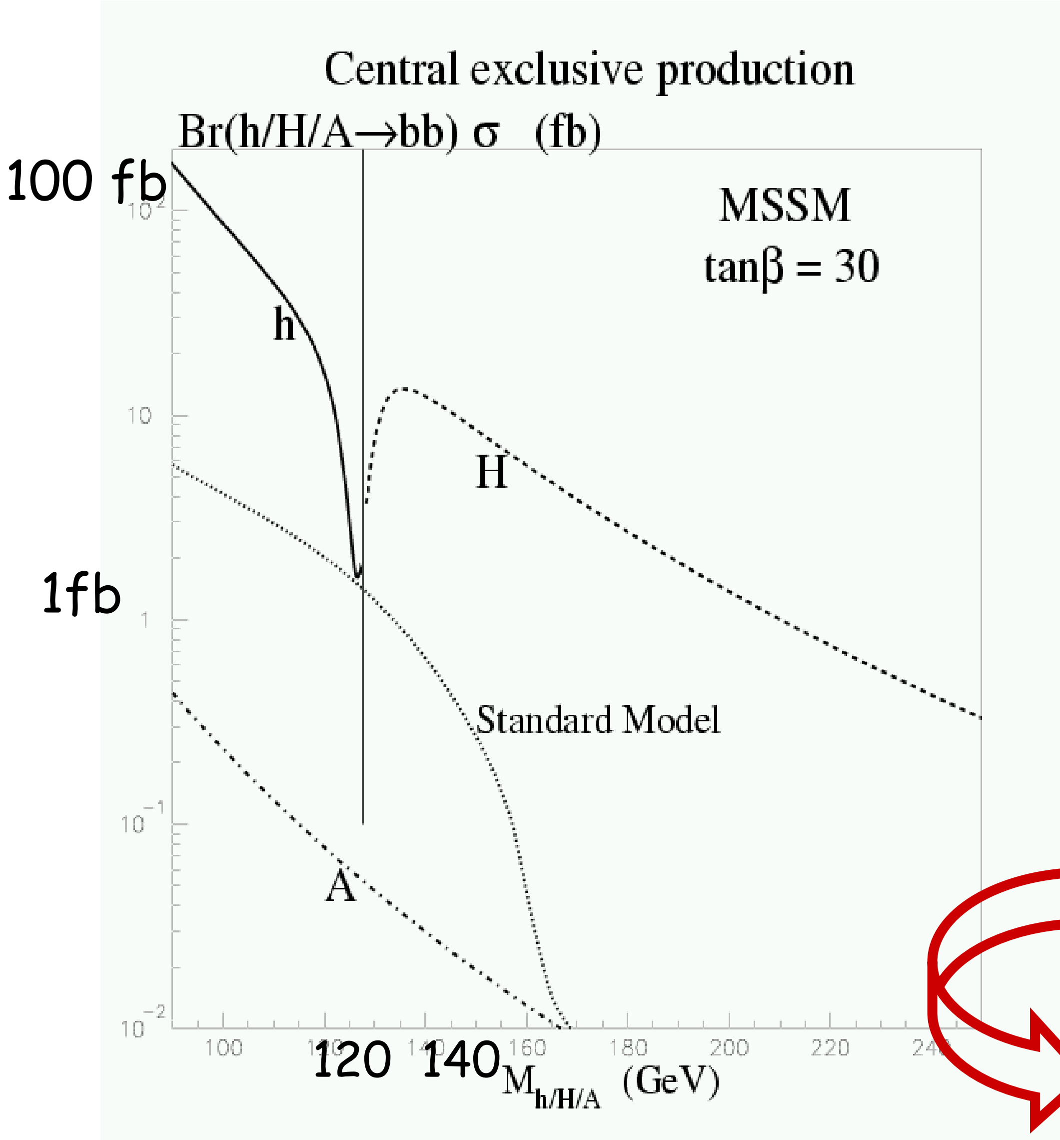
NB! Some effects are anticorrelated for ξ_1 & ξ_2 (e.g. transverse vertex position) ⇒ $\sigma(M)/M < \frac{1}{2}\sqrt{\Sigma_i \sigma(\xi_i)/\xi_i}$

Mass resolution 1-2% for symmetric events

Still being optimized

Can we improve the resolution? ⇒ would increase significance

Higgs Studies



SM Higgs: (30fb^{-1})
11 signal events (after cuts)
O(10) background events

Cross section factor
~ 10-20 larger in MSSM
(high tanβ)

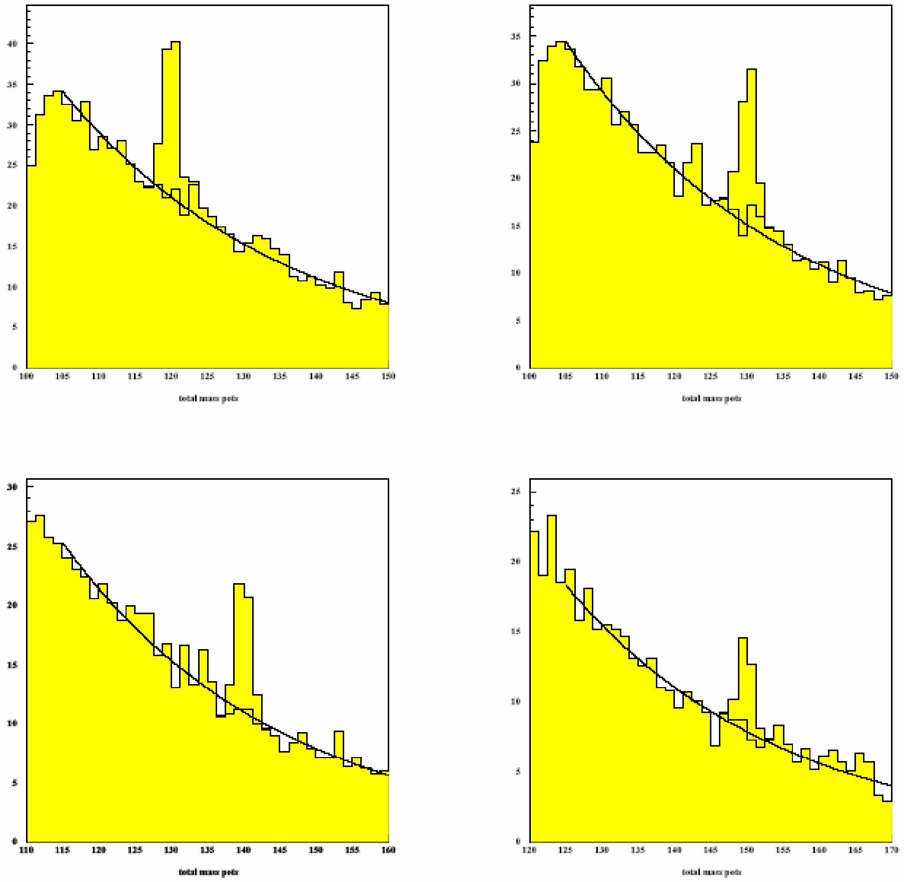
Kaidalov et al.,
hep-ph/0307064

⇒Study correlations between the outgoing protons to analyse the spin-parity structure of the produced boson

A way to get information on the spin of the Higgs
⇒ADDED VALUE TO LHC

Detailed Simulation Studies

Signals and background for different Higgs masses



100 fb^{-1}

Detailed studies ongoing
Fast detector simulation

Boonekamp/ATLAS
Royon,Tasevsky/CMS

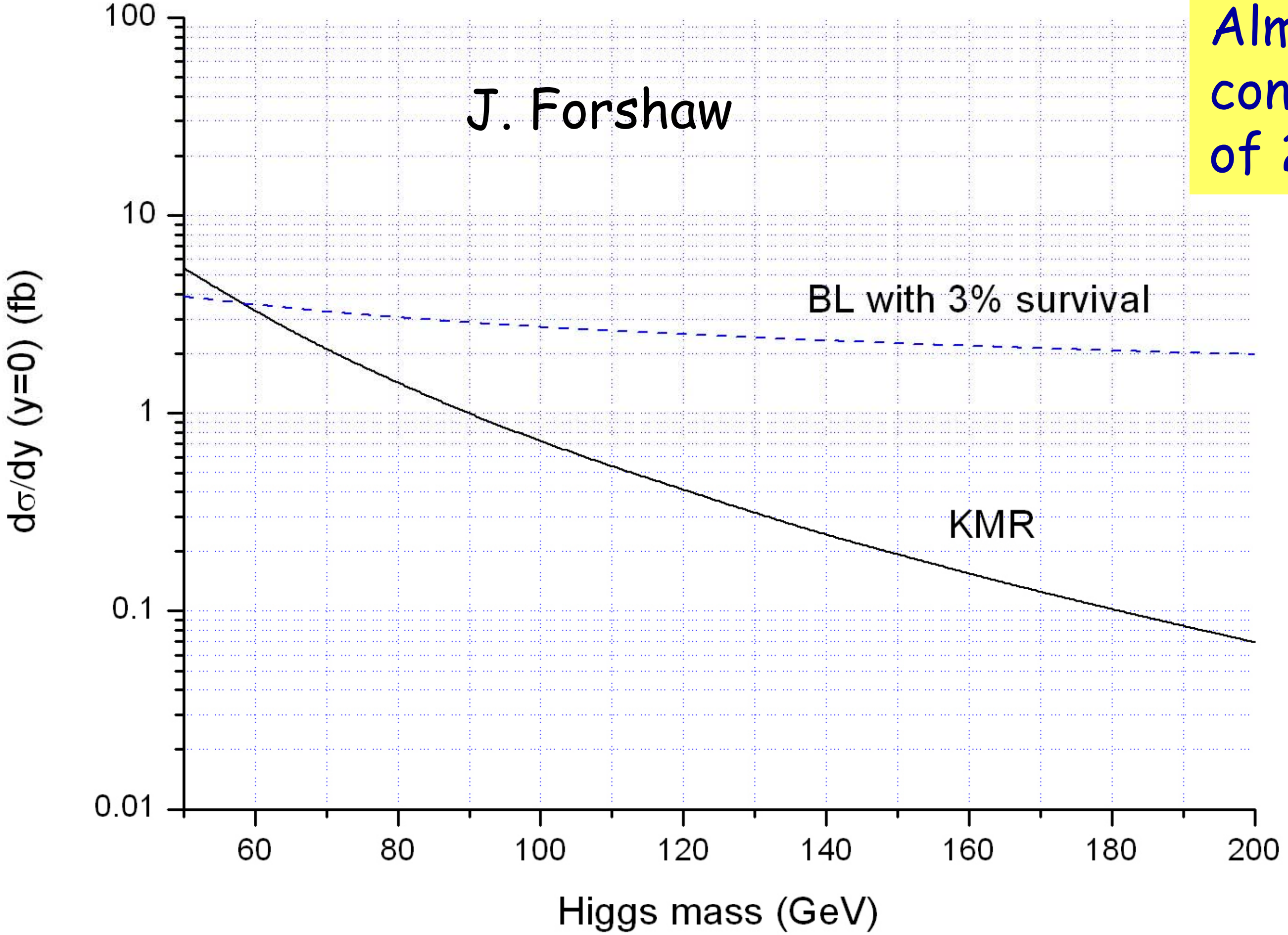
Include exclusive and inclusive bb background

Include missing mass resolution from the tagged protons

First look/needs to be optimized

Models…

Different models give different predictions for
- The cross sections
- The mass/energy dependence of the cross sections



Almost all calculations now converge to a cross section of 2-10 fb for a light Higgs

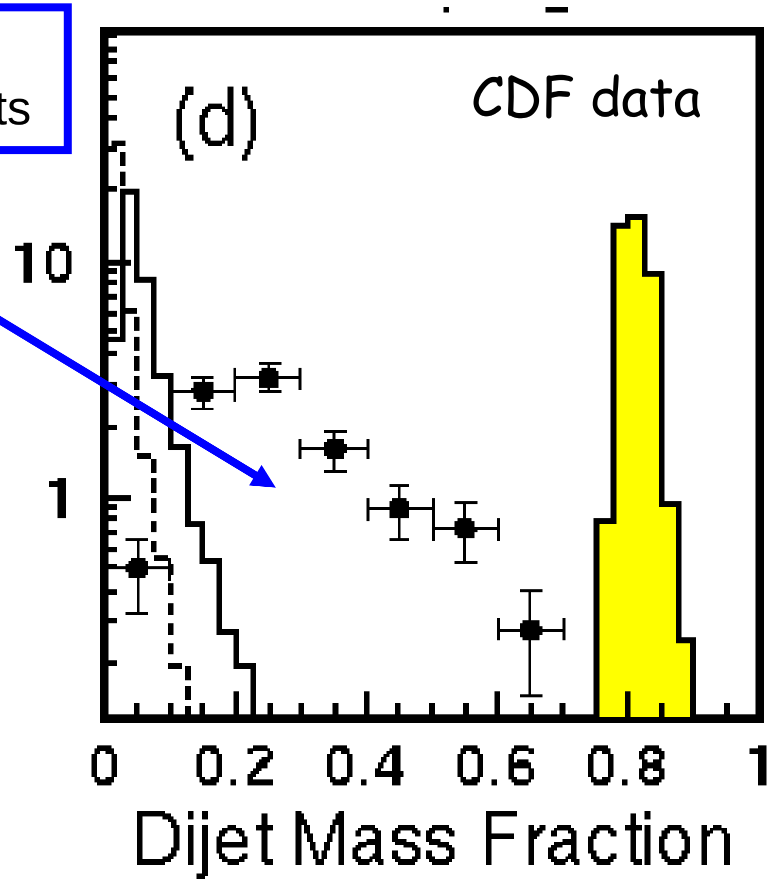
BL Bialas Landshof (soft Pomeron)

KMR: Khoze Martin Ryskin

Tevatron can test these models

Test at the Tevatron

Test for exclusive production at the Tevatron
⇒Energy in the two-jets/all energy for DPE events



CDF di-jets in DPE
upper limit 3.7 nb

Generally old predictions of
>O(100) pb for the Higgs
overshoot this predictions
y a factor 10-100
Hence → ruled out!

CDF and D0 should find &
measure a signal with run IIa

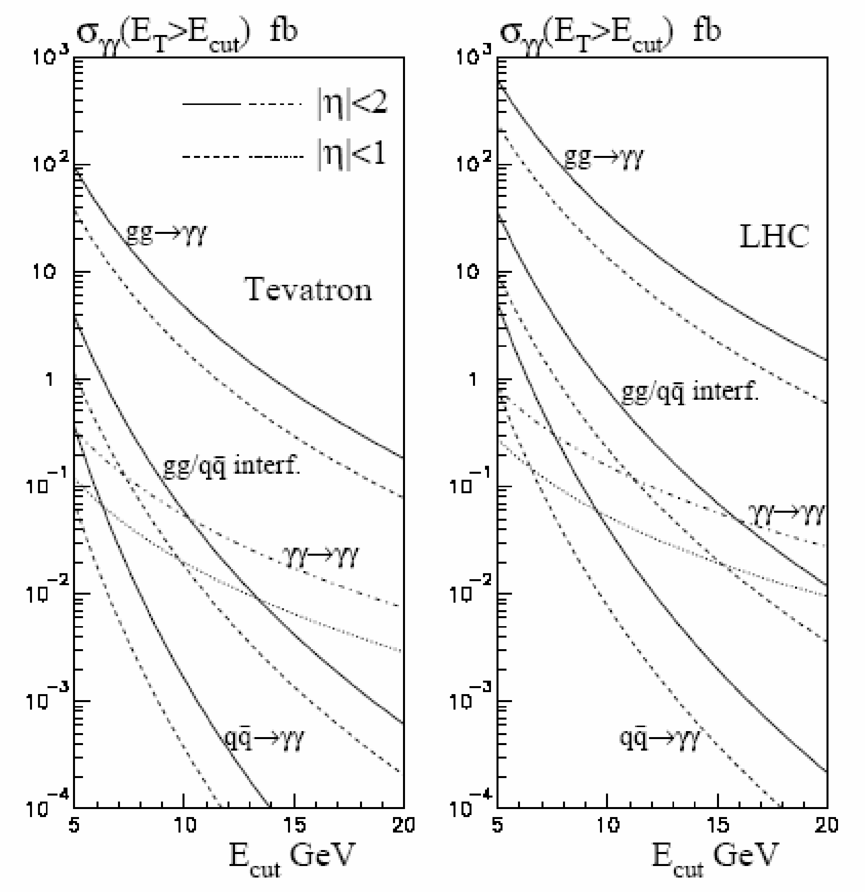
Needs optimal jet finder
Cone algorithm not the best

Smooth decrease of the cross section.
Can exclusive processes be seen on top of the non-exclusive background?

More Information from Tevatron!

Study of diffractive exclusive processes

V. Khoze et al., hep-ph/0409037



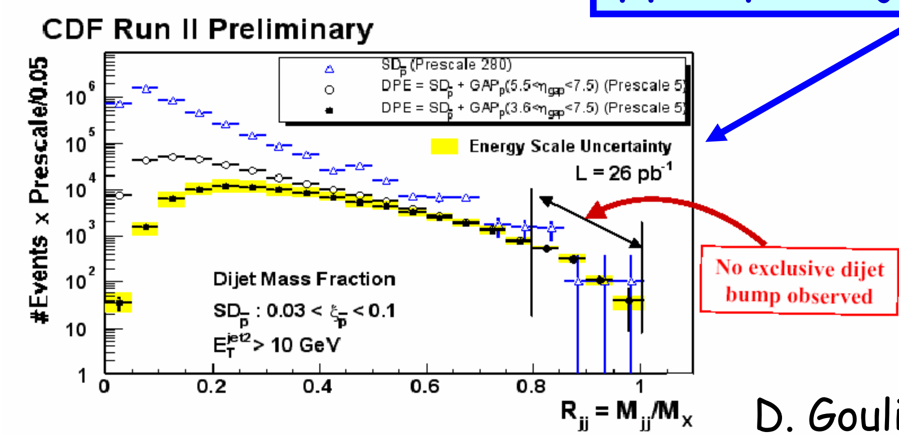
pp →p + γγ +p

V. Khoze et al., hep-ph/0403218

	Tevatron $\sqrt{s}=2$ TeV χ_c	Tevatron $\sqrt{s}=2$ TeV χ_b	LHC $\sqrt{s}=14$ TeV χ_c	LHC $\sqrt{s}=14$ TeV χ_b
$d\sigma_{excl}/dy\|_{y=0}$	130	0.2	340	0.6
σ_{excl}	650	0.5	3000	4
$d\sigma_{incl}/dy\|_{y=0}$	13	0.06	30	0.2
σ_{incl}	70	0.3	200	2

pp →p + χ_c +p

pp →p + dijets+p



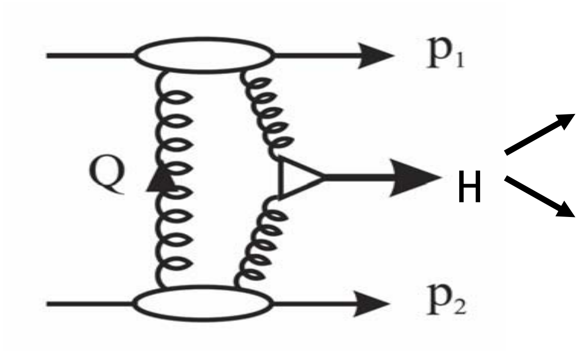
D. Goulianos

$|\eta_{jet1,2}|<2.5$, $0.03<\xi_{\bar{p}}<0.1$, $3.6<\eta_{gap}<7.5$, R = 0.7

Minimum E_T^{jet1}	Cross Section : $\sigma_{DPE}^{excl.\,jj}(R_{jj}>0.8)$
10 GeV	970 ± 65(stat) ± 272(syst) pb
25 GeV	34 ± 5(stat) ± 10(syst) pb

Exclusive Higgs production

Standard Model Higgs



b jets : M_H = 120 GeV s = 2 fb (uncertainty factor ~ 2.5)

M_H = 140 GeV s = 0.7 fb

M_H = 120 GeV : 11 signal / O(10) background in 30 fb^{-1}

with detector cuts

WW^* : M_H = 120 GeV s = 0.4 fb

M_H = 140 GeV s = 1 fb

M_H = 140 GeV : 8 signal / O(3) background in 30 fb^{-1}

with detector cuts

- The b jet channel is possible, with a good understanding of detectors and clever level 1 trigger (need trigger from the central detector at Level-1)
- The WW^* (ZZ^*) channel is extremely promising : no trigger problems, better mass resolution at higher masses (even in leptonic / semi-leptonic channel)
- If we see SM Higgs + tags - the quantum numbers are 0^{++}

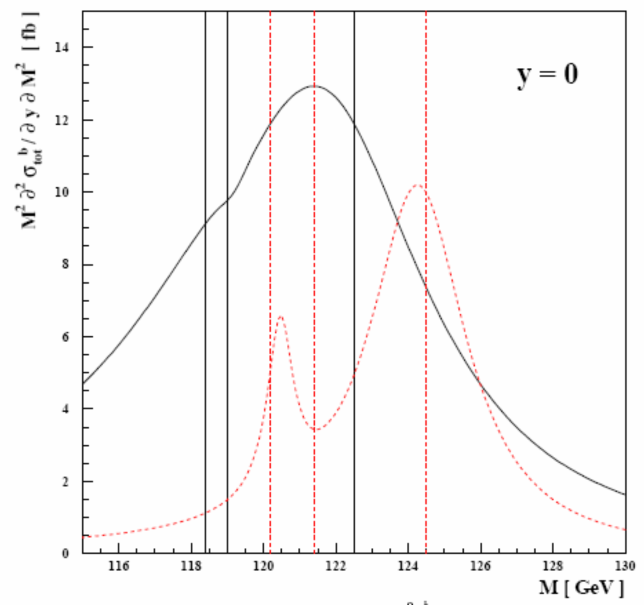
Phenomenology moving on fast

See e.g. J. Forshaw HERA/LHC workshop

"lineshape analysis"

J. Ellis et al.
hep-ph/0502251

Scenario with CP violation in the Higgs sector and tri-mixing



Experimental check: L. Rurua

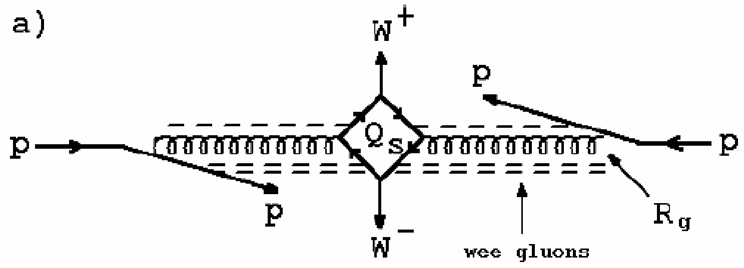
This example shows that exclusive double diffraction may offer unique possibilities for exploring Higgs physics in ways that would be difficult or even impossible in inclusive Higgs production. In particular, we have shown that exclusive double diffraction constitutes an efficient CP and lineshape analyzer of the resonant Higgs-boson dynamics in multi-Higgs models. In the specific case of CP-violating MSSM Higgs physics discussed here, which is potentially of great importance for electroweak baryogenesis, diffractive production may be the most promising probe at the LHC.

Anomalous WW Production

Alan White: theory of supercritical pomeron→ reggeized gluon+many (infinite) wee gluons

- color sextet quarks required by asymptotic freedom, have strong colour charge, (at least) few 100 GeV constituent mass
- Sextet mesons → EWSB
- UDD neutron dark matter candidate
- Explain high energy cosmic rays, Knee?
- Color sextet quarks couple strongly to W and Z and to the pomeron
- Phenomenology: Anomalous production of WW when above threshold ie. At the LHC (with possibly some onset already detectable at the Tevatron

color triplets			color sextets
u	c	t	U
d	s	b	D



⇒Measure exclusive WW,ZZ cross sections in DPE at the LHC
Expected Cross section orders of magnitude larger than in SM

Radions

Radions (graviscalars) RS models: quantum excitations of the brane separation

Three Fundamental Parameters :

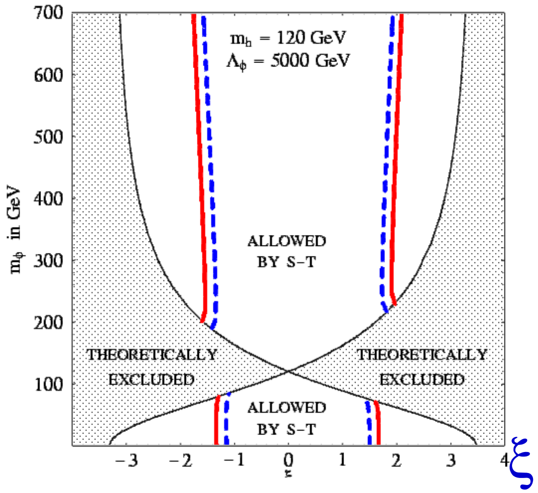
$$m_r \qquad \xi \qquad v/\Lambda$$

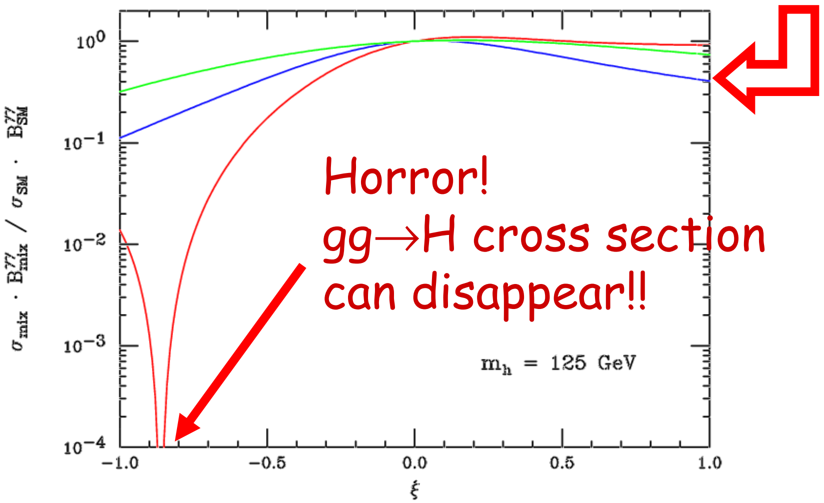
- Radion couplings to Gauge bosons and Fermions similar to SM Higgs
- ϕ mixing to H ξ causes shift in g_{HVV} and g_{Hff} couplings

$$\frac{g'_{HVV}}{g^{SM}_{HVV}} = \frac{g'_{Hff}}{g^{SM}_{Hff}} = f_1(\xi, v/\Lambda, m_\phi) + \frac{v}{\Lambda} f_2(\xi, v/\Lambda, m_\phi)$$

Couplings to $\gamma\gamma$ and gg receive anomalous contributions

EW constraints

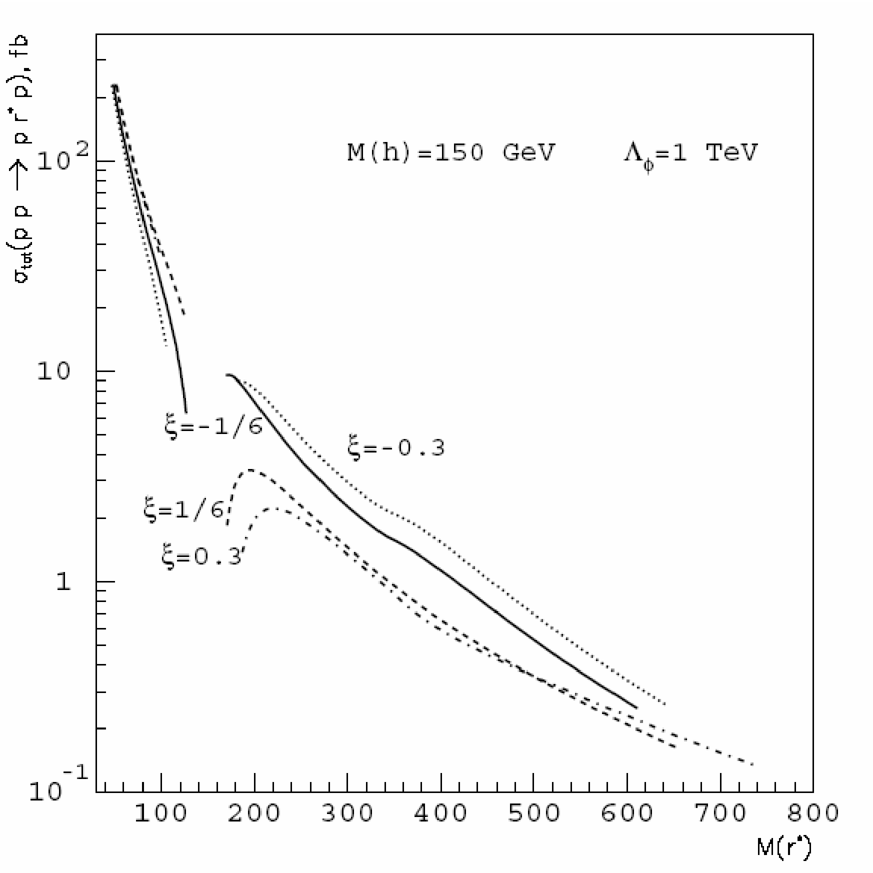




Gunion, Toharia & Wells hep-ph/0311219

Radions

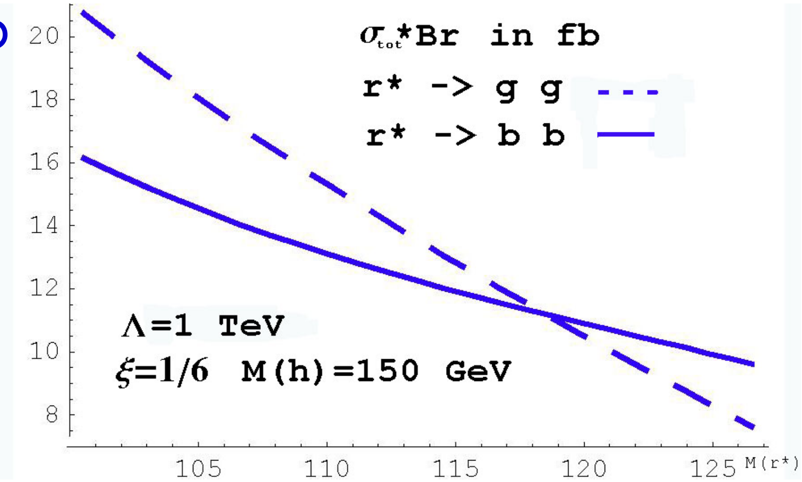
Radions like to couple to gluons
Large production rates in DPE



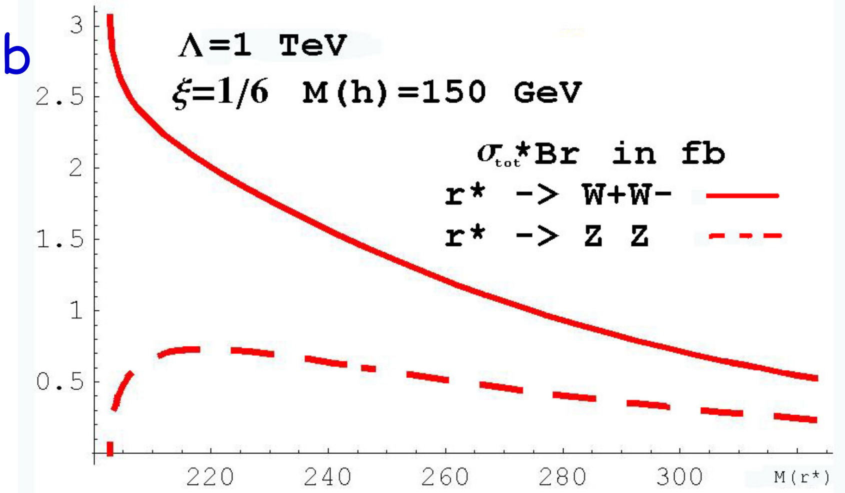
Large rate of $\phi \to bb$

Petrov
Ryutin

fb



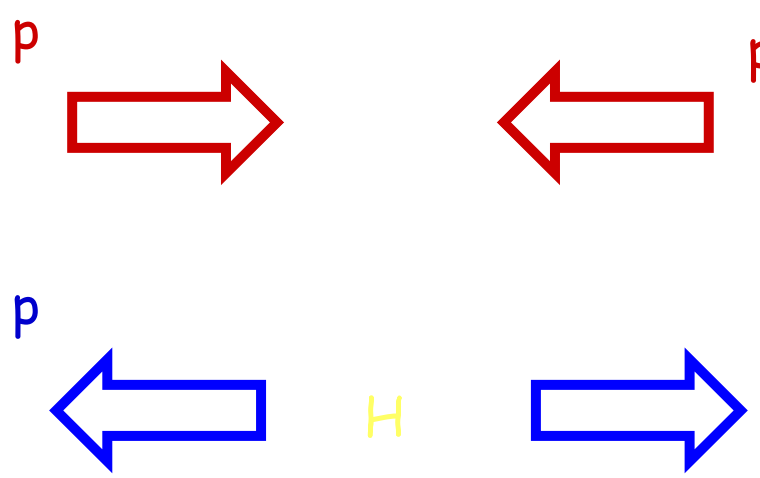
fb

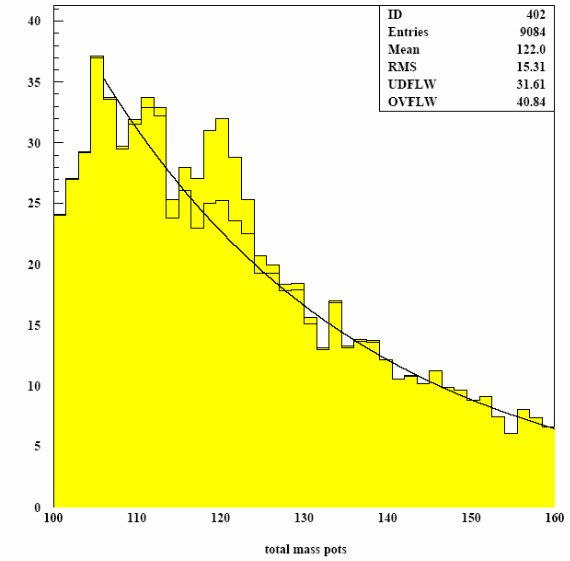


Invisible Higgs

Khoze et al.

Higgs decay into "invisible" particles, eg. neutralinos





M_H (GeV)	120	150	180	210
$\Gamma(H \to gg)$ (MeV)	2.2	4.1	6.9	10.8
σ (fb)	21	11	5.9	3.6
$\mathrm{Br}(b\bar{b})$	11%	4%	0.5%	0.2%
$\sigma(b\bar{b})$ (fb)	2.3	0.4	0.03	0.007

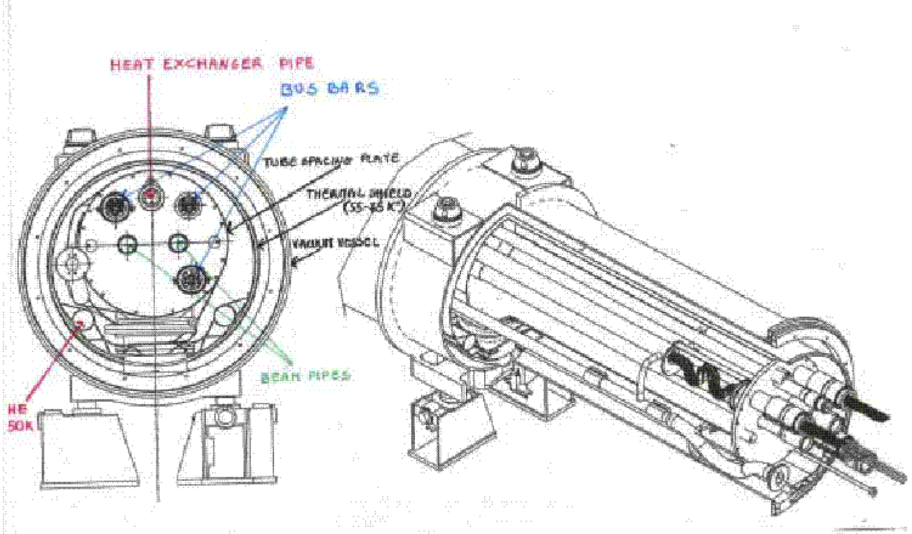
Scenario with 4^{th} generation

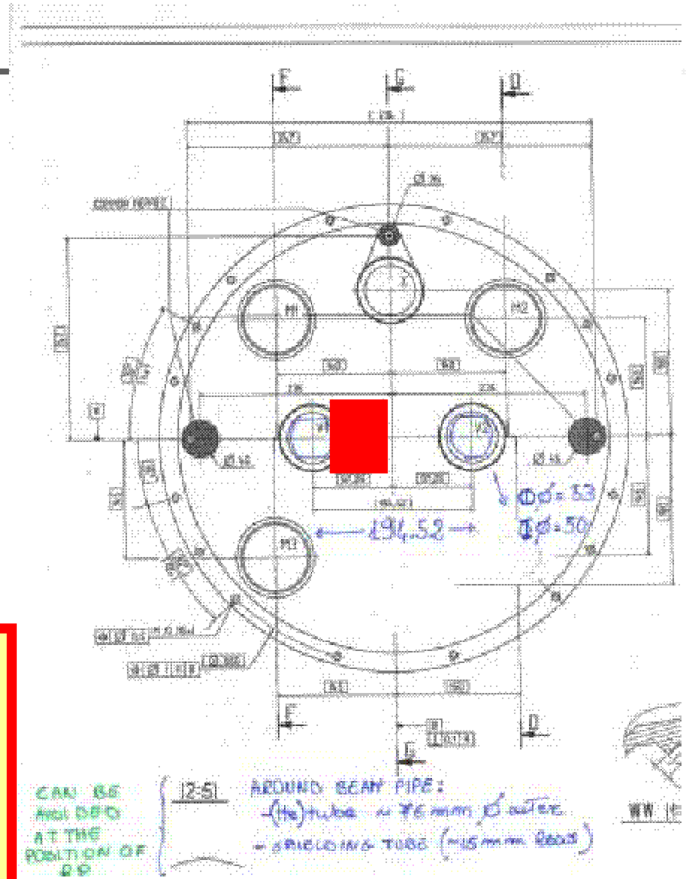
L1 Trigger Problem! Nothing in the central detector…
Works only at low luminosity
Effective luminosity at 10^{33} goes down to 10^{32}

$\Rightarrow$ 3 fb^{-1}/year

Detectors at 300/400m

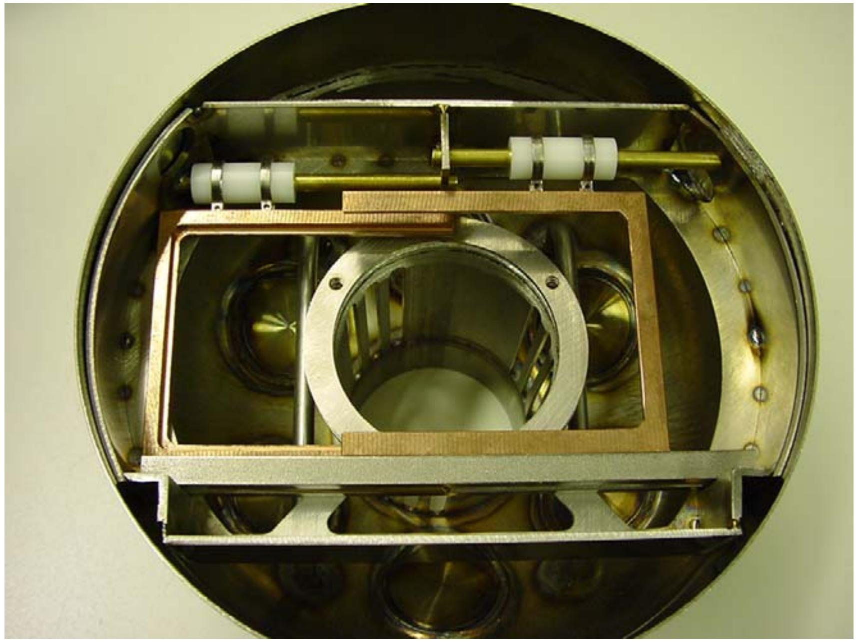
- Cold section: Detectors have to be integrated with cryostat
  Two options discussed with the machine
  Prefered option: 15m cold-warm transition with the detectors at 'room' temperature.

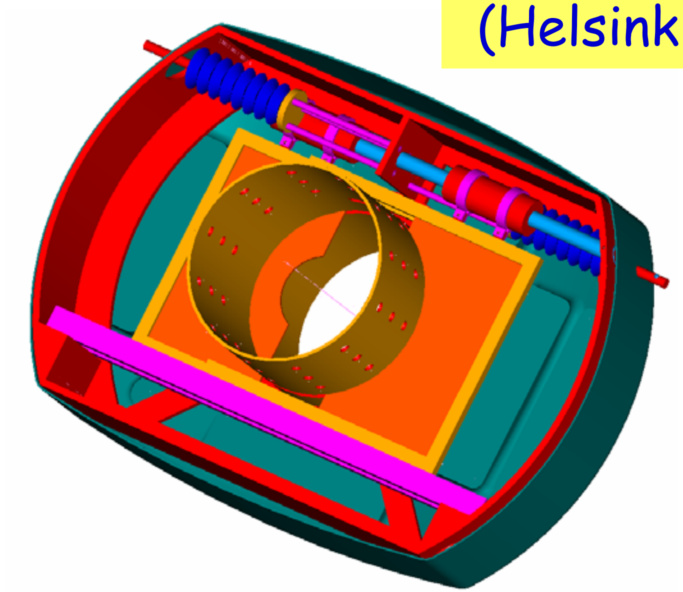




- Many machine components already ordered, some already delivered
- Machine wants "easy" start-up/no perturbation
  ⇒ Change means an "LHC upgrade" (phase II)
  ⇒ aim for 2009 run

Detectors: micro stations…

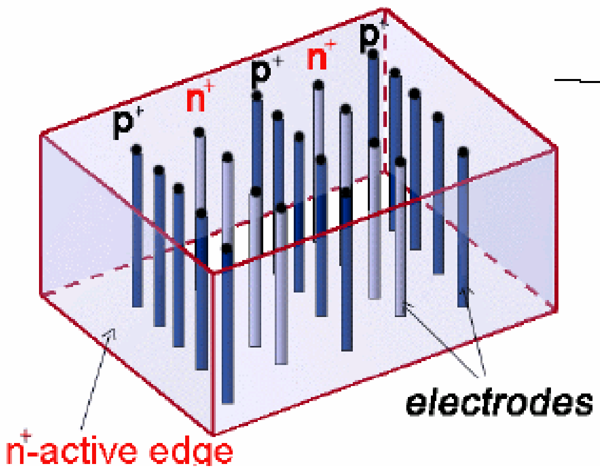


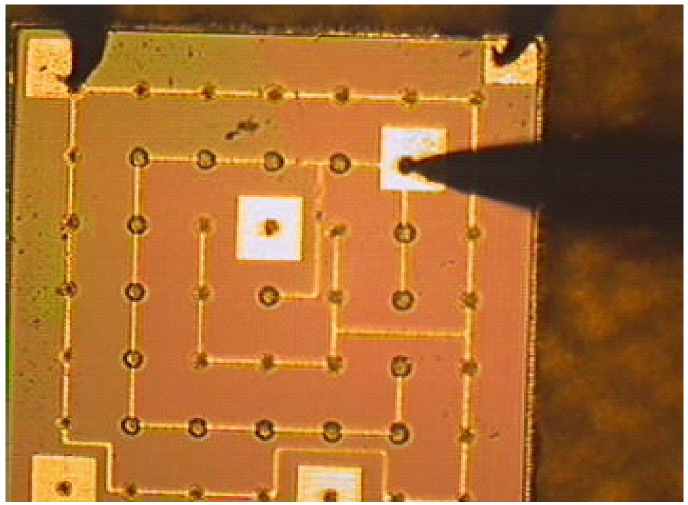


μ-station concept
(Helsinki propsal)

3D DETECTORS AND ACTIVE EDGES

Brunel, Hawaii, Stanford





Fast Timing Counters

Mike A + Jim Pinfold + others interested

Counters with ~ 10 ps timing resolution behind tracking
10 ps = 3 mm

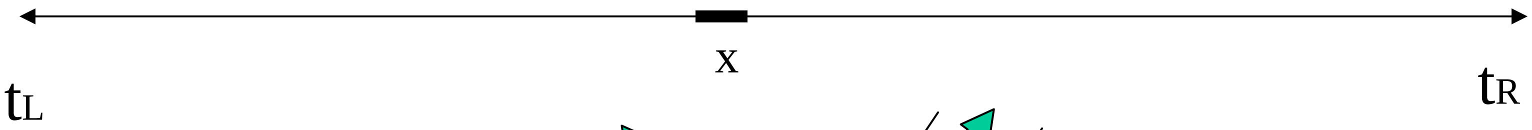
1) Check both p's from same collision (reduce background)
2) Get z(vertex) to match with central track vertex
3) Tell what part of bunches interacting protons were (F-M-B)

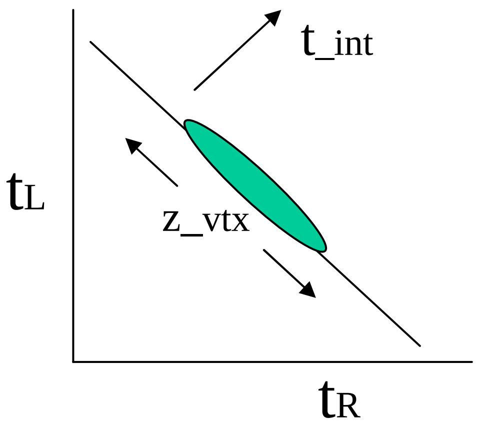
Likely solution:
Solid Cerenkov block or fibers (quartz?)
MCP-PMT (Micro-Channel Plate PMT) ... or APD?

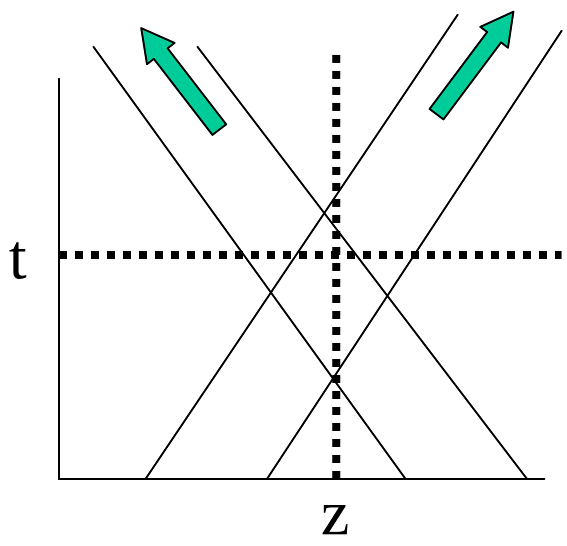
R&D effort initiated in the US in framework of FP420

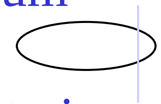
Put at back of 420m (220m?) tracking high precision timing counters.
Suggested in Tevatron LOI: Quartz Cerenkov + ~ Microchannel PMT
Then said 30 ps(?). Now tested (Japanese Gp) → **10 ps**

Check that p's came from same interaction vertex (& as central tracks)







Know position in each bunch of interacting p's.
Position-momentum correlation → 
Reduce uncertainty in incoming momenta.

Potentially valuable e.g. MSSM triplet (Higher cross section & close states)

Available online at www.sciencedirect.com
SCIENCE @ DIRECT®
ELSEVIER Nuclear Instruments and Methods in Physics Research A 528 (2004) 763–775
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

MCP-PMT timing property for single photons

M. Akatsu, Y. Enari, K. Hayasaka, T. Hokuue, T. Iijima, K. Inami*, K. Itoh, Y. Kawakami, N. Kishimoto, T. Kubota, M. Kojima, Y. Kozakai, Y. Kuriyama, T. Matsuishi, Y. Miyabayashi, T. Ohshima, N. Sato, K. Senyo, A. Sugi, S. Tokuda, M. Tomita, H. Yanase, S. Yoshino

Department of Physics, High Energy Physics Laboratory, Nagoya University, Furo-Cho, Chikusa, Nagoya 464-8602, Japan

Received 8 January 2004; received in revised form 1 April 2004; accepted 2 April 2004

Abstract

We have measured the performance, especially the timing properties, of micro-channel plate photo-multiplier tubes (MCP-PMTs) by irradiating with single photons with/without a magnetic field. A time resolution of $\sigma = 30$–35 ps was obtained for single photons under 1.5 T. With an MCP-PMT, a small time-of-flight counter by means of Cherenkov light radiation instead of scintillation light has been prepared, and a time resolution $\sigma \sim 10$ ps was attained for a high-energy π-beam by multiple photons.

It's been done!

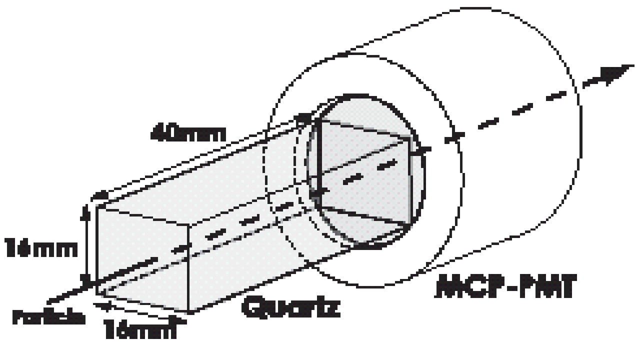


Fig. 12. Schematic drawing of the test TOF counter. HPK10 is used as the MCP-PMT.

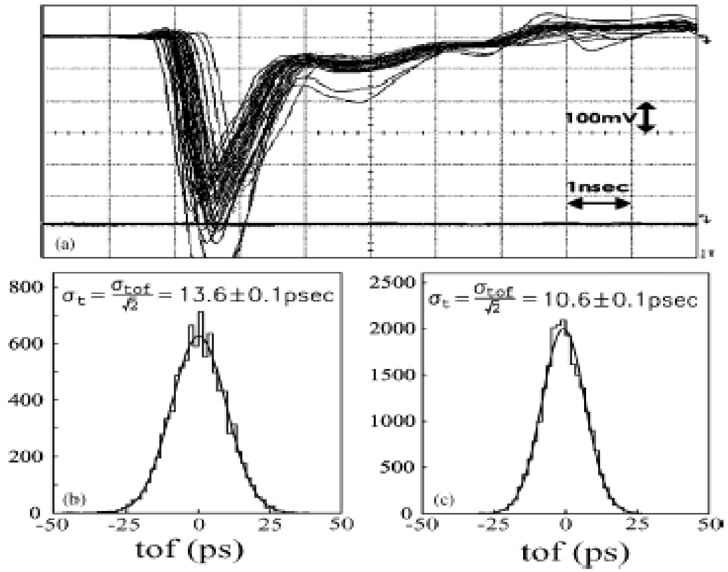


Fig. 13. (a) shows HPK10s output signal for 3 GeV/c pion beam; (b) and (c) are the distributions of the time difference between two test counters without and with a quartz radiator, respectively. Their resulting time resolutions of the single counter are obtained as $\sigma_t = \sigma_{tof}/\sqrt{2} = 13.6\pm0.1$ ps and 10.6 ± 0.1 ps.

Summary

- Diffractive and forward physics is on the physics program of LHC experiments. CMS+TOTEM developing, working towards a LOI.
  - ⇒ Diffractive and forward physics will be done from the start at the LHC
  - ⇒ Don't hesitate to come up with new ideas, new measurements, new test!
- Upgrades for the experiments are being proposed
  - In particular large momentum for 420m region is materializing.
  - CMS/ATLAS expand coverage in the forward coverage
- Large field of Physics Topics
  - Hard (& soft) diffraction, QCD and EWSB (Higgs), New Physics
  - Low-x dynamics and proton structure
  - Two-photon physics: QCD and New Physics
  - Special exotics (centauro's, DCC's in the forward region)
  - Cosmic Rays, Luminosity measurement, pA, AA…
- Opportunities for present/new collaborators to join forward physics
  - ⇒ No doubt will provide useful measurements on QCD, new physics and measurements for the Cosmic Ray community

Require hits in 220 m and 420 m RPs

Probably not possible on L1 - cannot beat the speed of light
Still - require hits on one side in 220m RPs and on one side in 420m RPs
(in effect means on opposite side - events where xi values of 2 protons are very different, i.e. “asymmetric” events)

Richard Croft

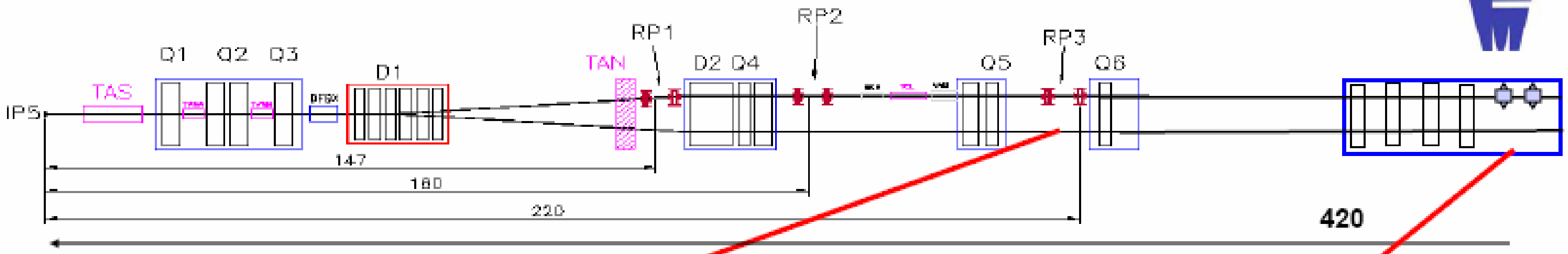
Luminosity $[\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	# Pile-up events per bunch crossing	L1 2-jet rate [kHz] for $E_T > 40\mathrm{GeV}$ per jet	Total reduction needed	Reduction when requiring track in RP detectors				
				at 220 m	at 220 m, $-\xi < 0.1$	at 420 m	at 220 m & 420 m (asymmetric)	$-\xi < 0.1$
1×10^{32}	0	2.6	2	370				
1×10^{33}	3.5	26	20	7	15	27	160	380
2×10^{33}	7	52	40	4	10	14	80	190
5×10^{33}	17.5	130	100	3	5	6	32	75
1×10^{34}	35	260	200	2	3	4	17	39

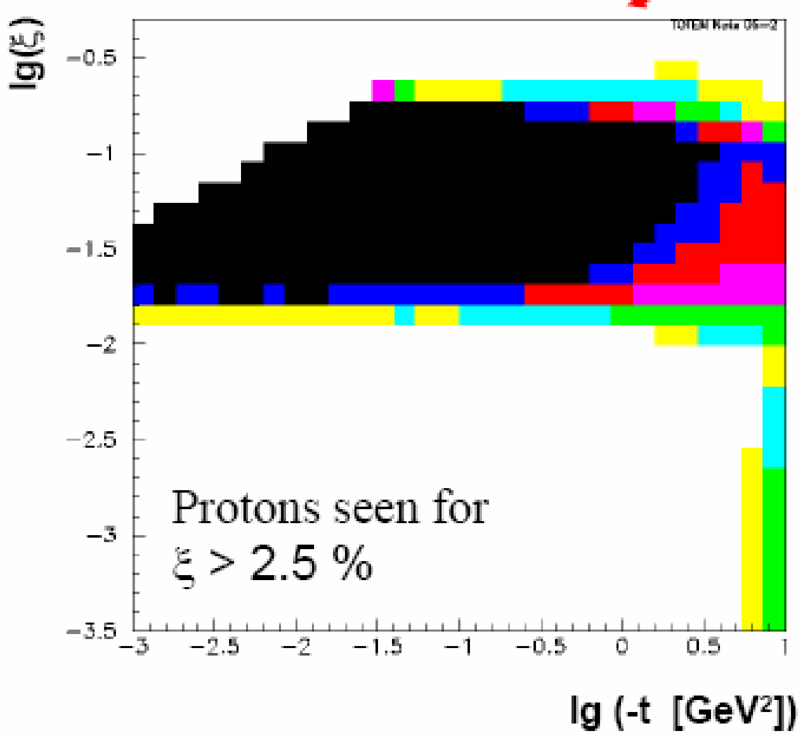
For H (120 GeV, DPE prod) $\rightarrow$ b bbar, adding L1 conditions on the RPs at 220m and 420m would provide a rate reduction sufficient to meet the CMS L1 bandwidth limits at luminosities up to 10^{34} cm^{-1} s^{-1}

Running Scenarios

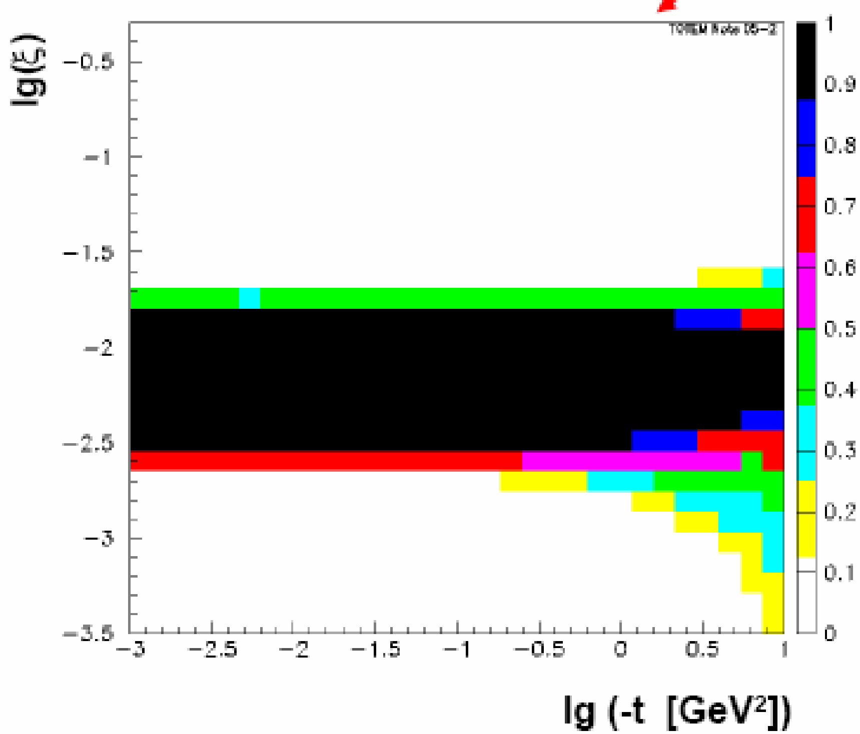
Scenario Physics:	1 low |t| elastic, σ_{tot}, min. bias, soft diffraction	2 diffraction	3 large |t| elastic	4 hard diffraction large |t| elastic (under study)
β^* [m]	1540	1540	18	90
N of bunches	43	156	2808	936
N of part. per bunch	0.3×10^{11}	$(0.6 - 1.15) \times 10^{11}$	1.15×10^{11}	1.15×10^{11}
Half crossing angle [μrad]	0	0	160	100
Transv. norm. emitt. [μm rad]	1	1 - 3.75	3.75	3.75
RMS beam size at IP [μm]	454	454 - 880	95	200
RMS beam diverg. [μrad]	0.29	0.29 - 0.57	5.28	2.4
Peak luminosity [$cm^{-2} s^{-1}$]	1.6×10^{28}	2.4×10^{29}	3.6×10^{32}	2×10^{31}

CMS+TOTEM: Diffraction at $\beta^* = 0.5$ m





Protons seen for
$\xi > 2.5$ %



Summary: L1 signal efficiencies

- RP condition for 220m RPs reduces 2-jet L1 trigger signal efficiency by factor ~2
Result of limited acceptance of RPs in diffractive peak region

- Requiring 2-jet trigger threshold of ET=40 GeV and a proton be seen on one side in 220m RPs: signal efficiency for H(120 GeV) -> b bbar is of the order **20%** (Exhume)

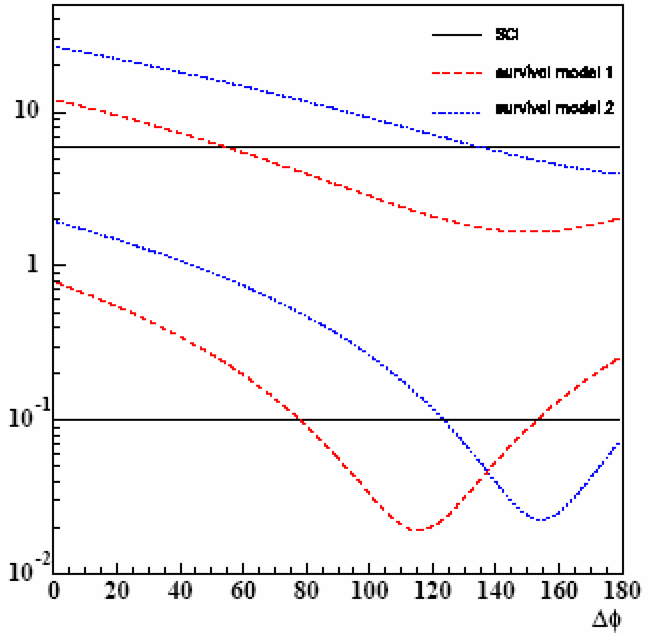
- Requiring in addition that a proton be seen in the 420m RPs on the other side results in signal efficiency of about **15%**

- Requiring 2-jet trigger threshold of ET=40 GeV and a proton be seen on one side in 420m RPs: signal efficiency for H(120 GeV) -> b bbar is of the order **30%**

More Information from Tevatron

Kupco, Peschanski, Royon

Study of the gap survival probability



- dijet production with $p_T > 5\,\text{GeV}$ at Tevatron
  - upper plots: $|t_p| > 0.6$, $|t_{\bar{p}}| > 0.1\,\text{GeV}^2$
  - lower plots: $|t_p| > 0.5$, $|t_{\bar{p}}| > 0.5\,\text{GeV}^2$
- Pomeron models
  - POMWIG interfaced with the calculation of survival probability
  - two-channel eikonal model (Model 1)
  - elastic channel model (Model 2)
- SCI model - modified version of Pythia with color string reconnection

Different azimuthal correlation between the two protons for different models for the gap survival
Important for CP studies in the Higgs sector @ LHC

- Einstein and beyond: Introduction to General relativity
  - Sponsor: M. Luescher
  - Speaker: N. Straumann,
  - DATES : 3-7 October, OK

- Exploring the planets and moons in our solar system
  - Sponsor E. Lillestol/M. Doser
  - Status: Sponsors still looking for candidate speaker

- Effective field theories into action
  - Sponsor: G. Giudice
  - canceled – all wished speakers declined

- Studing anti-matter
  - Sponsor: Albert De Roeck
  - Speaker: R. Landua
  - Dates fixed : 8-12 May

- Tevatron: studying pp collisions at the highest energy
  - Sponsor: Albert De Roeck
  - Speaker: Beate Heinemann
  - Dates fixed : 15-18 May - Contract sent

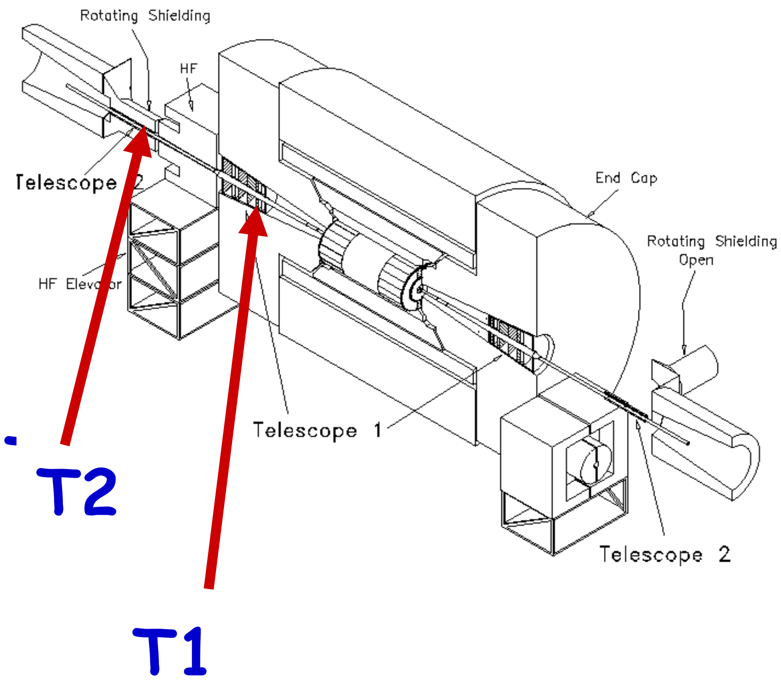
- Searching for Supersymmetry at the LHC
  - Sponsor: G. Giudice
  - Speaker: M. Drees
  - Dates fixed : 20-24 March - Contract sent

- Detector challenges for the LHC upgrade
  - Sponsor: G. Monarcchi/S. Schuh
  - Dates reserved : 11-19 March - waiting for speaker names

- The world of Quantum Matter
  - Sponsor: R. Landua
  - Speaker: M. Weidemüller
  - Status: speaker has accepted. Dates not fixed?

- Deep Space Telescopes
  - Sponsor: F. Navarria
  - Status: Giovanni Bignami
  - Dates fixed : 13 to 17 February

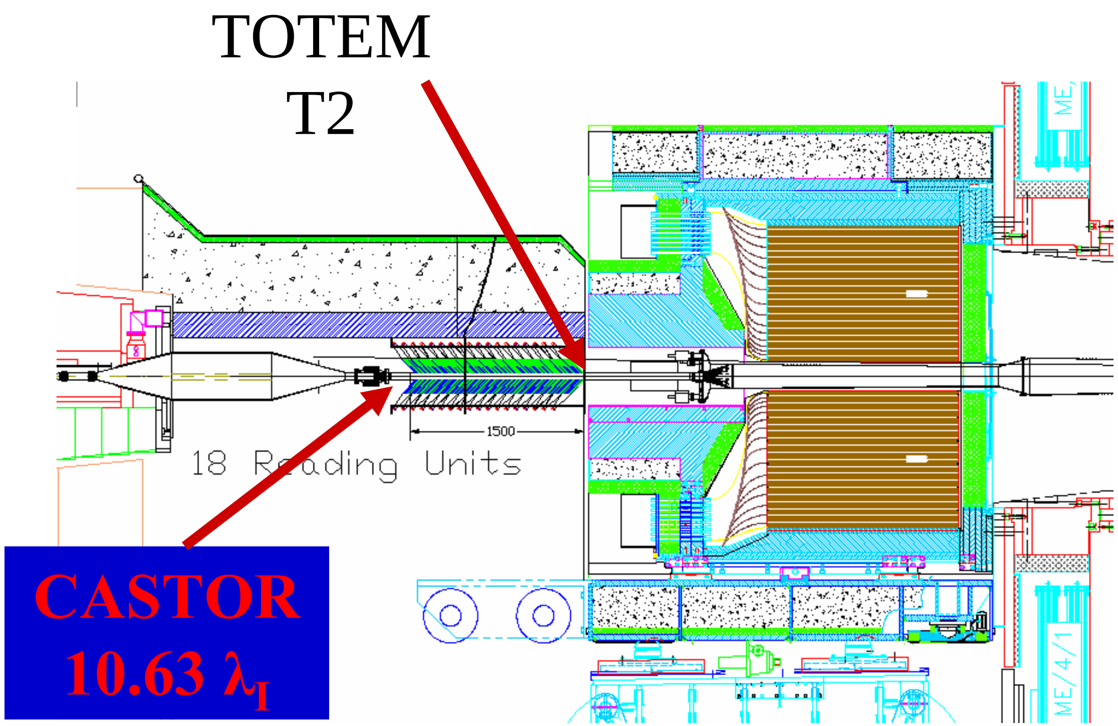
TOTEM/CMS Forward Detectors



T1/T2 inelastic event taggers

- T1 CSC/RPC tracker ('99 LOI)
- T2 GEM or Silicon tracker (TOTEM/New)
- CASTOR Calorimeter (CMS/New)
- ZDC Calorimeter (CMS/New)

T1 $3.1< \eta <4.7$
T2 $5.3<\eta <6.7$
Castor $5.25<\eta <6.5$



Extend the reach in η from $|\eta|<5$ to $|\eta| <6.7$

Opportunities to contribute to the LOI !!

CASTOR CALORIMETER DESIGN V11

Electromagnetic section:

Tungsten plate: thickness = 5.0mm, @45° = 7.07 mm = $7.258 \times 10^{-2}\ \lambda_I$ = 1.988 Xo
Fused Silica: thickness = 2.0mm, @45° = 2.83 mm = $6.618 \times 10^{-3}\ \lambda_I$ = 2.413×10^{-2} Xo

1-Sampling Unit (SU) = 1W-plate +1Q-plate: L = 9.9 mm = 0.0792 λ_I = 2.012 Xo
1-Reading Unit (RU) = 11 SU = 22.13 Xo = 0.871 λ_I

Number of W– plates: 11 x 8 = 88
Number of Q– plates: 11 x 16 = 176

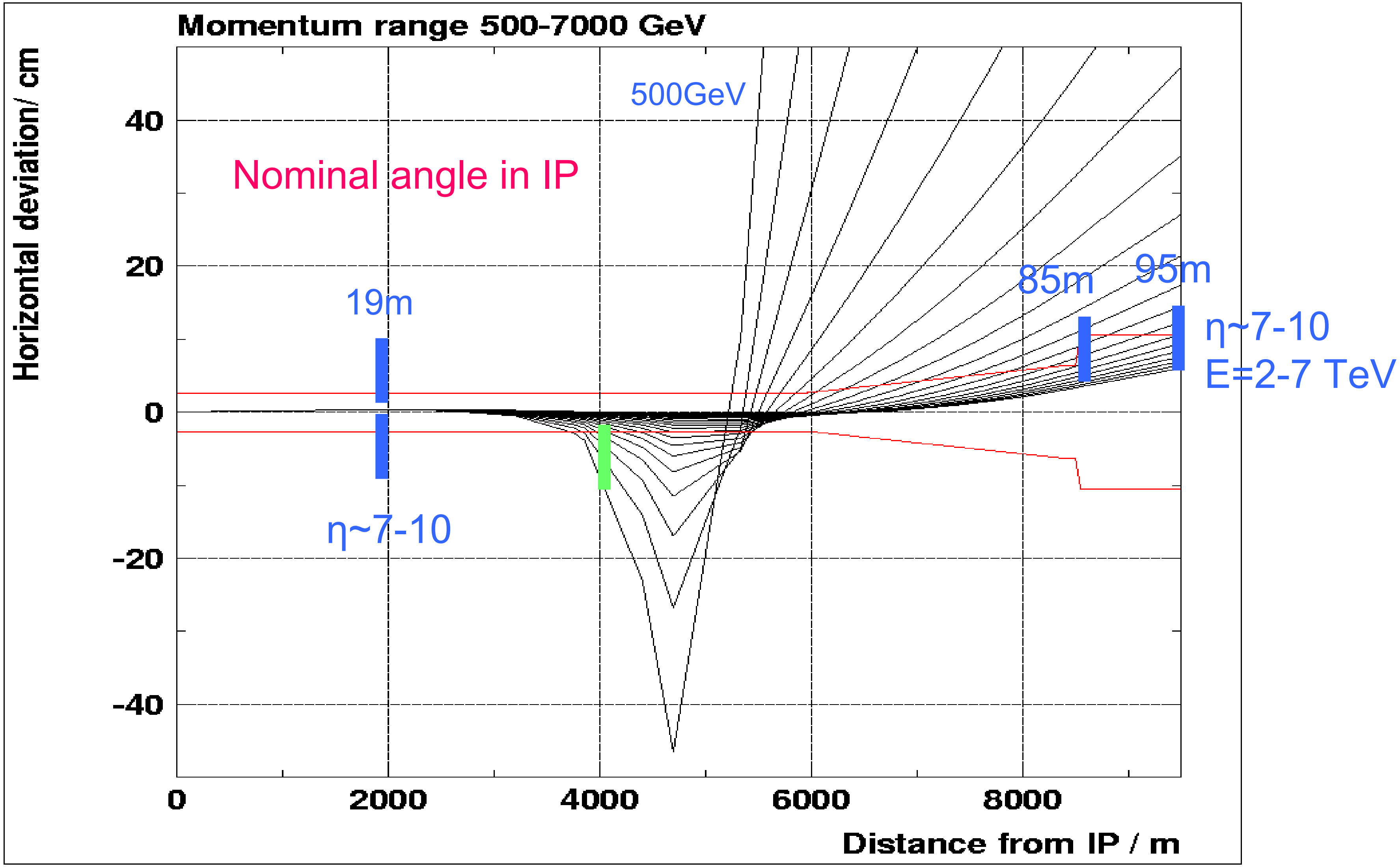
Hadronic section:

Tungsten plate: thickness = 10 mm, @45° = 14.14 mm = $1.452 \times 10^{-1}\ \lambda_I$
Fused Silica: thickness = 4 mm, @45° = 5.66 mm = $1.324 \times 10^{-2}\ \lambda_I$

1-Sampling Unit (SU) = 1W-plate +1Q-plate: L = 19.8 mm = 0.1584 λ_I
1-Reading Unit (RU) = 6 SU = 0.95 λ_I
Number of RUs = 10

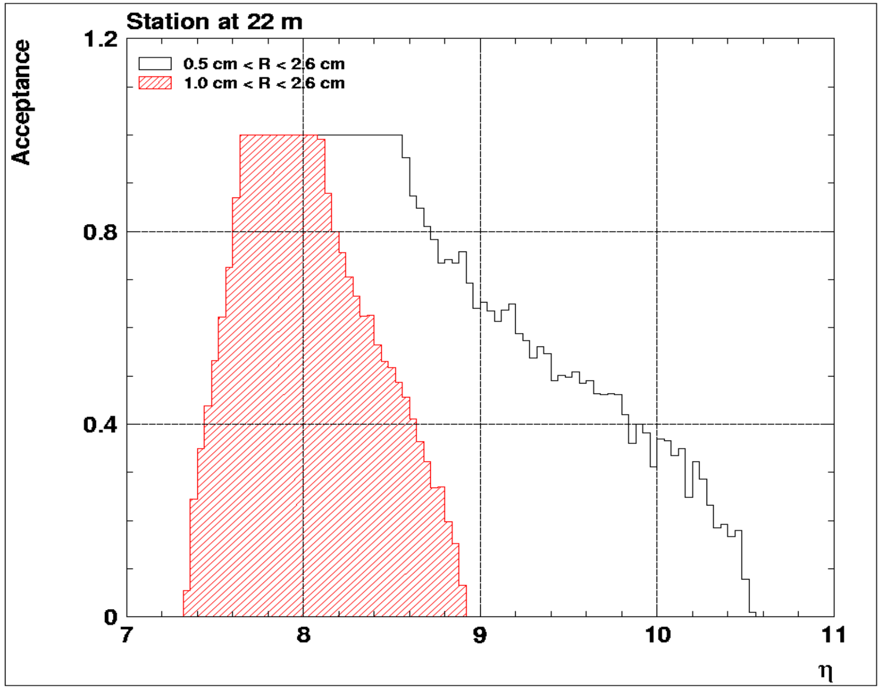
Number of W–plates: 6 x 10 x 8 = 480
Number of Q–plates: 6 x 10 x 16 = 960

Trajectory of forward protons



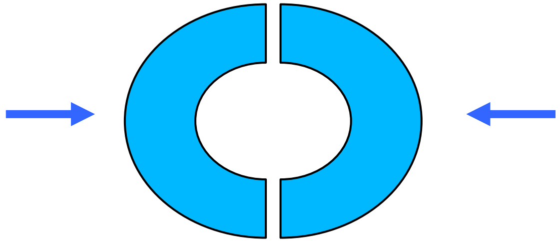
Acceptance as function of pseudo-rapidity η

2 Stations at 19m



R_{min} = 1.0, 0.5 cm

R_{max} = 2.5 cm



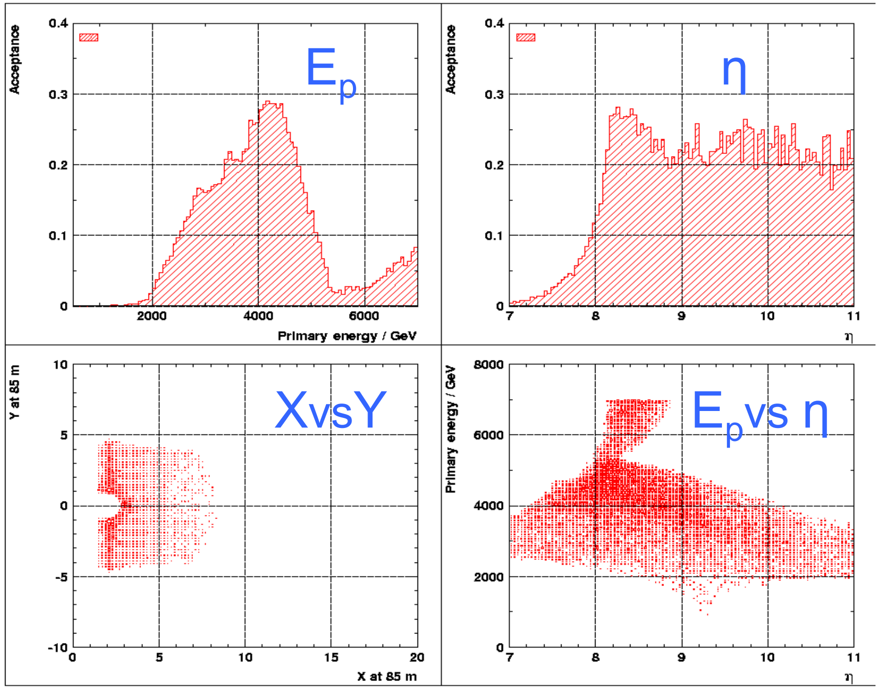
Coordinate/position uncertainty ~0.5mm

➔η resolution: 0.05-0.15

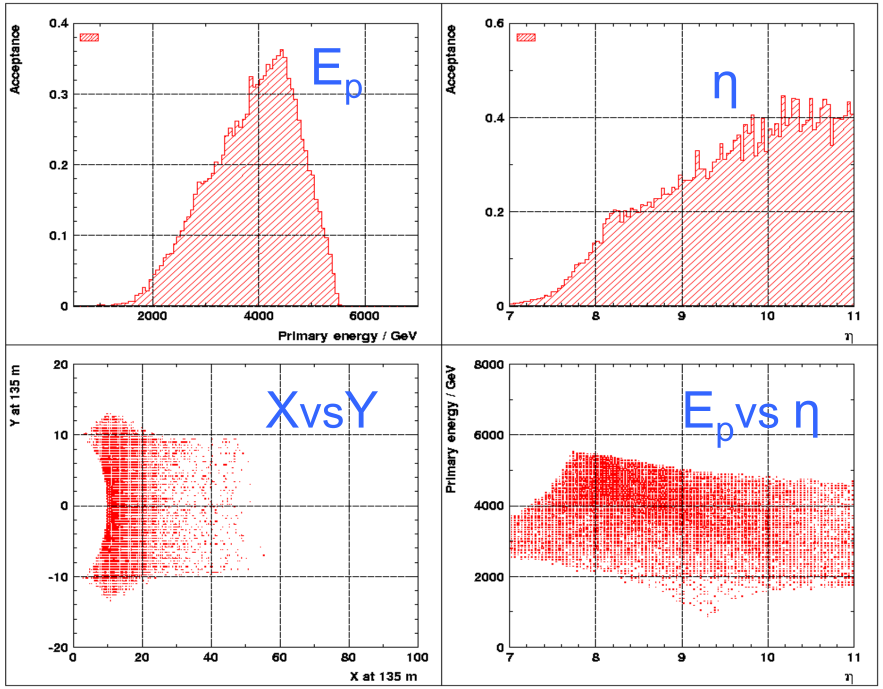
69

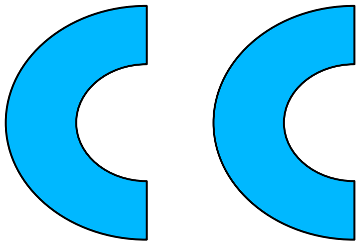
Acceptance as function of E_p and η

Stations at 85m and 95m



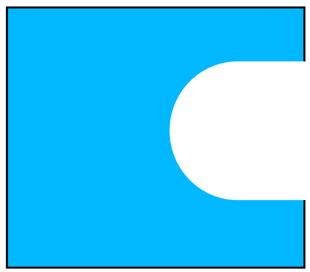
Hadronic calorimeter at 135m





R_{min} = 1.0 cm
R_{max} = 2.5 cm

Position uncertainty ~0.5mm
➔ση ~ 5-15%, σP ~ 1-3%



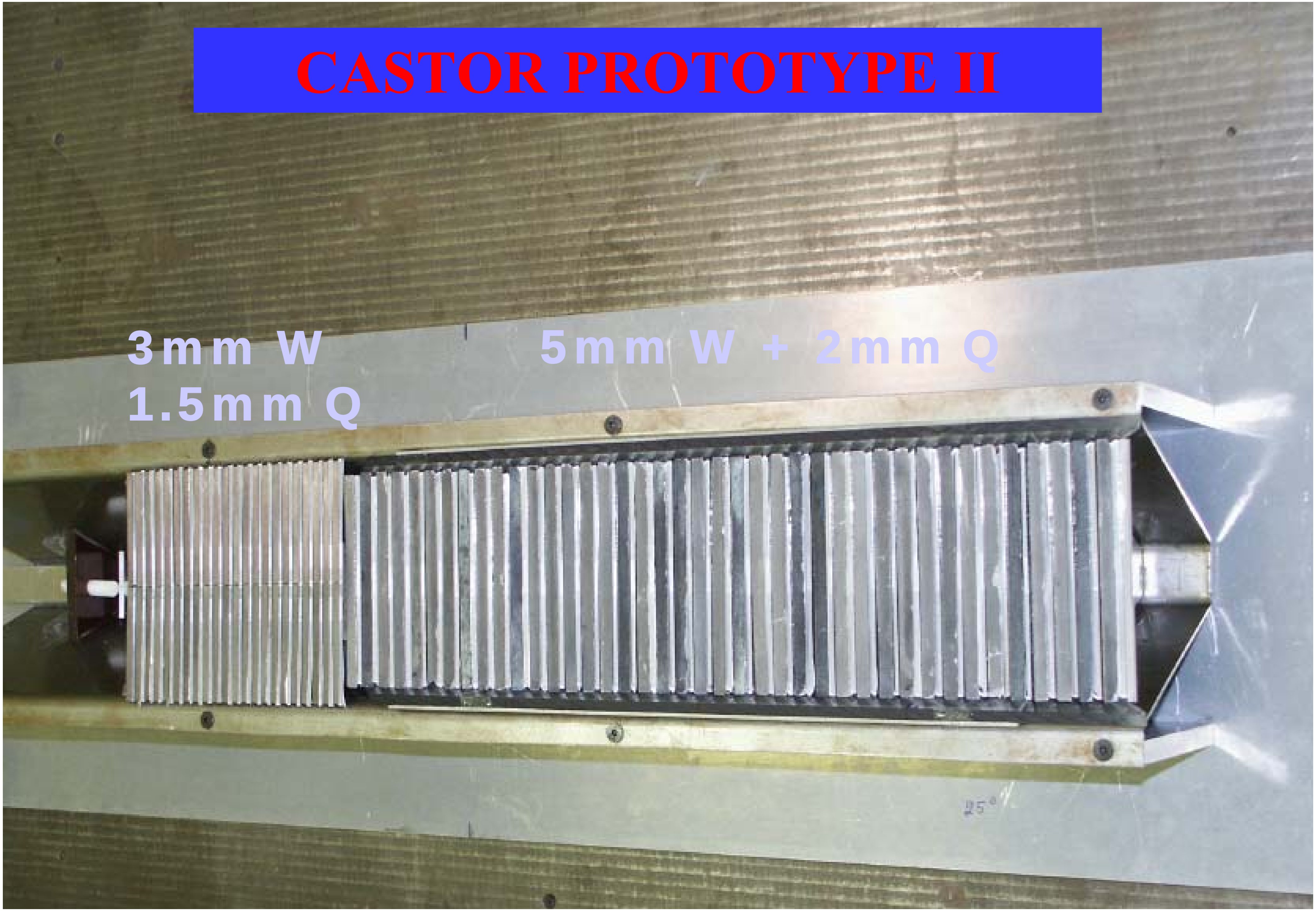
R_{min} = 10 cm

σE ~ 3%

Acceptance as function of E_p / η

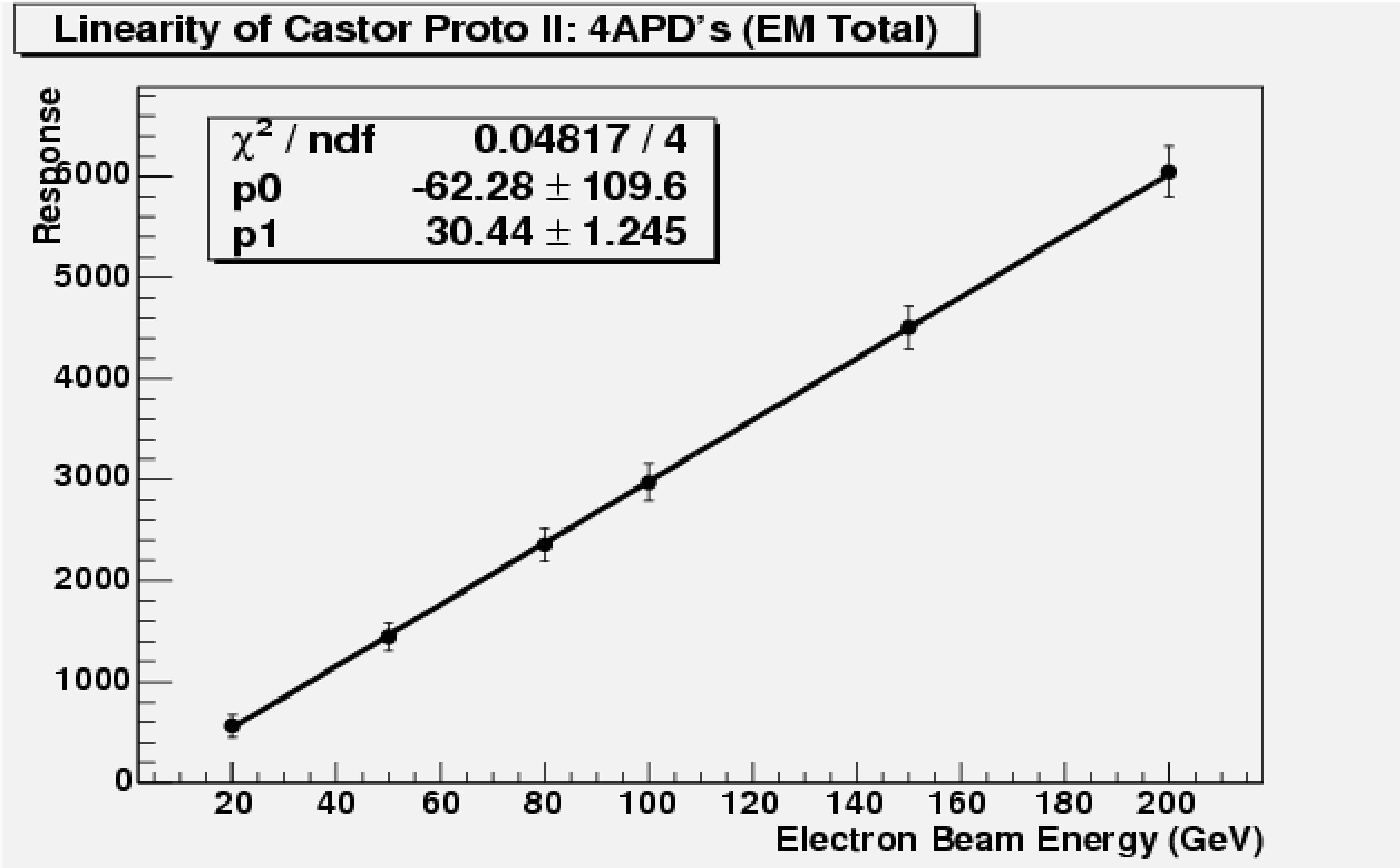
η / E_p	0.5-7 TeV	2-5.5 TeV
2 Roman Pots at 85,95m η=7-10	11%	21%
η=7-8	<10%	10-20%
η=8-9	15-25%	30-55%
η=9-10	20-25%	55-60%
Calorimeter at 135m, η=7-8	<15%	<25%
η=8-9	20-25%	35-45%
η=9-10	25-40%	45-60%

CASTOR PROTOTYPE II



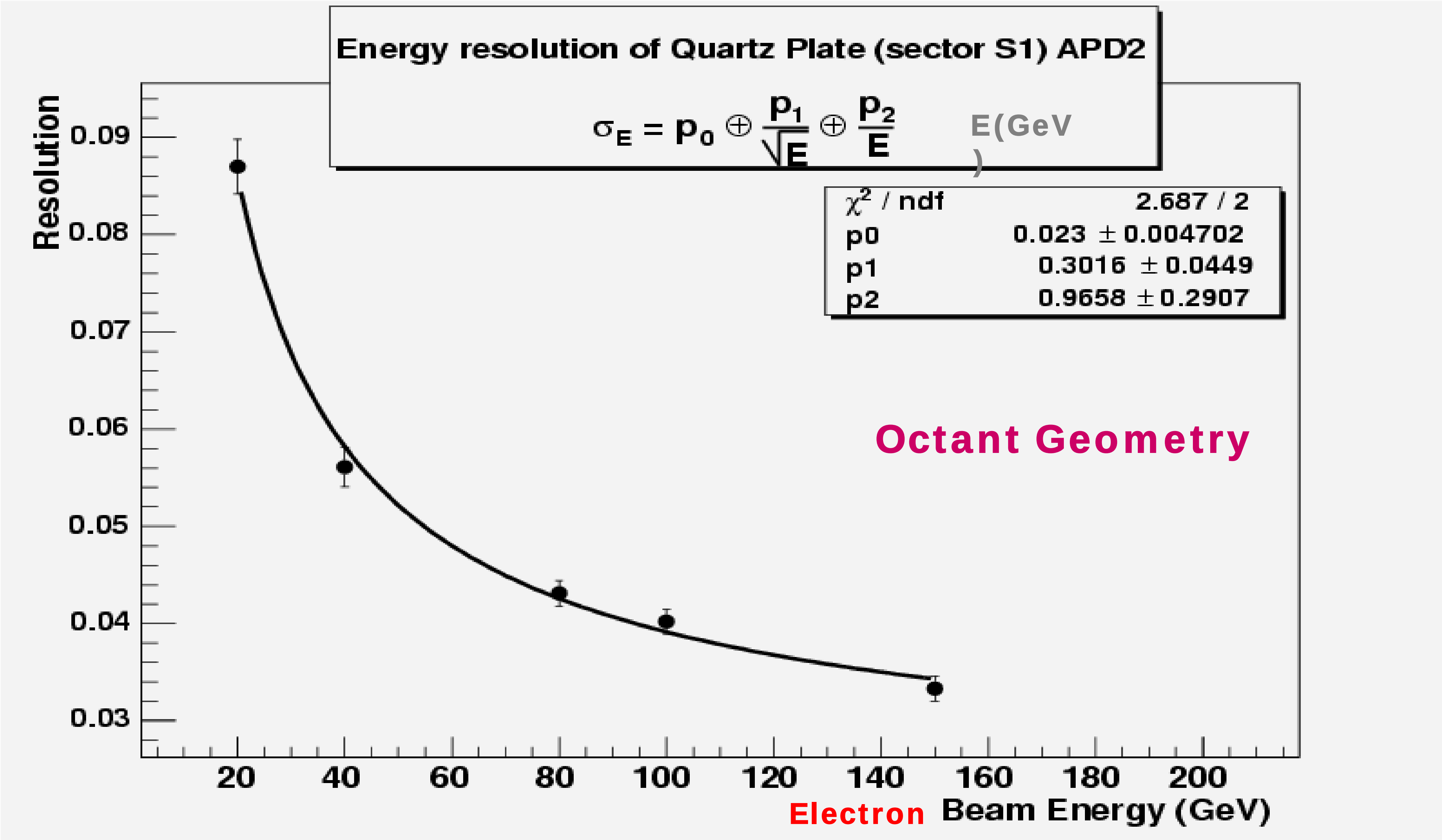
Summary

- Diffractive Higgs@LHC studies under way
  - Both exclusive, inclusive, and also in single pomeron exchange
- Main issues for exclusive channel
  - Cross section ~ fb, but some die-hards believe it could be still larger
    - Calculations seem to start converging, but still differences
    - Tevatron will be the referee: DPE χ_c, χ_b, $\gamma\,\gamma$, dijet … production
  - New detectors needed at 400 m (mechanics, 3D silicon detectors?)
  - Optimize: acceptance of the detectors, mass resolution (alignment?)
  - L1 trigger: 400m RP signals are too late for L1 (ATLAS/CMS)
  - Background from inclusive and exclusive channels. Generators in place. Isolate exclusive events.
  - Study of other signals apart from bb ($\tau\tau$, WW in progress…)
- Note
  - Higgs is only part of a broad diffractive program @ LHC
  - Adding such detectors to LHC is NOT a walk in the park
  - Tevatron (HERA) RP experience at this stage of the project is vital!



Linearity of Castor Proto II: 4APD's (EM Total)
χ² / ndf 0.04817 / 4
p0 -62.28 ± 109.6
p1 30.44 ± 1.245
Response
0
1000
2000
3000
4000
5000
6000
20
40
60
80
100
120
140
160
180
200
Electron Beam Energy (GeV)

Energy resolusion in tst beam (APDs)



Summary: L1 signal efficiencies

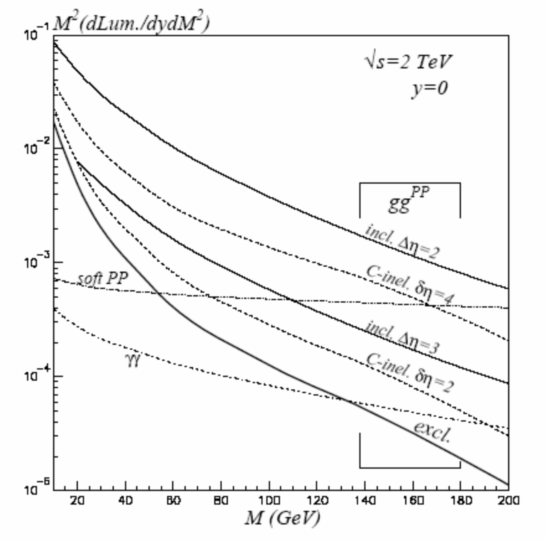
- RP condition for 220m RPs reduces 2-jet L1 trigger signal efficiency by factor ~2
Result of limited acceptance of RPs in diffractive peak region

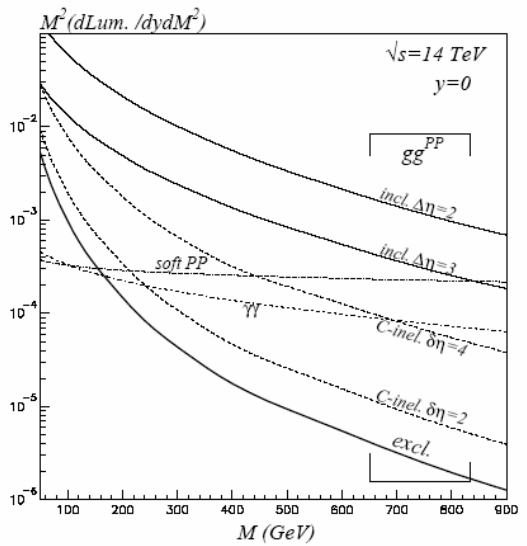
- Requiring 2-jet trigger threshold of ET=40 GeV and a proton be seen on one side in 220m RPs: signal efficiency for H(120 GeV) -> b bbar is of the order **20%** (Exhume)

- Requiring in addition that a proton be seen in the 420m RPs on the other side results in signal efficiency of about **15%**

- Requiring 2-jet trigger threshold of ET=40 GeV and a proton be seen on one side in 420m RPs: signal efficiency for H(120 GeV) -> b bbar is of the order **30%**

Gluino production





"luminosity functions"
To be convoluted with
cross sections
(Khoze et al 2001)

Exclusive diffraction

For example, if we take sparticle masses of 250 GeV and integrate from threshold (500 GeV) up to 625 GeV, then we find

$$\Delta\hat{\sigma}^{\rm excl}(\tilde{g}\tilde{g}) \simeq 6.5 \text{ pb}, \qquad \Delta\hat{\sigma}^{\rm excl}(\tilde{q}\tilde{\bar{q}}) \simeq 1.8 \text{ pb}. \qquad (78)$$

$$\Delta\sigma(pp \to p + \tilde{g}\tilde{g} + p) \simeq 0.15 \text{ fb}$$

$$\Delta\sigma(pp \to p + \tilde{q}\tilde{\bar{q}} + p) \simeq 0.04 \text{ fb}$$

Inclusive diffraction

$$\Delta\hat{\sigma}^{\rm incl}(\tilde{g}\tilde{g}) \simeq 24 \text{ pb}, \qquad \Delta\hat{\sigma}^{\rm incl}(\tilde{q}\tilde{\bar{q}}) \simeq 1 \text{ pb},$$

leading to

$$\Delta\sigma(pp \to X + \tilde{g}\tilde{g} + Y) \simeq 50 \text{ fb},$$

$$\Delta\sigma(pp \to X + \tilde{q}\tilde{\bar{q}} + Y) \simeq 2 \text{ fb}.$$

Cross sections low!

Exclusive Stop production in DPE

On the other hand ⇒

C. Royon et al. based on Bialas /Landshof model, with gap survival probability

No Sudakov suppression factors in this model

Cross section 100x larger

Acceptance for stop events with 200m pots

- Cross section for a stop mass of 250 GeV: $\sigma_{tot} = 8$ fb, $\sigma_{acc} = 6$ fb
- Possibility to distinguish between top and stop: using the differences in spin