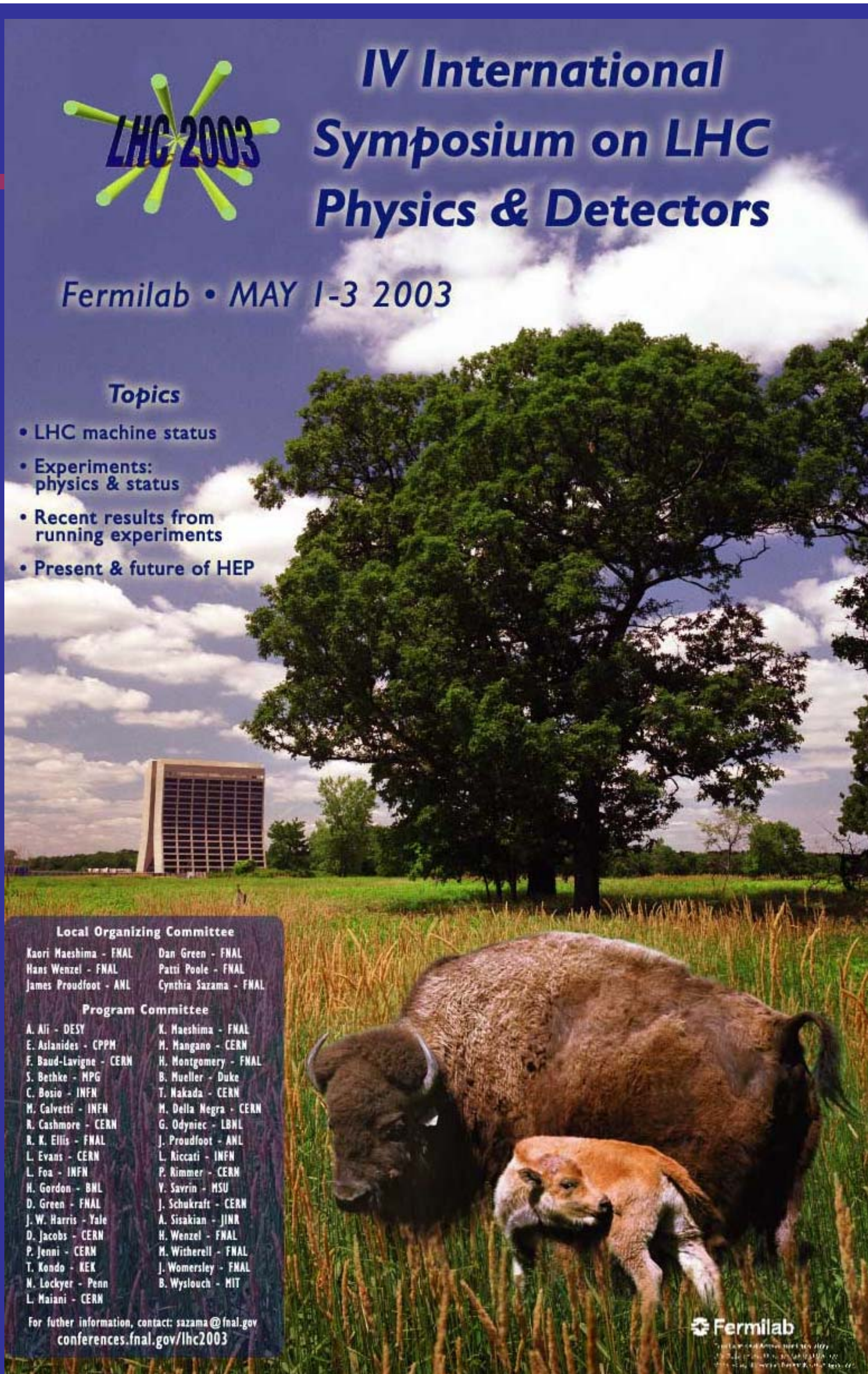


Highlights from the LHC 2003 Symposium

http://conferences.fnal.gov/lhc2003/

Kerstin Hoepfner
RWTH Aachen, Physics Institute IIIA

Topics (in total 50 talks)

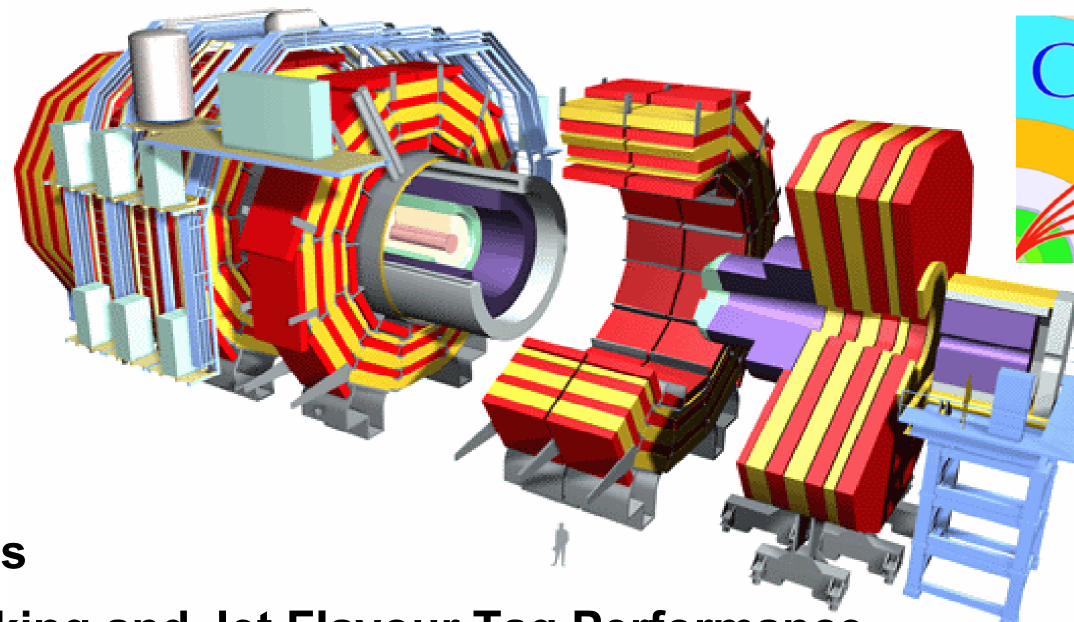
1. Introduction and Status of the LHC
2. CMS Status, performance & **early physics** (8 talks)
3. ATLAS Status, performance & **early physics** (8 talks)
4. **Physics results and prospects of Tevatron Run II** (3 talks)
5. **Heavy Ions:** results from RHIC and prospects at the LHC (8 talks)
   → see Heavy Ion conference summary
6. **B-physics: results from e^+e^- machines and from Tevatron, Prospects at the LHC** (12 talks)
7. Grid tools and the LHC Data Challenges (2 talks)
8. Potential LHC accelerator and detector upgrades (3 talks)

Marked in yellow: will be covered in this summary.

A partly personal selection

All talks can be found at http://conferences.fnal.gov/lhc2003/

CMS Presentations



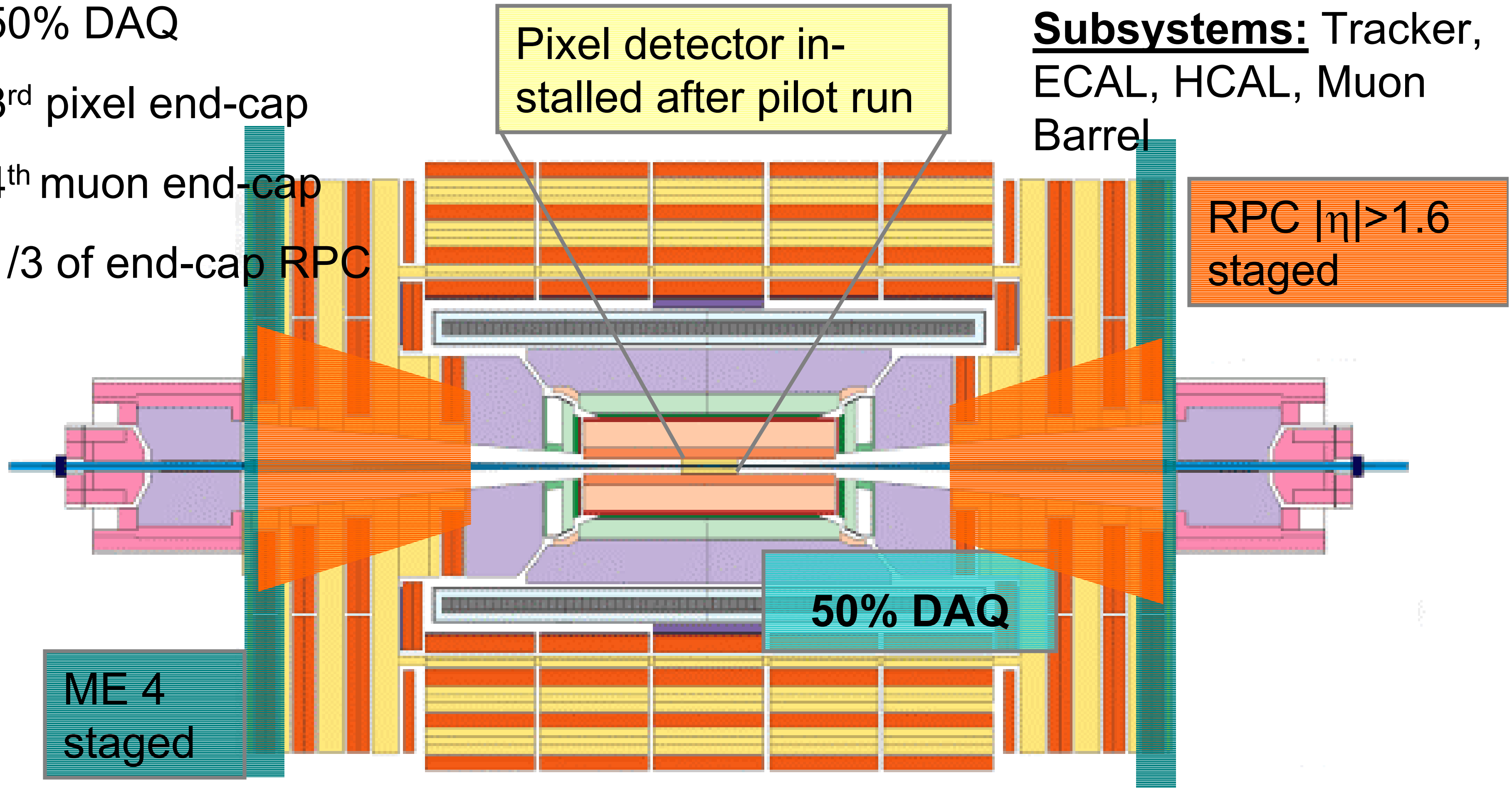
1. CMS Status — M. Della Negra
2. Inner Tracking and Jet Flavour Tag Performance — M. Manelli
3. System and Physics Performance — S. Lacaprara
4. Electromagnetic Calorimetry and e/gamma Performance — G. Dissertori
5. Hadronic Calorimetry and jets/Etmiss/tau Performance — D. Elvira
6. Trigger — C. Seez
7. Early Physics and Detector Commissioning — K. Hoepfner
8. Physics Reach at High and Very High Luminosities — J. Rohlf

CMS Detector at Start-Up

Initial detector is the complete CMS except for the **staged items** (consistent with financial plan):

- 50% DAQ
- 3rd pixel end-cap
- 4th muon end-cap
- 1/3 of end-cap RPC

__Complete Subsystems:__ Tracker, ECAL, HCAL, Muon Barrel



Consequences of Staging

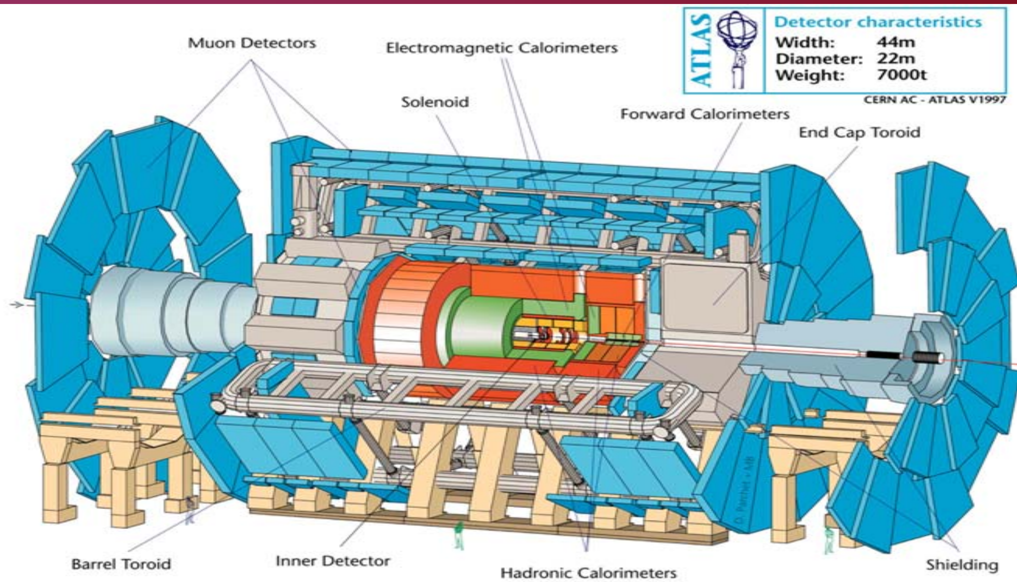
- Reduced DAQ can handle the lower rate (lower luminosity)
  → Adaptation of trigger thresholds through the whole trigger chain to preserve interesting physics

- Staged pixel endcap reduces redundancy in very forward region

- 4th endcap muon station staged
  → Loss in redundancy, now trigger 3 out of 3 stations required

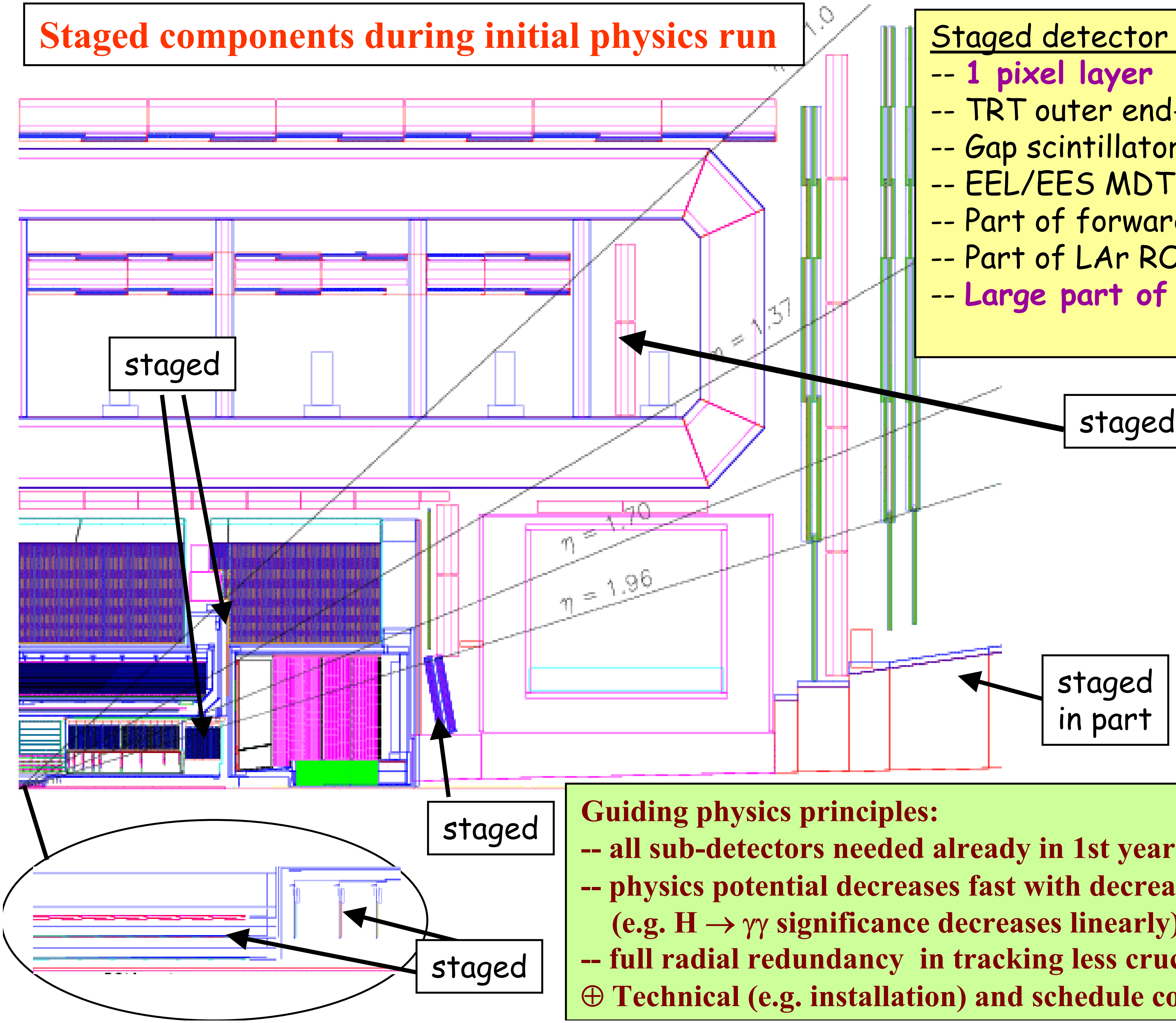
- RPC for eta > 1.6 staged
  → Full geometric acceptance provided by CSC system
  → Some loss in efficiency at high eta. Two ways to handle:
    - Accept x10 higher trigger rate
    - Install ME4 (under discussion)

ATLAS Presentations



1. ATLAS Status	M. Nessi
2. Inner Tracking and Jet Flavour Tag Performance	R. Hawkings
3. System and Physics Performance	L. Pontecorvo
4. Electromagnetic Calorimetry and e/gamma Performance	P. Schwemling
5. Hadronic Calorimetry and jets/Etmiss/tau Performance	B. Caron
6. Trigger	R. Hauser
7. Early Physics and Detector Commissioning	I. Fleck
8. Physics Reach at High and Very High Luminosities	B. Zhou

Staged components during initial physics run



<u>Staged detector components:</u>

- -- 1 pixel layer
- -- TRT outer end-cap
- -- Gap scintillator
- -- EEL/EES MDT and half CSC
- -- Part of forward shielding
- -- Part of LAr ROD
- -- Large part of HLT/DAQ

Guiding physics principles:

-- all sub-detectors needed already in 1st year

-- physics potential decreases fast with decreasing η coverage (e.g. $H \rightarrow \gamma\gamma$ significance decreases linearly)

-- full radial redundancy in tracking less crucial at ~ 10^{33}

⊕ Technical (e.g. installation) and schedule constraints

Physics Impact of Staging

Staged items	Main impact during first run on	Effect
1 pixel layer	ttH → ttbb	~8% loss in significance
Gap scintillator	H → 4e	~8% loss in significance
Muon detector (MDT)	A/H → 2μ	~5% loss in significance for m~ 300 GeV
HLT /DAQ	B-physics → High-p_T physics →	program jeopardised no safety margin (e.g. for EM triggers)

Requires 10-15% more integrated luminosity to compensate

Complete detector needed at high luminosity

Detector Commissioning

ATLAS & CMS presented commissioning of subdetectors

Note: Commissioning is already going on

Several steps:

- Test beams
- Mapping of detector material and B-field
- Alignment
- Electronic calibration
- Cosmic running
- One proton beam
- Proton proton collisions

Precision of detector under-standing is given by **desired precision of physics results**

Equal error on Higgs mass from W- and top mass measurement:

$$\Delta m_W \approx 0.7 \times 10^{-2} \Delta m_{top}$$

Error on top mass: 2 GeV

Error on W mass: 15 MeV

→This puts severe constraints on detector understanding

Example: ATLAS Inner detector

Alignment :

Degrading of track parameters by misalignment less than 20%

→Pixel Rϕ alignment 7 μm

→ SCT Rϕ alignment 12 μm

Use single μ from W (rate 3 Hz) or B-decays (rate 50 Hz for p_T > 6 GeV)

After 1 running day track fits result in

	residual	precision
Pixel	20 μm	1 μm
SCT	40 μm	2 μm

Measurement of W mass to 20 MeV:

→ Knowledge of momentum scale to 0.02%

B-Field:

1.Mapping with Hall probes →0.05%

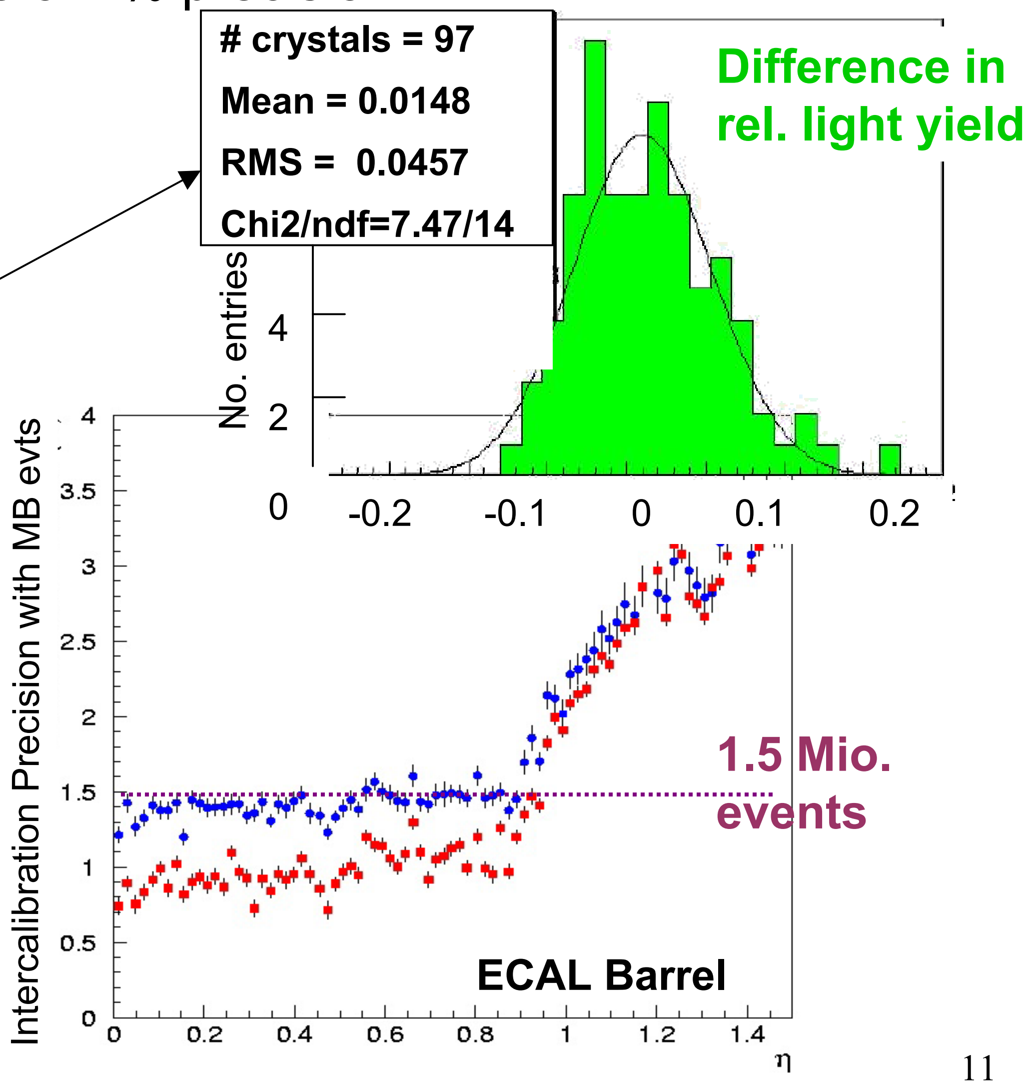
2.With tracks: Using fit B-field can be reconstructed with precision of 4 Gauss, i.e. 0.02 %

Map ID amount of material:

- W→ eν decays to measure E/p from calorimeter (EM) and ID
- E/p distribution very sensitive to amount of material at different radii
- Final accuracy of 0.02% needs understanding of ID material distribution of 1%
- Within a few weeks of data taking this precision will be reached

Example: CMS ECAL Calibration

1. **Testbeam:** Very precise ($\Delta E/E < 0.1$ %) for a small sample (~1/4)
   Extrapolation to CMS, target value of 2% precision
2. **Lab measurements during production**
   Intercalibration precision ~4.5%
3. **Fast calibration with min. bias events**
   use phi symmetry of deposited energy to intercalibrate crystals within rings of constant eta
4. **Z → $e^+ e^-$**
   for final precision



Physics in 2007

Results on most important variables will stem from Tevatron, HERA, Belle, BaBar, LEP

Expected precision:

W mass	**20 – 30 MeV**	**LEP + Tevatron**
Top mass	**2 GeV**	**Tevatron**
Structure functions:	**Few percent up to $Q^2 = 10^4$ GeV^2**	**HERA**
Higgs	**possible exclusion up to 175 GeV, discovery unlikely, but hint may be there**	**Tevatron**

What can ATLAS & CMS achieve with 10 fb^{-1}?

Higgs @ LHC Start-up

114 GeV < m_H < 1 TeV

m_H ~ 115 GeV

- combine several channels

200 GeV < m_H < 600 GeV

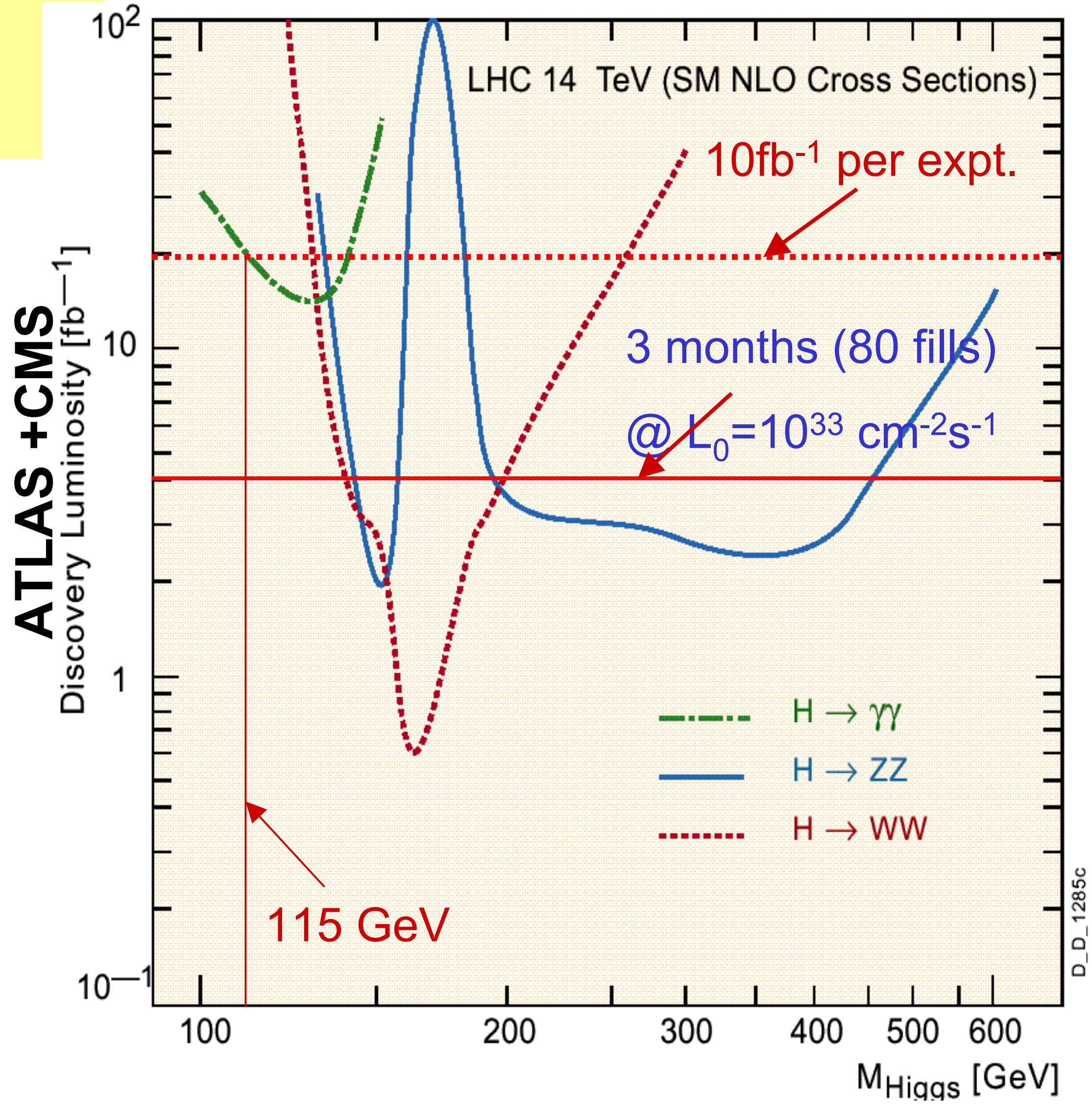
-discovery in $H \to ZZ \to l^+l^- l^+l^-$

-confirmation in $H \to ZZ \to l^+l^-$ jj

m_H > 600 GeV

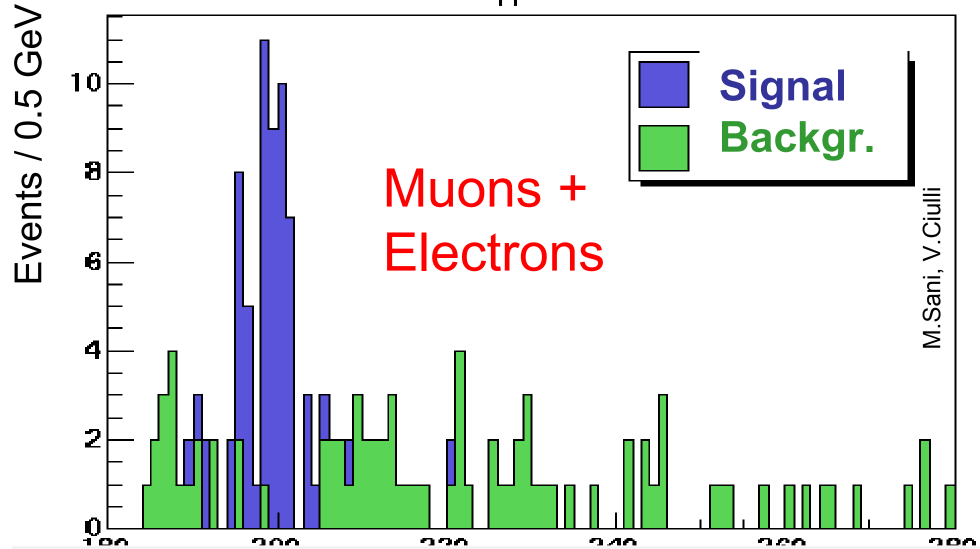
- 4l channel statistically limited
- $H \to ZZ \to l^+l^- \nu\nu$
- $H \to ZZ \to l^+l^-$ jj , $H \to WW \to l\nu$ jj (150 x BR than 4l channel)

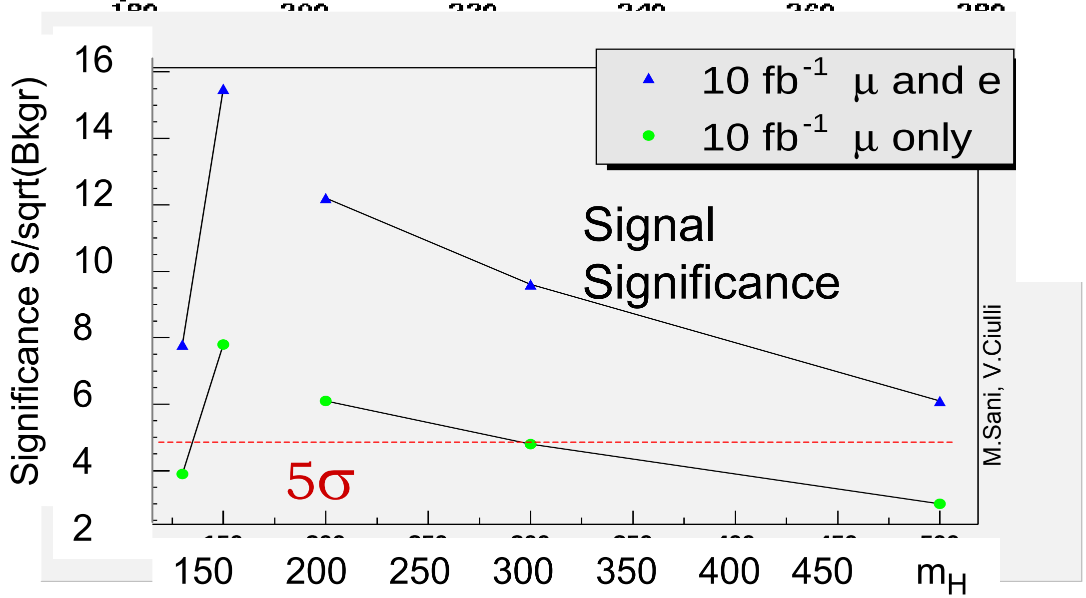
SM Higgs Discovery Reach (5σ): ATLAS +CMS



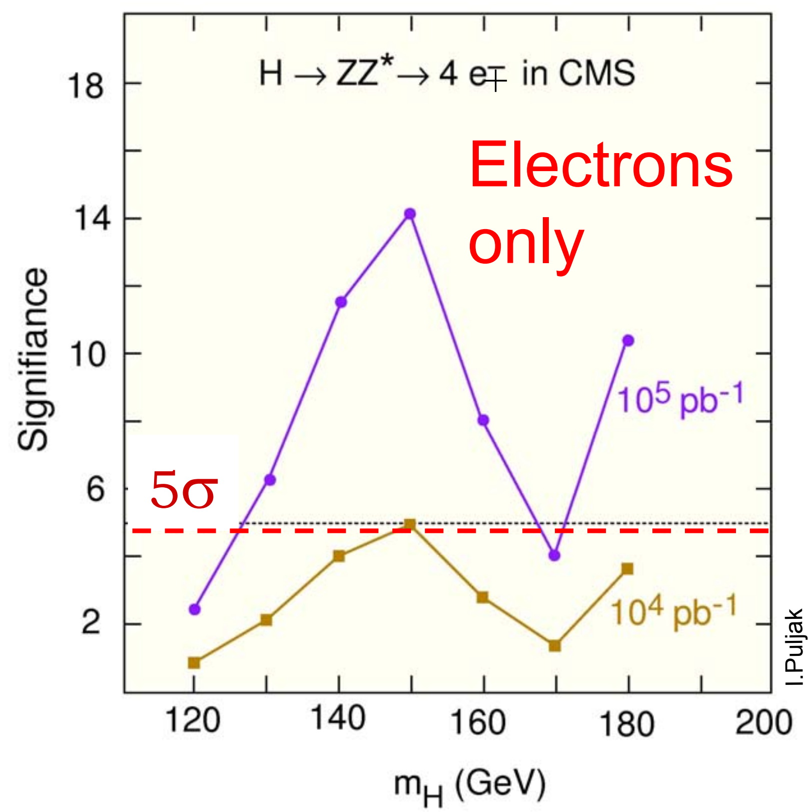
$H_{SM} \rightarrow$ 4 Leptons with 10 fb^{-1}

H -> ZZ -> 4 l, m_H = 200 GeV





Signal significance (4 electrons)



Acceptance and reconstruction efficiency are crucial for these channels

Low Mass Higgs

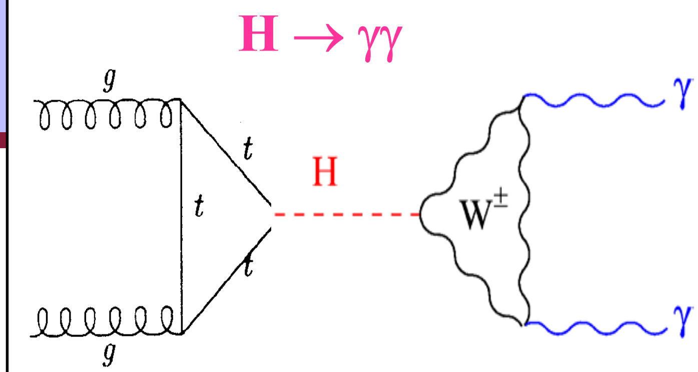
M(Higgs) ~ 115 GeV, favoured by LEP

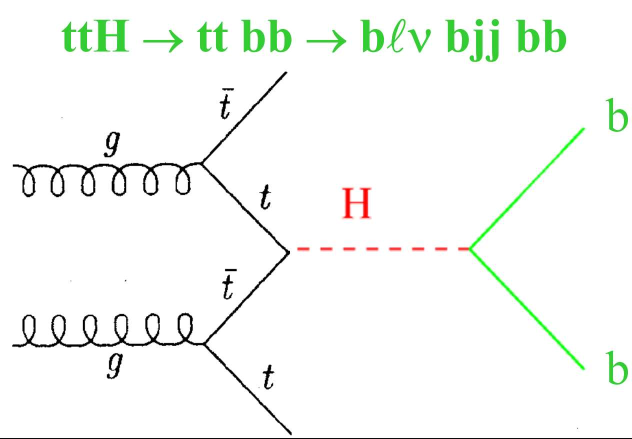
Several channels give ~ 2 σ significance
$\rightarrow$ observation of all channels important to extract convincing signal in first year

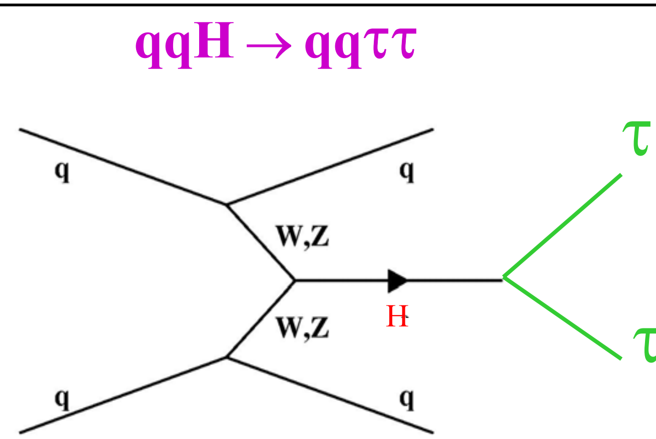
H $\rightarrow \gamma\gamma$ relies only on electromagnetic calorimeter

	H $\rightarrow \gamma\gamma$	ttH $\rightarrow$ ttbb	qqH $\rightarrow$ qq$\tau\tau$ ($\ell\ell$ + ℓ-had)
S B	130 4300	15 45	~ 10 ~ 10
S/ $\sqrt{B}$	2.0	2.2	~ 2.7

$K-\text{factor} \equiv \frac{\sigma_{NLO}}{\sigma_{LO}} \approx 2$ not included

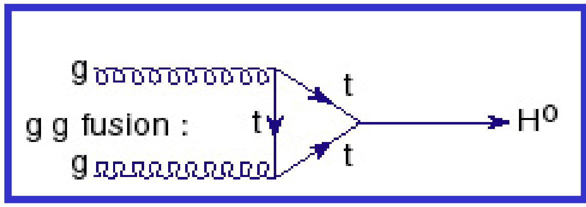


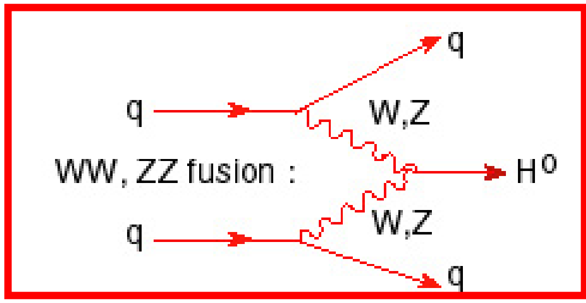




Ivor Fleck, ATLAS Early Physics

Vector Boson Fusion

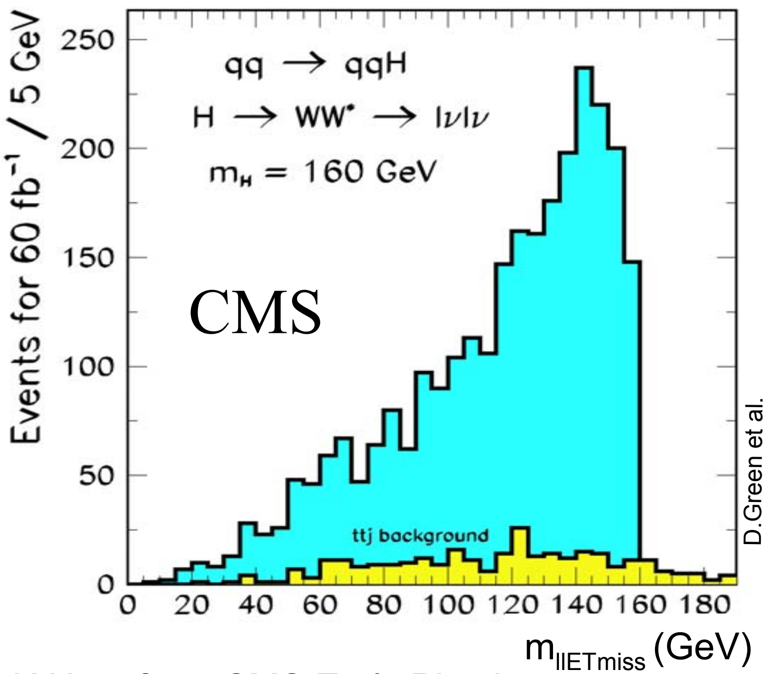


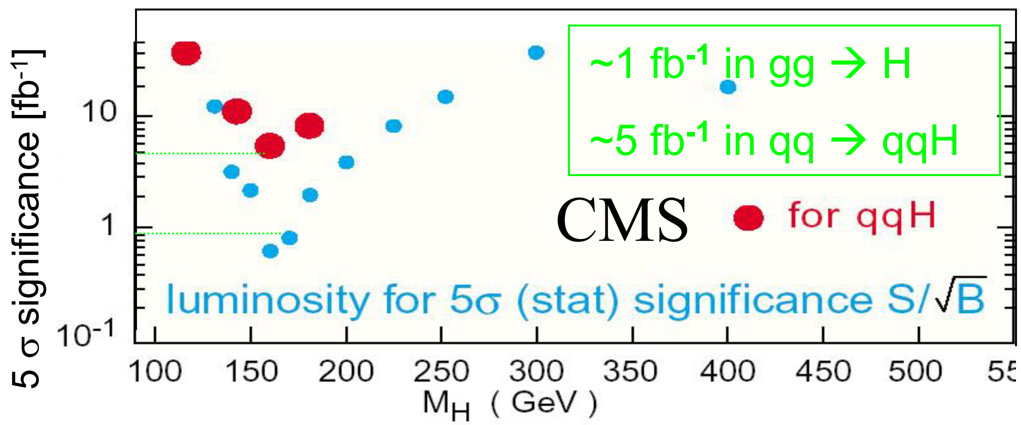


- **gg fusion:**
- Backgrounds:
  - WW → ℓνℓν
    Discriminate by cos Φ due to spin correlation
  - t t → W b W b → ℓνℓν b b
  - W t b → W b W b → ℓνℓν b b
    Both reducible by jet veto

WW, ZZ fusion (qqH final state):

tt(j) → W b W b bkgr. considered





Vector Boson Fusion

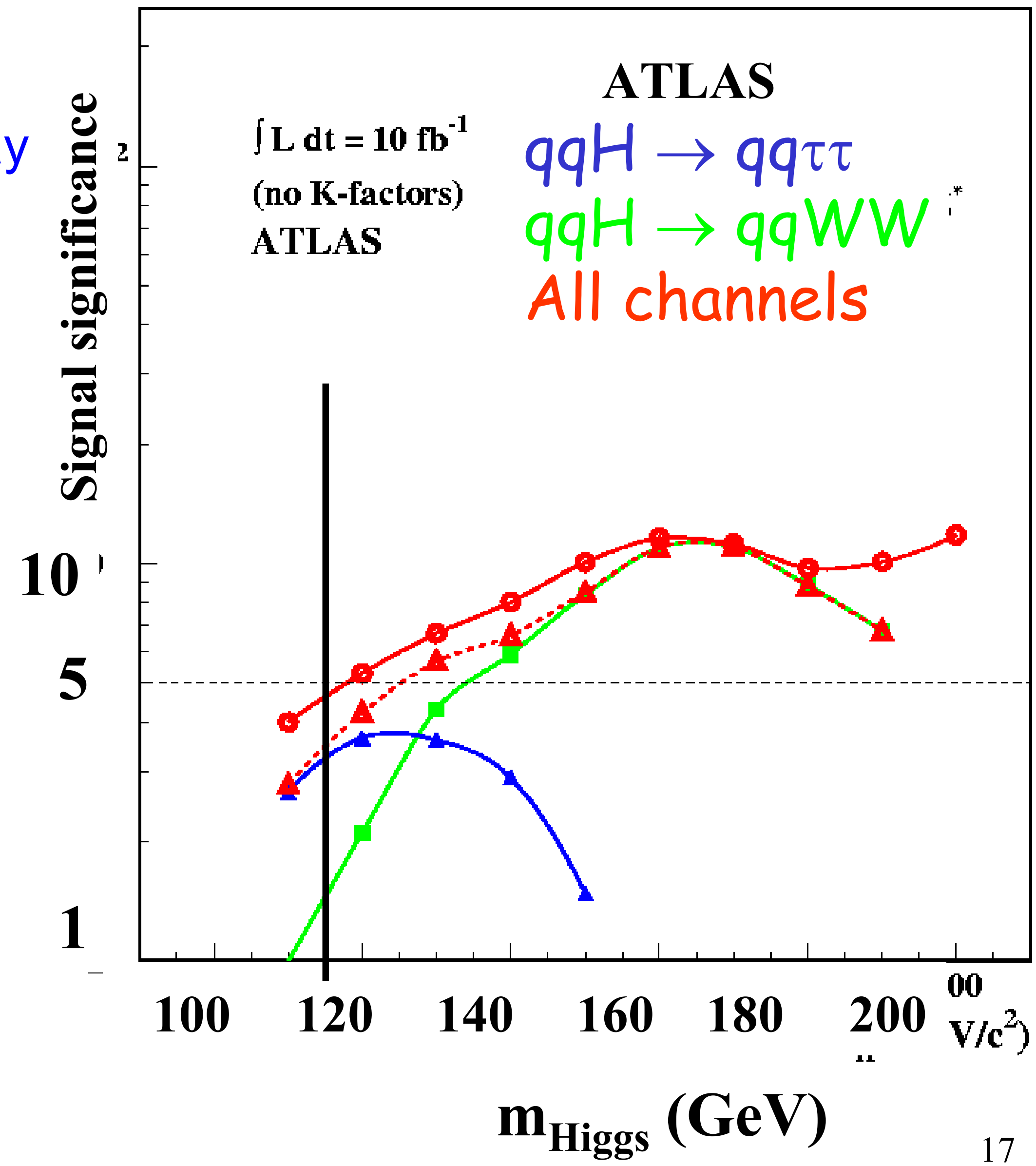
Recent studies demonstrate that vector boson fusion channels may be accessible in the low mass region already in the first year.

Several ATLAS studies to improve performance

For m(Higgs) = 115 GeV combined significance ~ 5σ

Results are conservative:

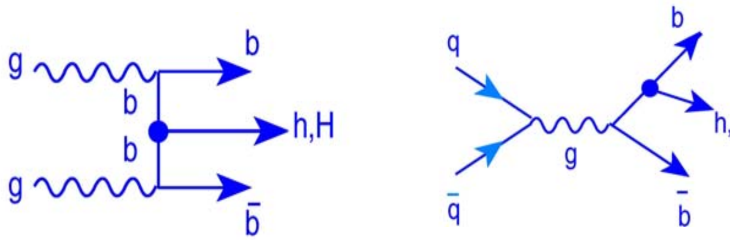
- K-factor not included
- very simple analyses used



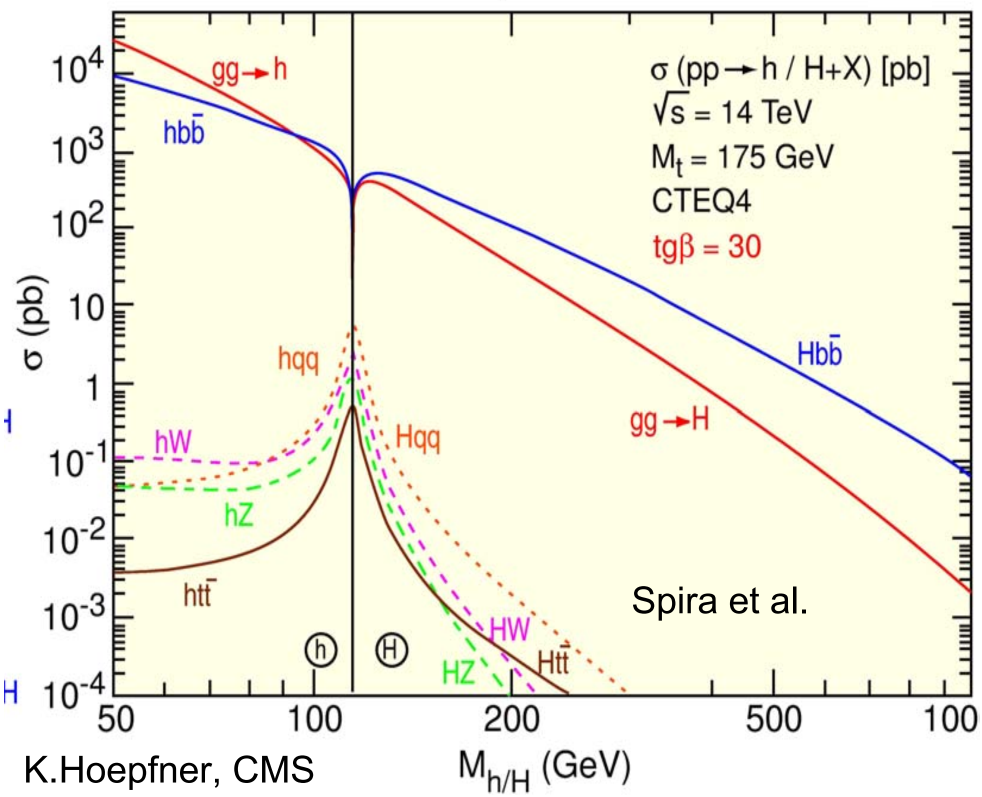
MSSM Higgs

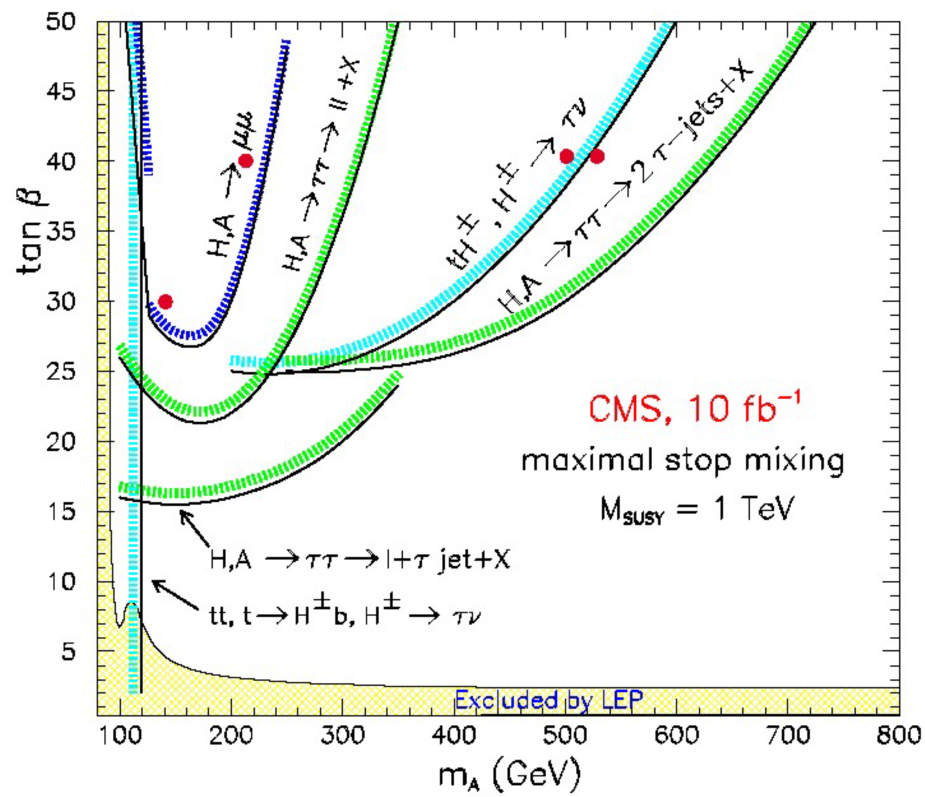
SUSY 5 Higgs: h, H, A, H^{+-} Many more decay modes.

Example: bbH final states enhanced by $\tan^2\beta$ in MSSM w.r.t. SM



For large tan β, search can start at 10 fb^{-1}

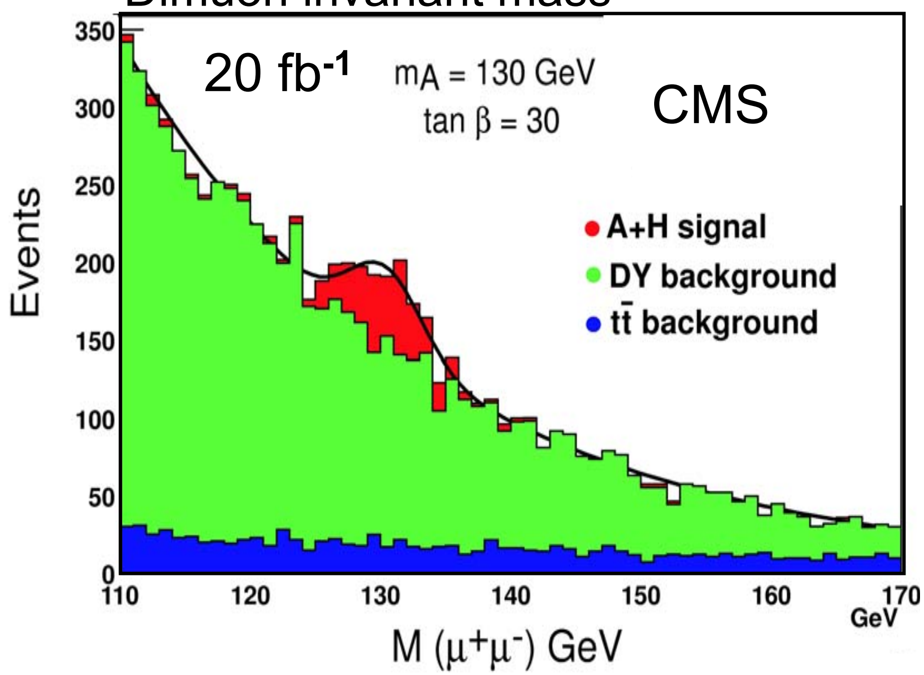




K.Hoepfner, CMS

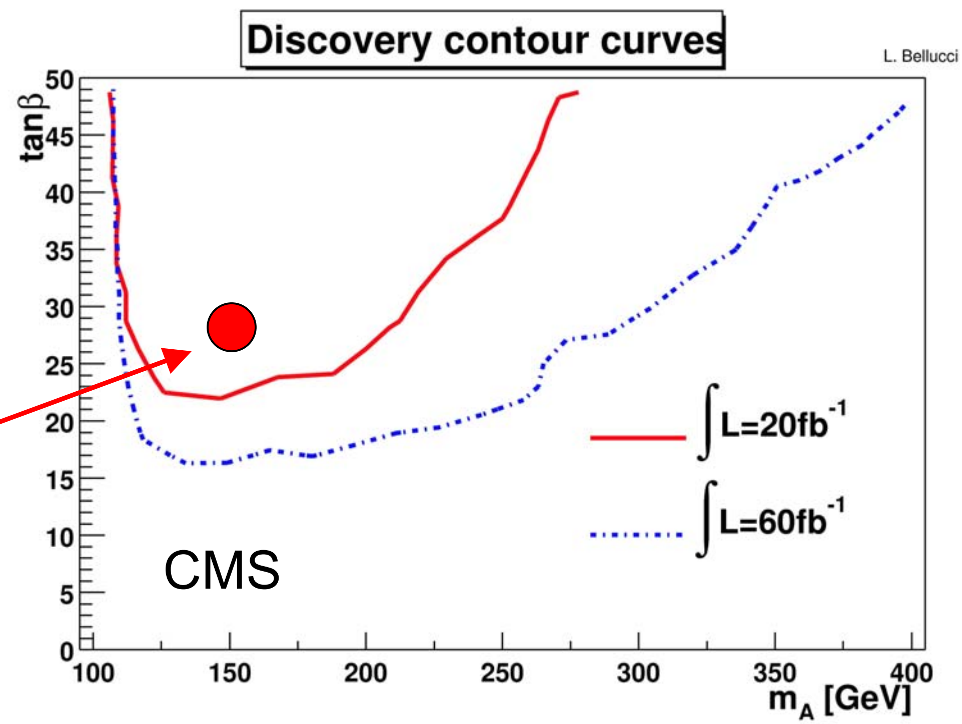
A / H → μ μ in bbH$_{SUSY}$ Production

Dimuon invariant mass



New decay channel H/A → μμ covers large part of region not excluded by LEP

Muon spectrometer crucial



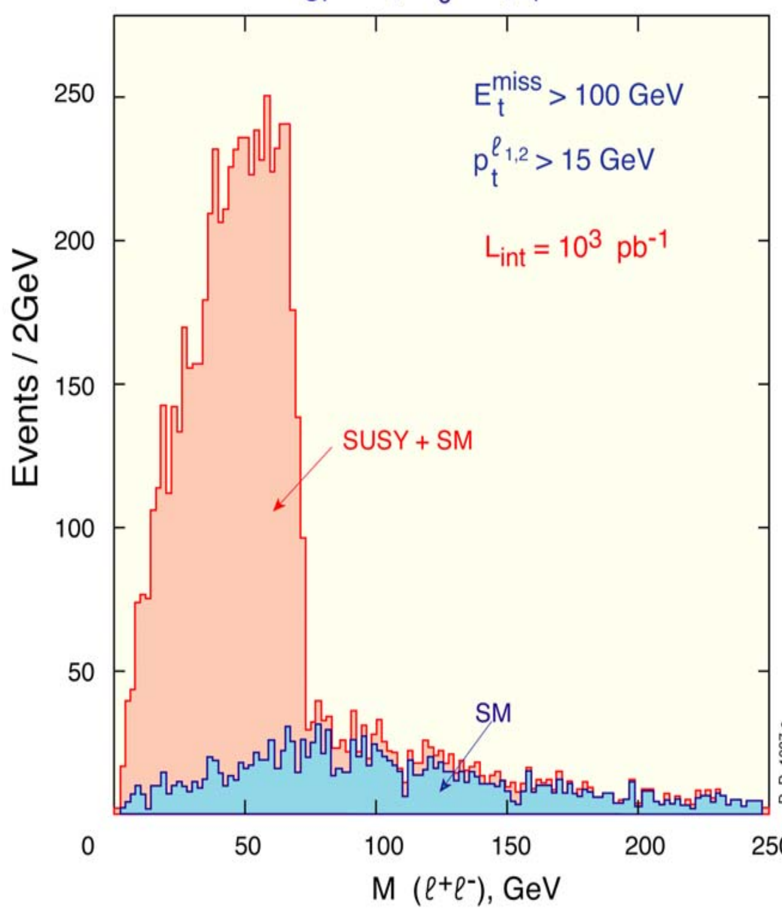
Search already possible with 10 fb^{-1}

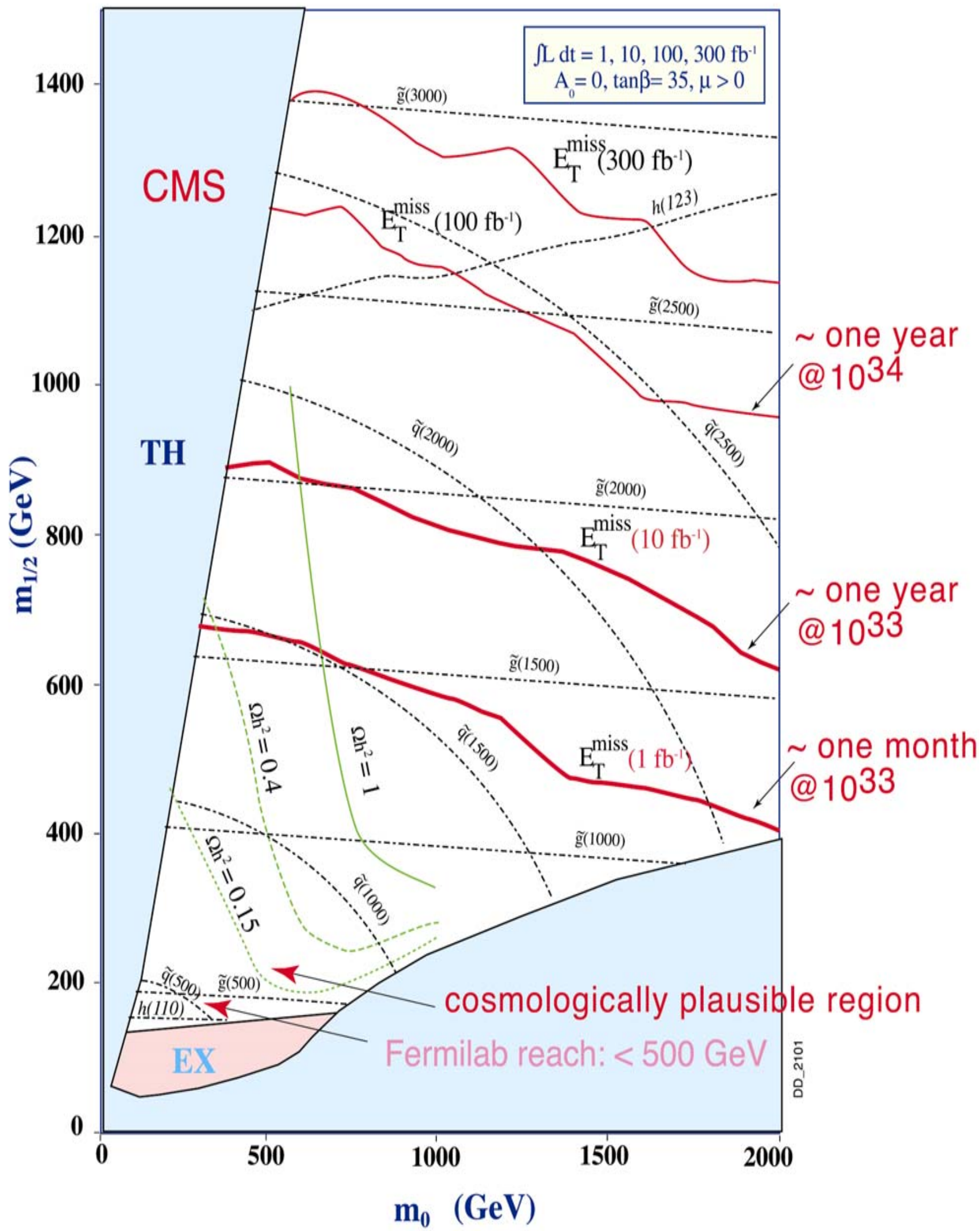
Requires b-tagging, efficient track reconstruction without ultimate track reconstruction resolution

SUSY might appear early

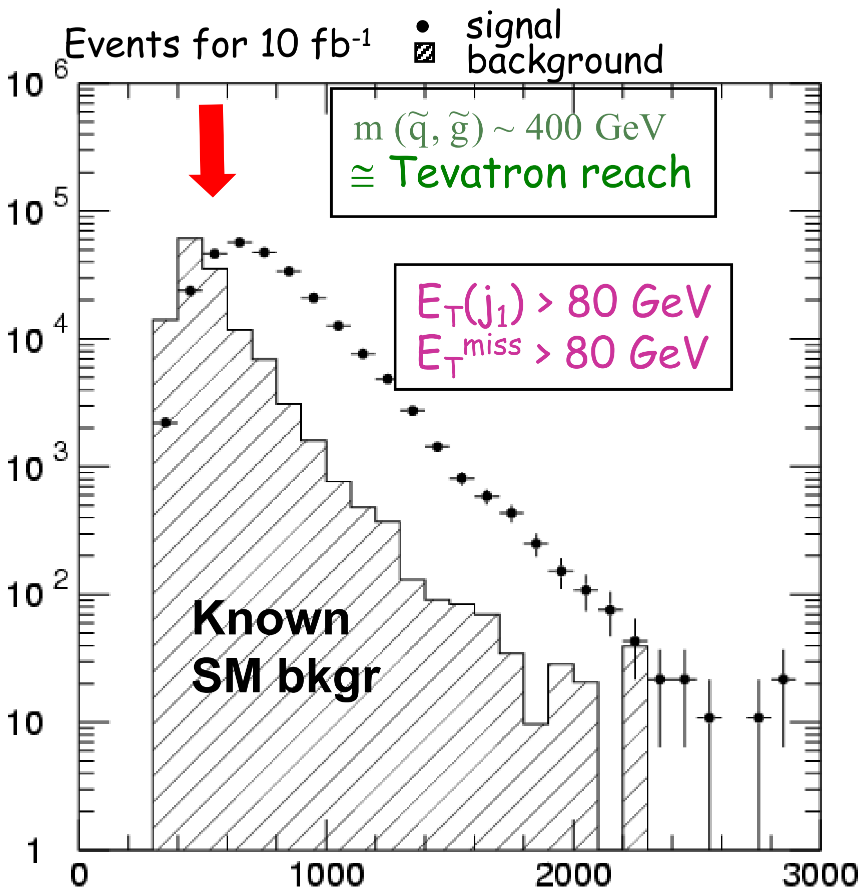
Inclusive $\ell^+\ell^- + E_t^{miss}$ final states

m_0 = 200 GeV, $m_{1/2}$ = 160 GeV,
tgβ = 2, A_0 = 0, μ<0





Lower SUSY masses



$$M_{eff} = E_T^{miss} + \sum_{i=1}^{4} p_T\,(jet_i) \quad (GeV)$$

Position of peak correlated to SUSY mass scale

$$M_{SUSY} \equiv \min\left(m(\tilde{q}), m(\tilde{g})\right)$$

Measurement of SUSY mass scale ≈ 20% (mSUGRA) with 10 fb^{-1}

Low trigger thresholds necessary to measure mass scale in overlap region with Tevatron (400 GeV)

Calorimeter must have good hermeticity up to $|\eta|=5$

The Startup of Run II

Snapshot of

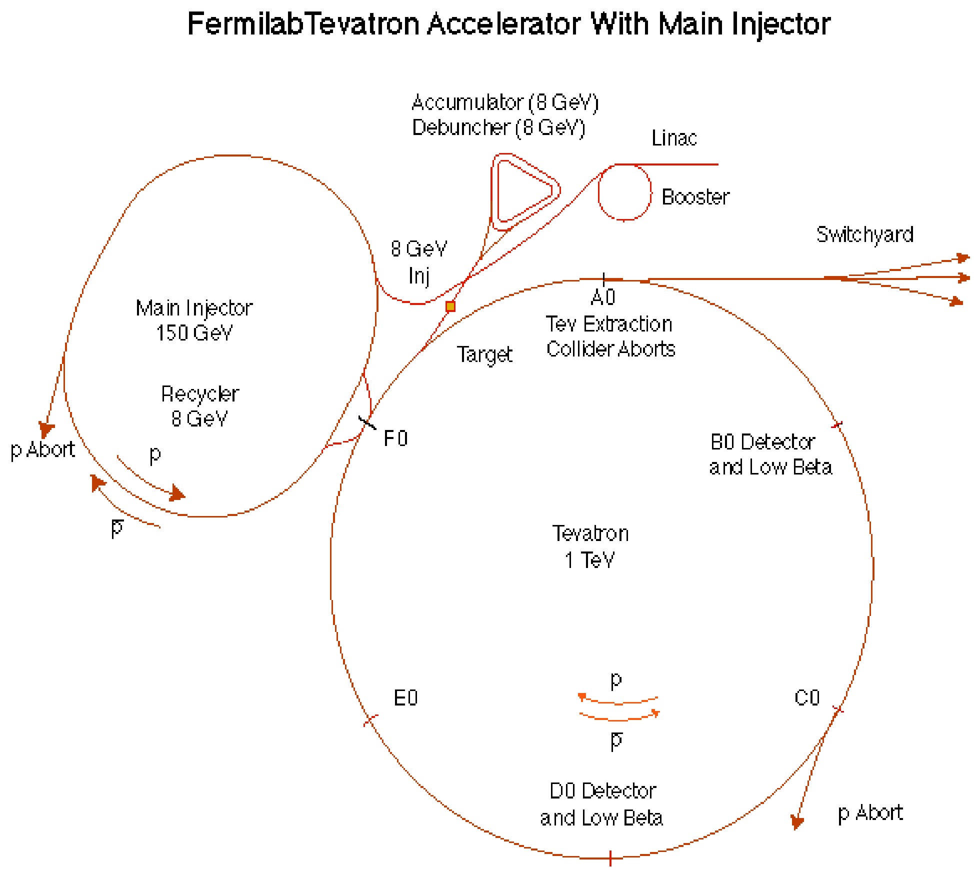
Tevatron collider
CDF detector
DØ detector
&
First Run II results

CDF

DØ

J.Oian, C.Gerber, G.Veramendi

Tevatron Complex



New for Run II:

Main injector (150 GeV proton storage ring) replaces main ring

New permanent magnet storage ring for pbar accumulation (commiss.)

Increased center-of-mass energy (1.8 $\Rightarrow$ 1.96 TeV)

More bunches (6 $\Rightarrow$36, 396 ns crossing time)

Higher luminosity

Run 2 goal: 3 - 4E32 $cm^{-2}\ s^{-1}$

Run 1 maximum: 2.4E31 $cm^{-2}\ s^{-1}$

Integrated Luminosity

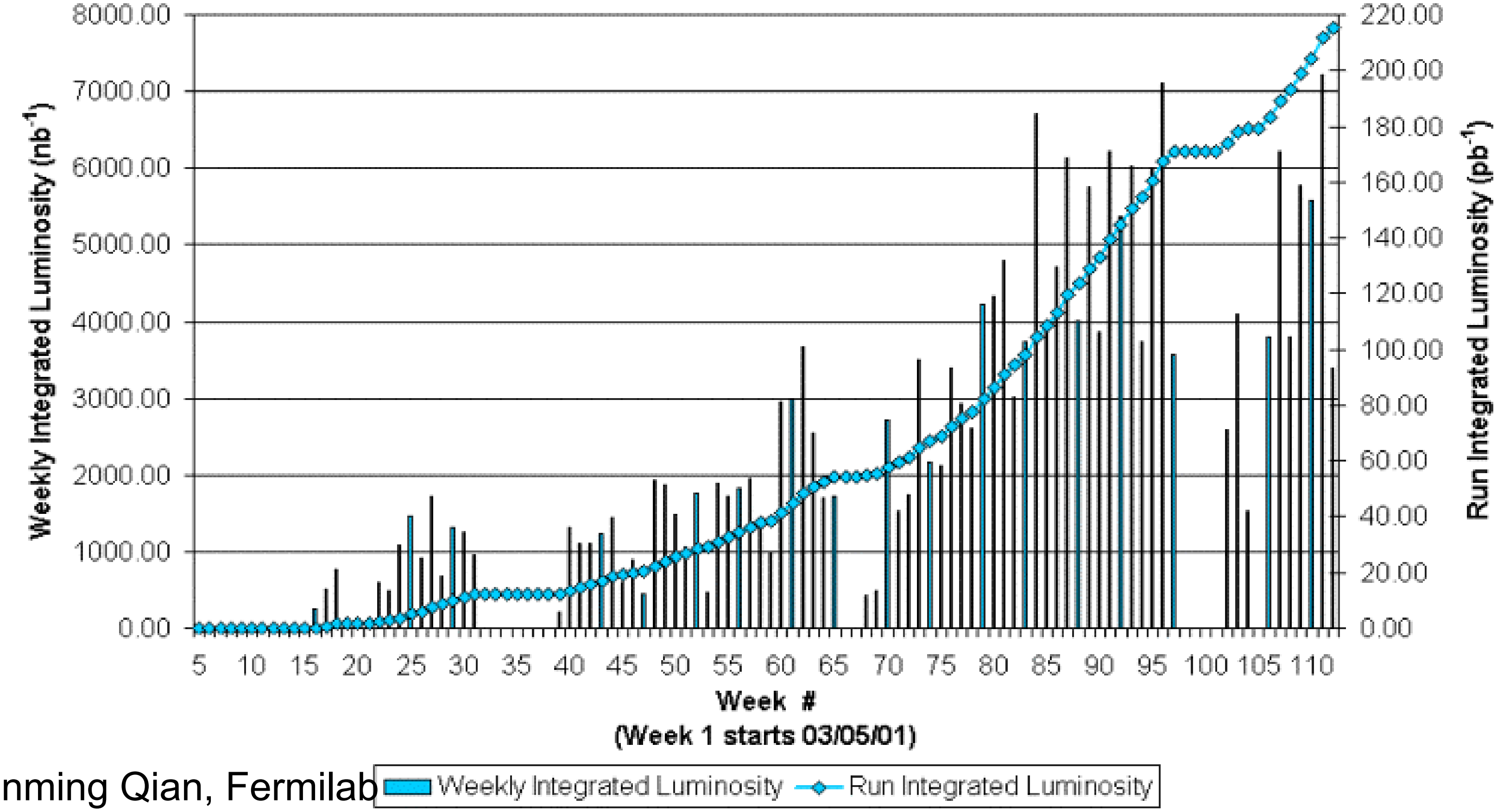
Luminosity

Run 2 goal: 3 - 4E32 $cm^{-2}\ s^{-1}$

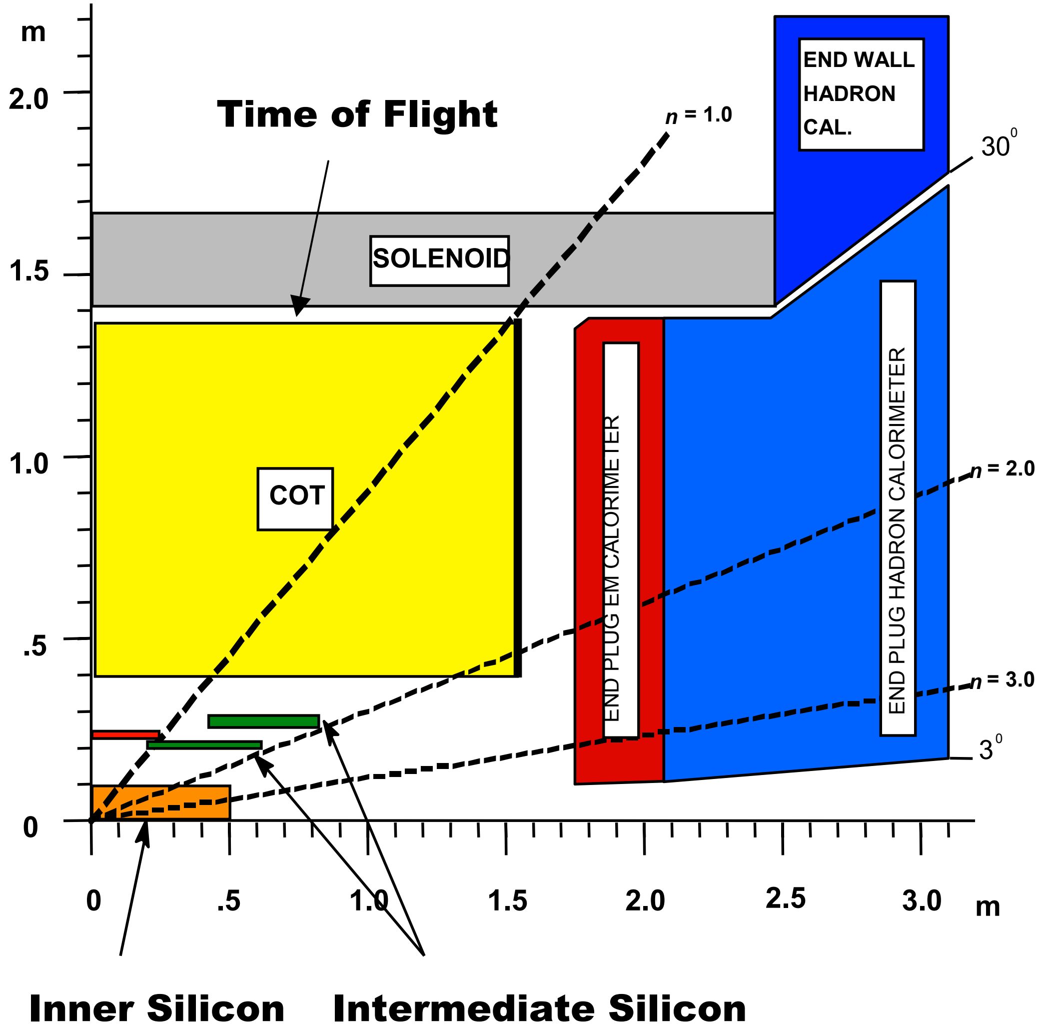
(plans: short term factor 2, long term factor 5 pbar limited)

Run 2 maximum: 4.1E31 $cm^{-2}\ s^{-1}$ (to date)

Run 1 maximum: 2.4E31 $cm^{-2}\ s^{-1}$



CDFII Detector



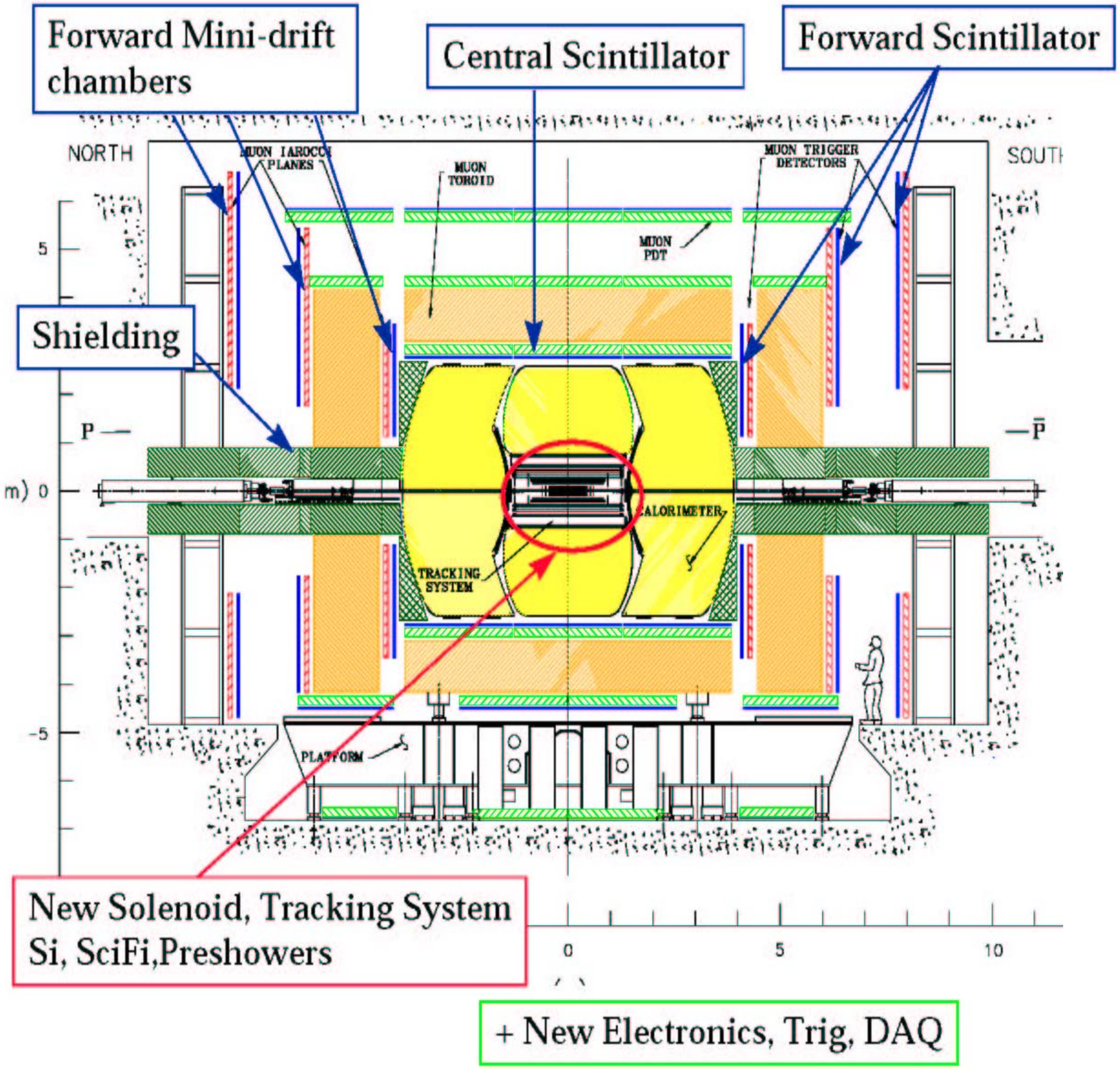
Retained from Run I

Solenoid (1.4 Tesla)
Central calorimeters
Central muon detectors

New in Run II

New central tracker
  8 layers of 3-D silicon up to $|\eta|=2$
End plug calorimeter
Intermediate muon detectors
Time of flight system
Front-end electronics
Trigger and DAQ

DØ Run II Detector



Retained from Run I

LiAr Calorimeter
Central muon detector
Muon Toroid

New for Run II

2 T Magnet
Central tracker
Preshower detectors
Forward muon detector
Forward proton detector
Front-end electronics
Trigger and DAQ

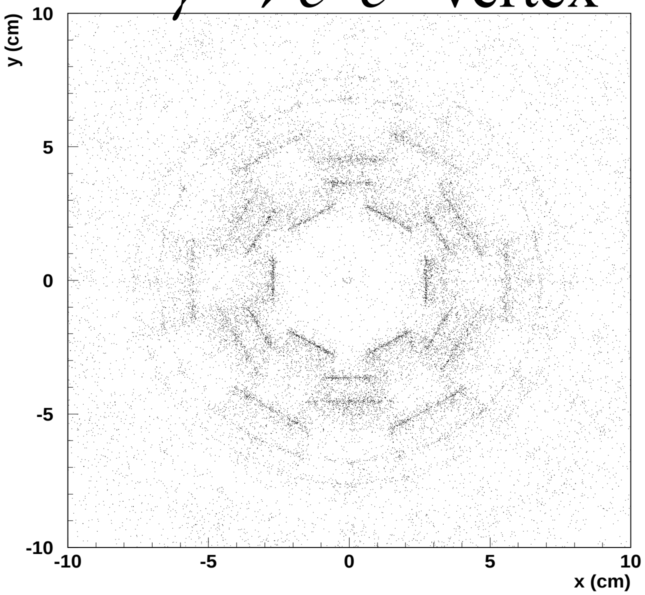
It's a qualitatively new experiment.

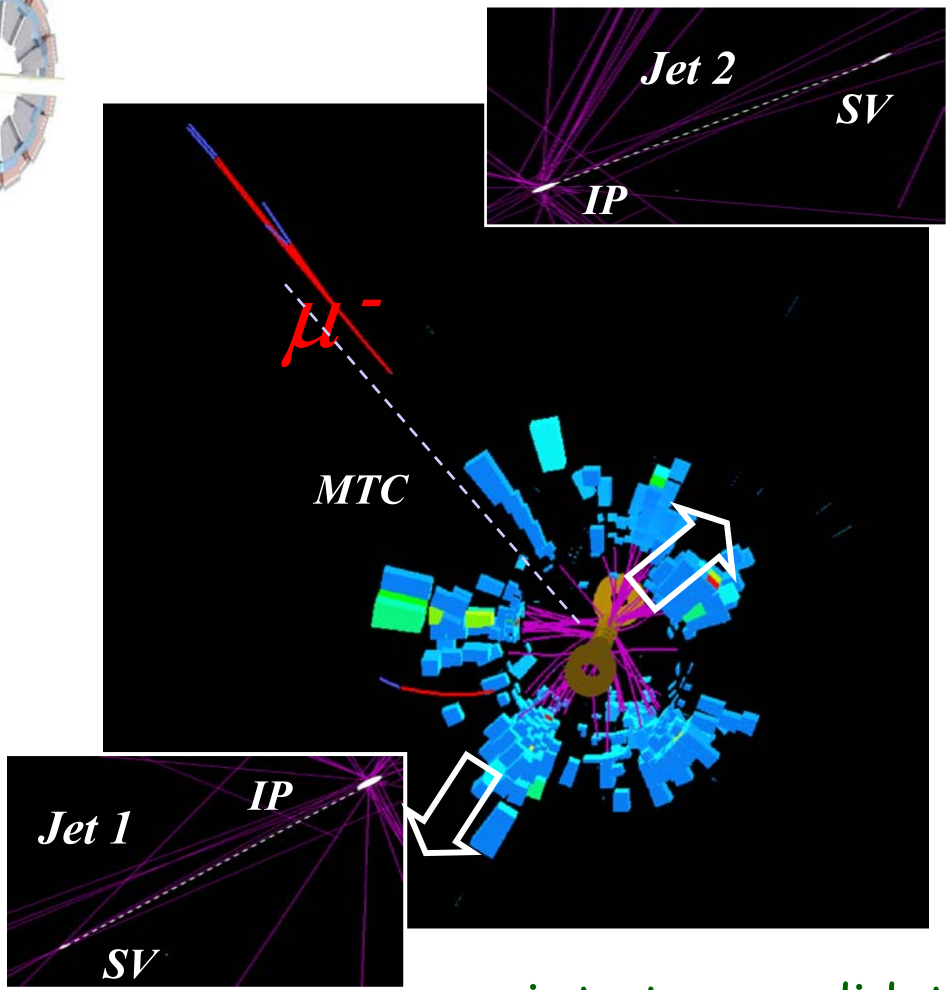
Vertexing Performance

Silicon Microvertex Detector (SMT)

S/N > 10
~91% channels alive

$\gamma \rightarrow e^{+}e^{-}$ vertex



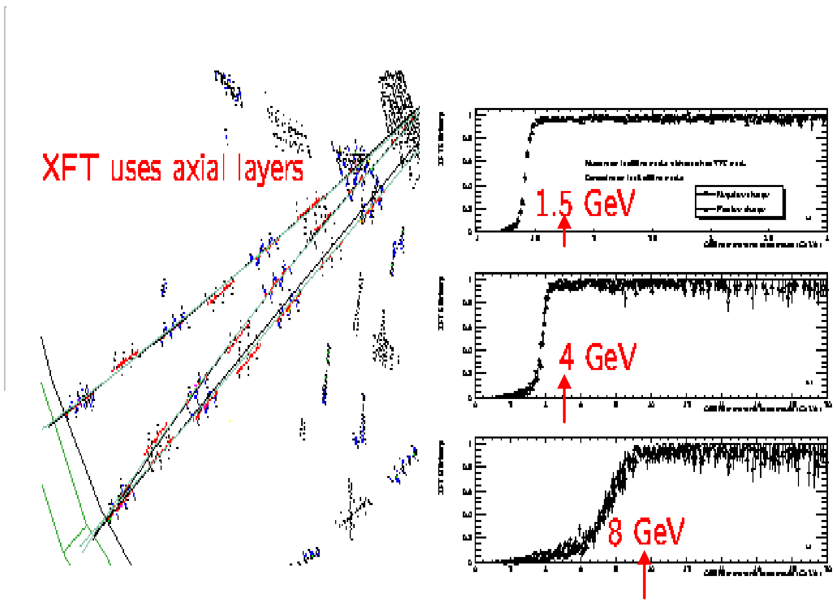


μ+jets top candidate

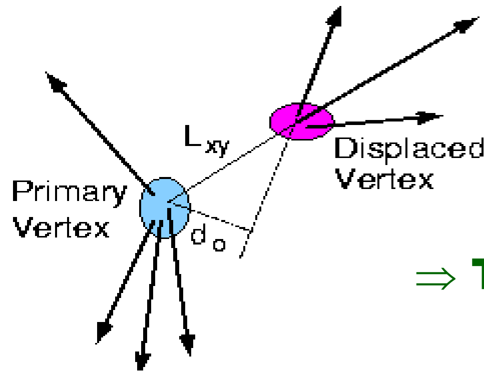
C.Gerber, D0

Track and Vertex Triggers

XFT:
uses COT axial to find high pT tracks at L1



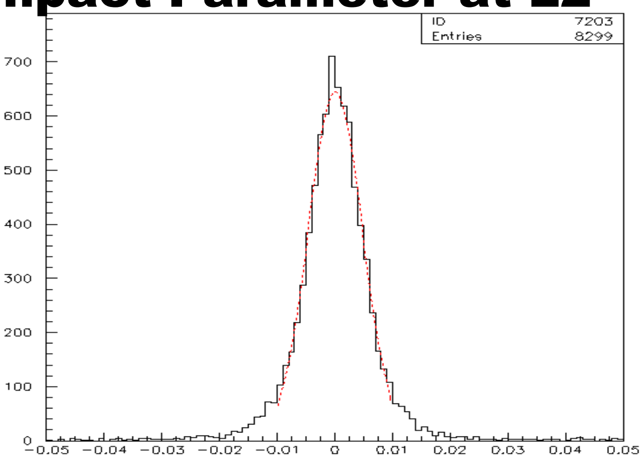
$\Delta p_T / p_T = 1.65\%\ p_T\ (GeV/c)$



SVT:
uses L1 XFT and SVXII

⇒ Trigger b and c in hadronic decays

Impact Parameter at L2



$\sigma = 50\ \mu m$
$= 43 \mu m\ (reso) \oplus 25 \mu m\ (beam)$

Many Preliminary Results

Top quark physics
- Re-discovered the top quark, preliminary studies on properties, …

Electroweak
- W/Z productions, di-boson production, e+e- forward-backward asymmetry, …

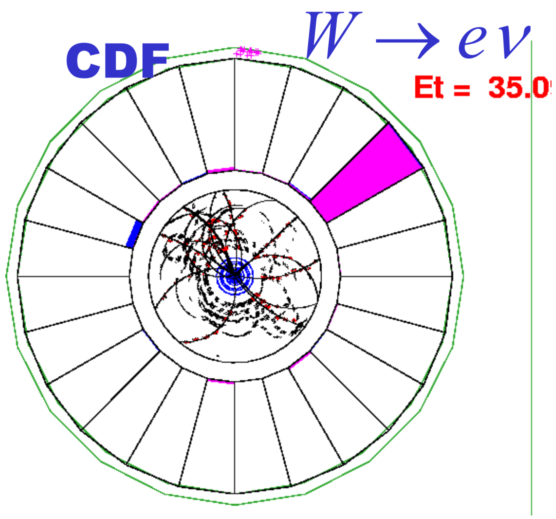
New phenomena searches
- Higgs bosons, supersymmetry, leptoquark, large extra dimensions, Z', …

Heavy flavor
- resonance reconstructions, masses, lifetimes, branching fractions, rare decays, …

QCD
- jet structure, inclusive jet cross section, dijet mass distribution, …

See the talks by M. Bishai, G. Borissov, C. Gerber, G. Veramendi for details

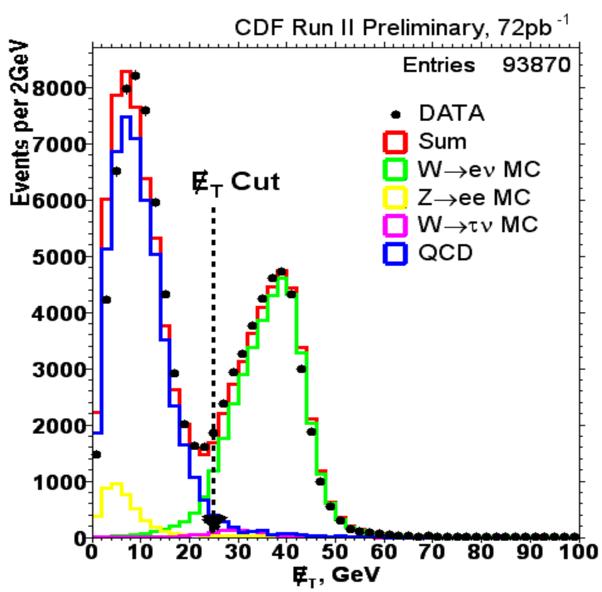
W/Z Production

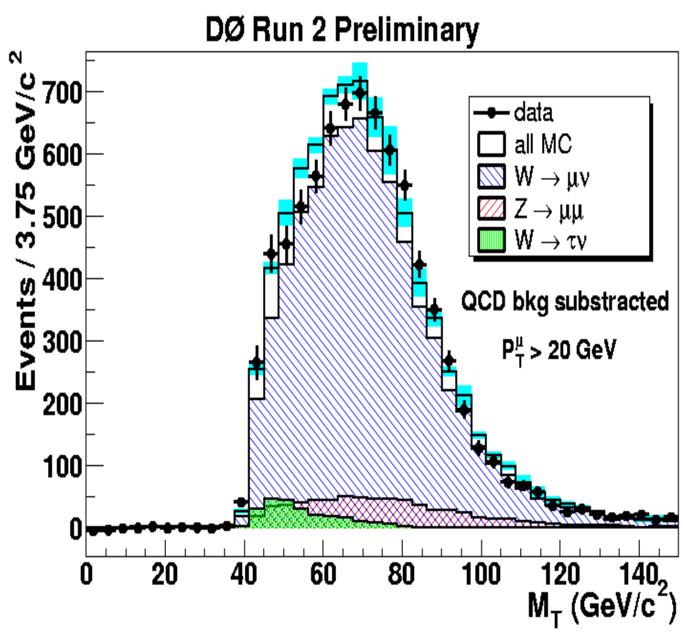


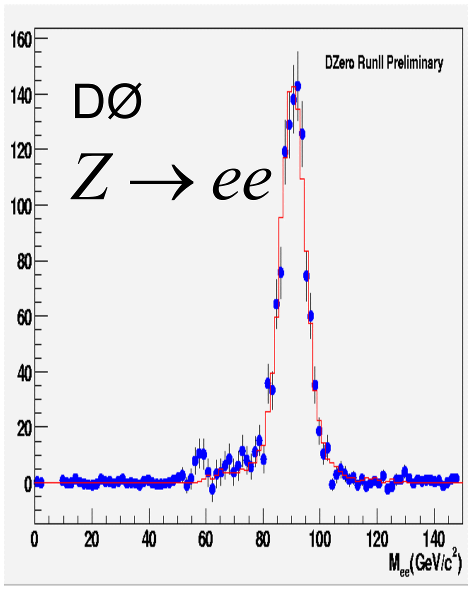
Standard candle for high pT

Ideal for calibration and precision measurements

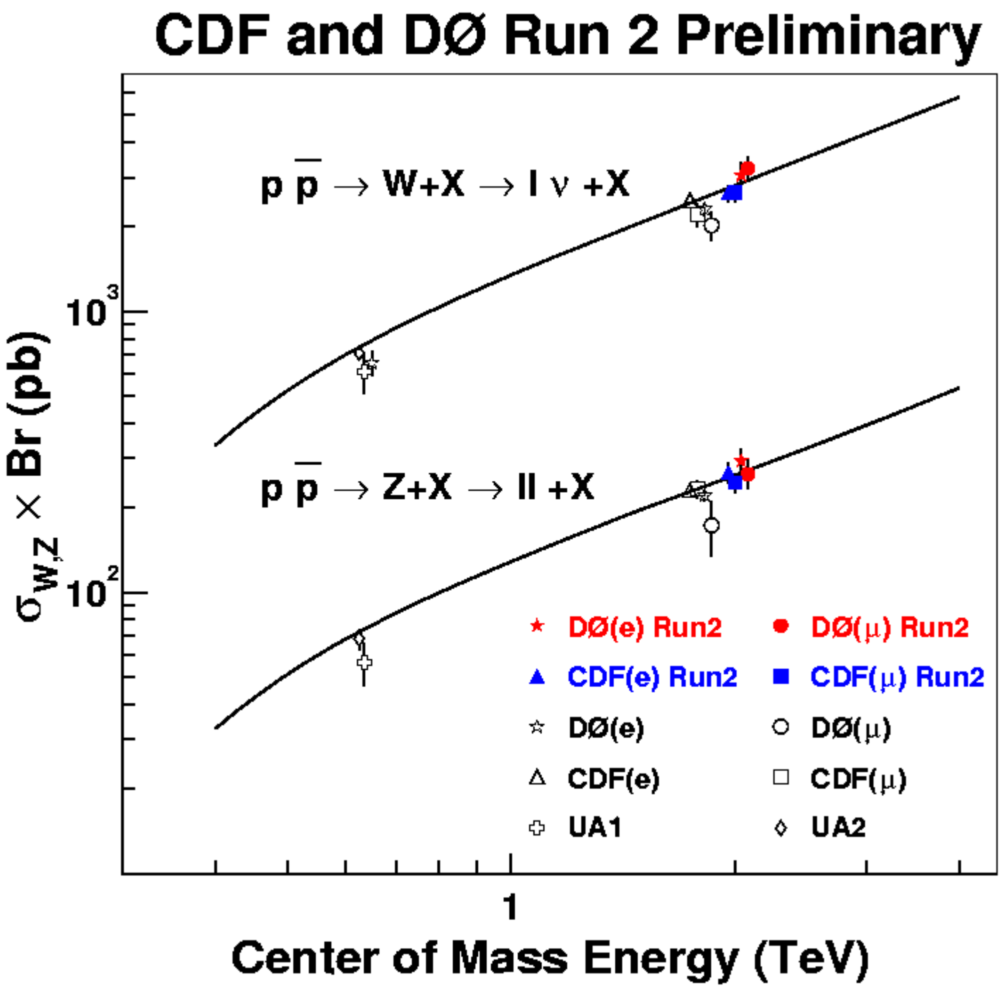
- **Simple event topologies**
- **Easy trigger and identification**
- **High rate and small background**

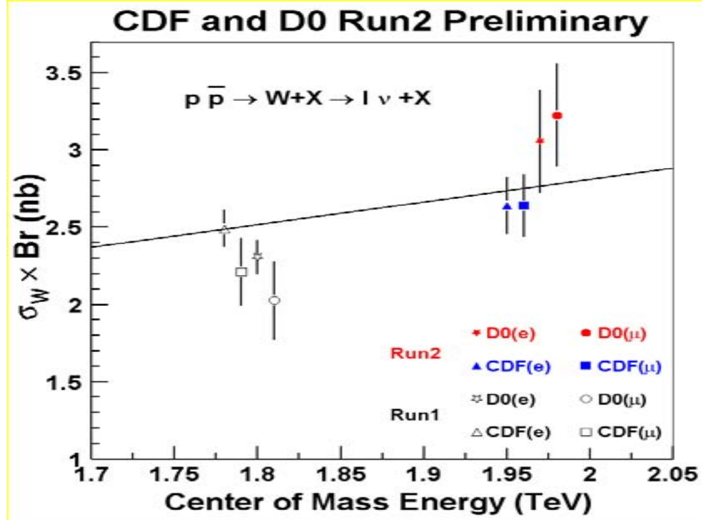


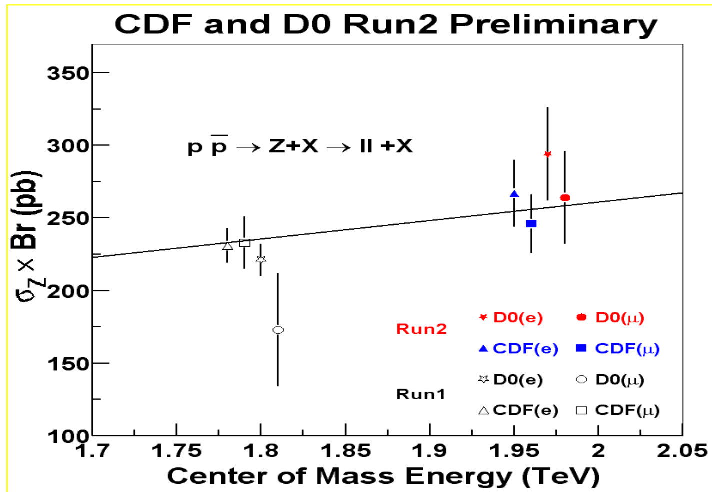




W/Z Cross Section



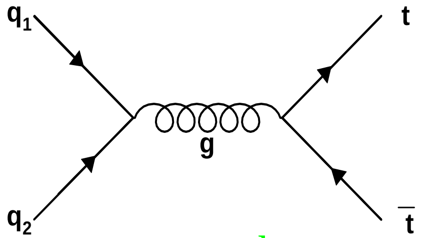


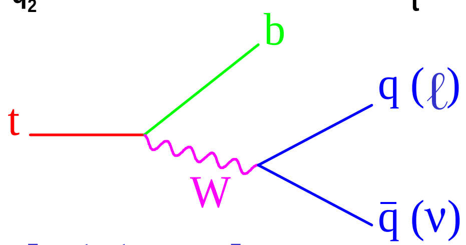


C. R. Hamberg, W.L. van Neerven and T. Matsuura, Nucl. Phys. B359 (1991) 343

Top Quark Physics

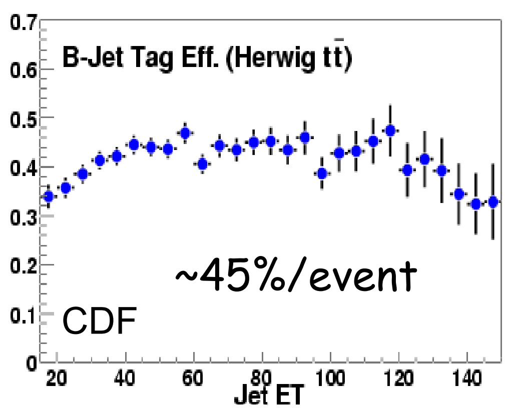
Production/Decay



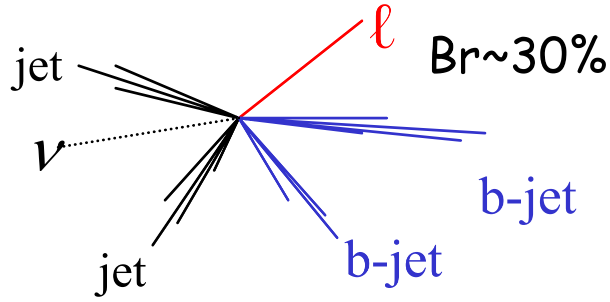


b-jet tagging:

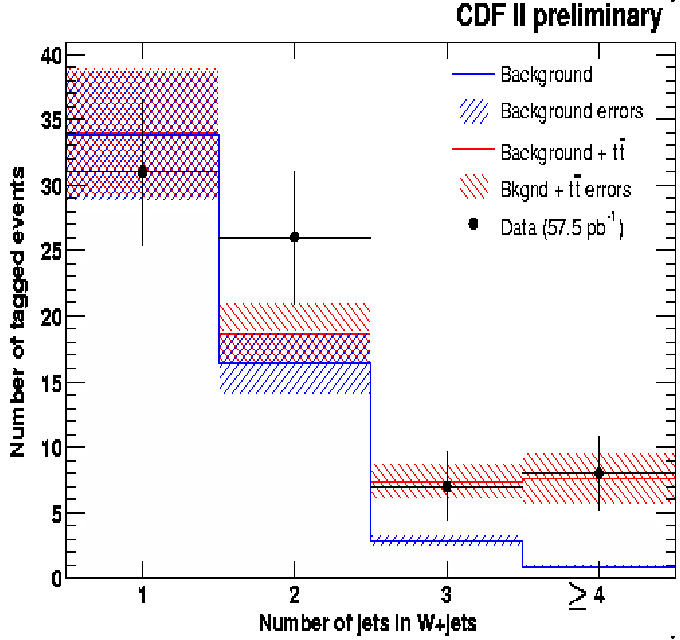
- long lifetime (CDF)
- semi-leptonic decays (CDF, DØ)



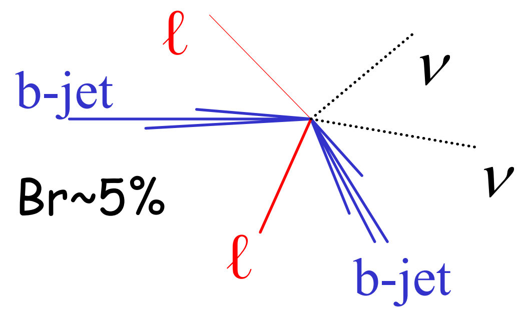
Lepton+jets events



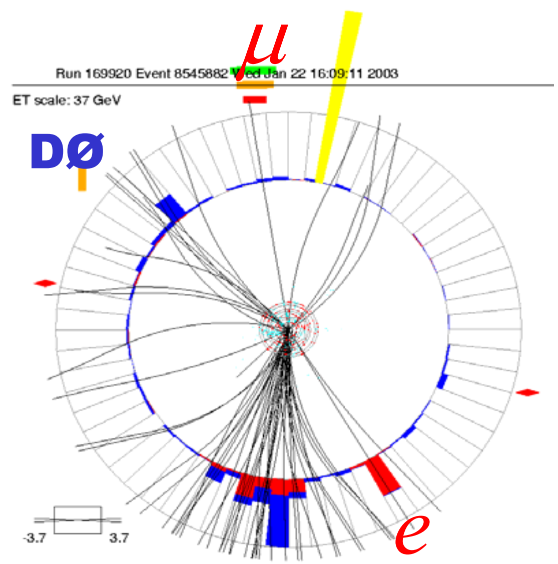
Background:
W+jets, fakes



Dilepton events

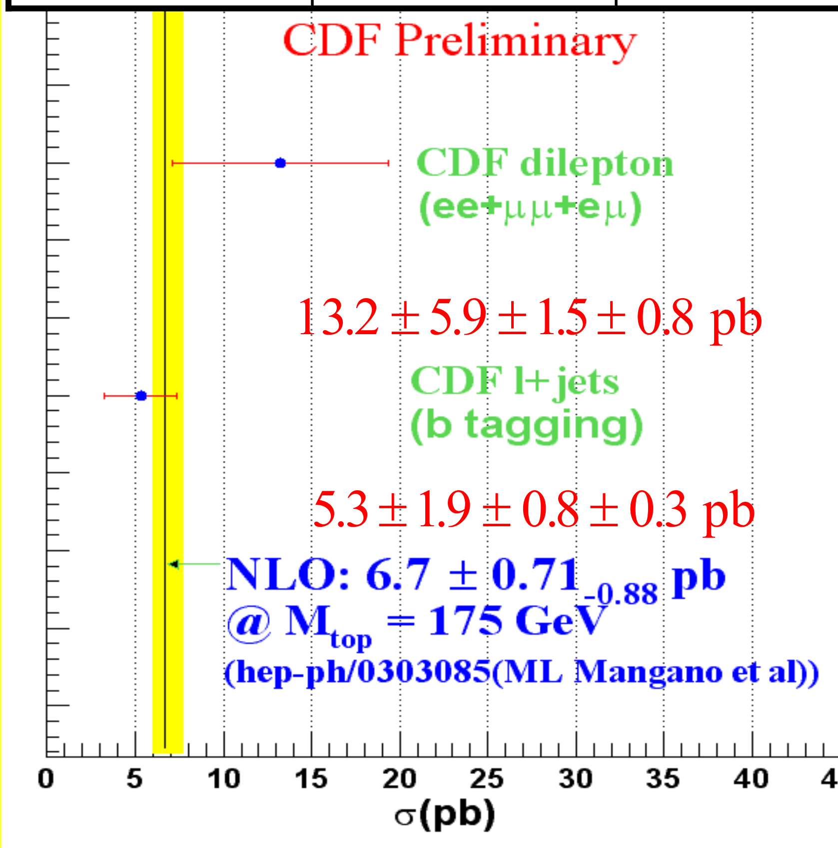


Background:
$WW, WZ, Z \to \tau\tau$, fakes

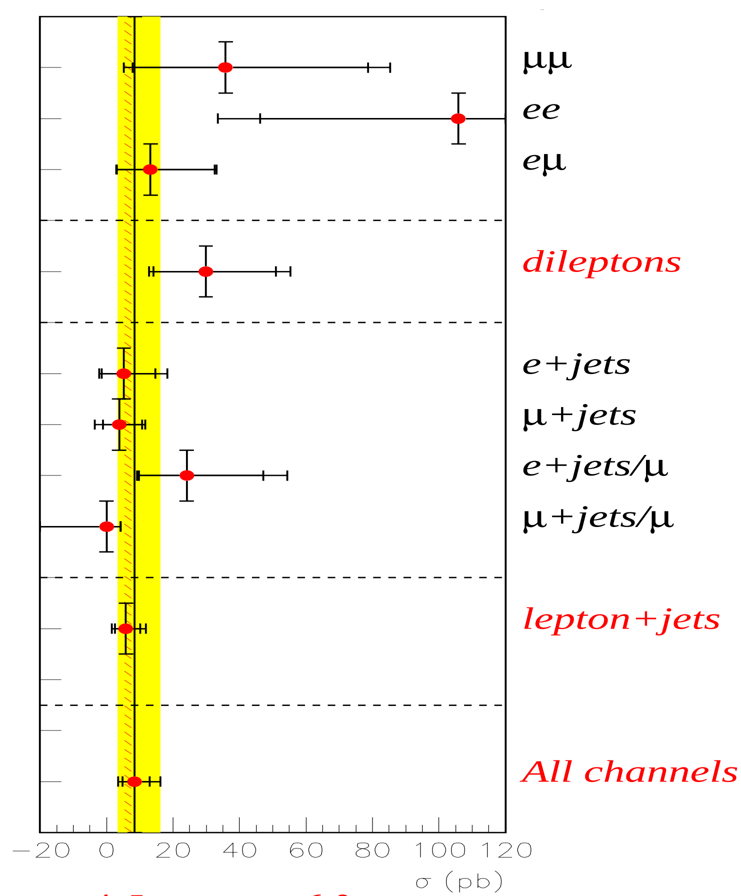


Top Pair Cross Section

luminosity	dilepton	lepton+jets
CDF	79 pb^{-1}	57.5 pb^{-1}
DØ	33-48 pb^{-1}	40-50 pb^{-1}



DØ Run II Preliminary



$$\sigma_{t\bar{t}} = 8.5^{+4.5}_{-3.6}(stat)^{+6.3}_{-3.5}(sys) \pm 0.8(lumi)\ \text{pb}$$

First Look at m_{top}

CDF made a preliminary measurement of the top quark mass using the likelihood method

$$m_{top} = 171.2 \pm 13.4 \pm 9.9 \text{ GeV} / c^2$$

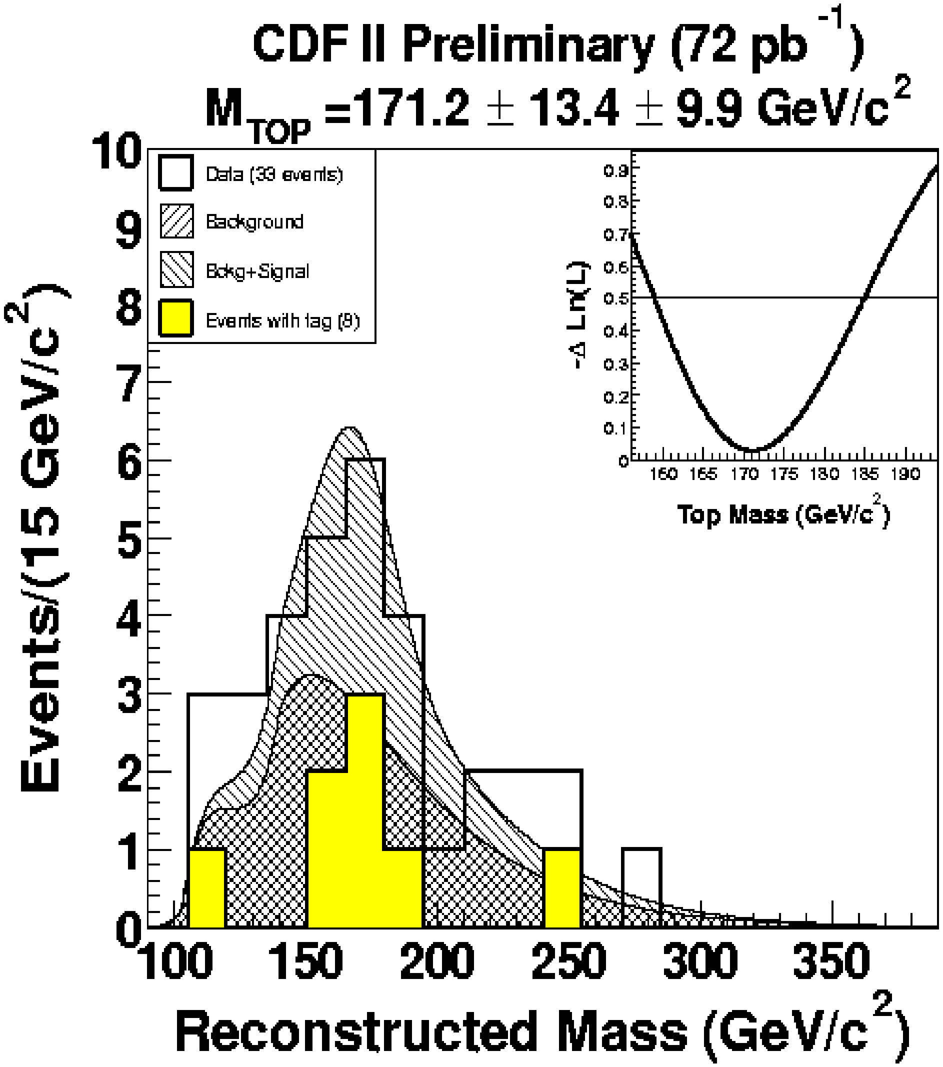
(without using b-tagging information)

Consistent with CDF/DØ combined Run I results

$$m_{top} = 174.3 \pm 3.2 \pm 4.2 \text{ GeV} / c^2$$

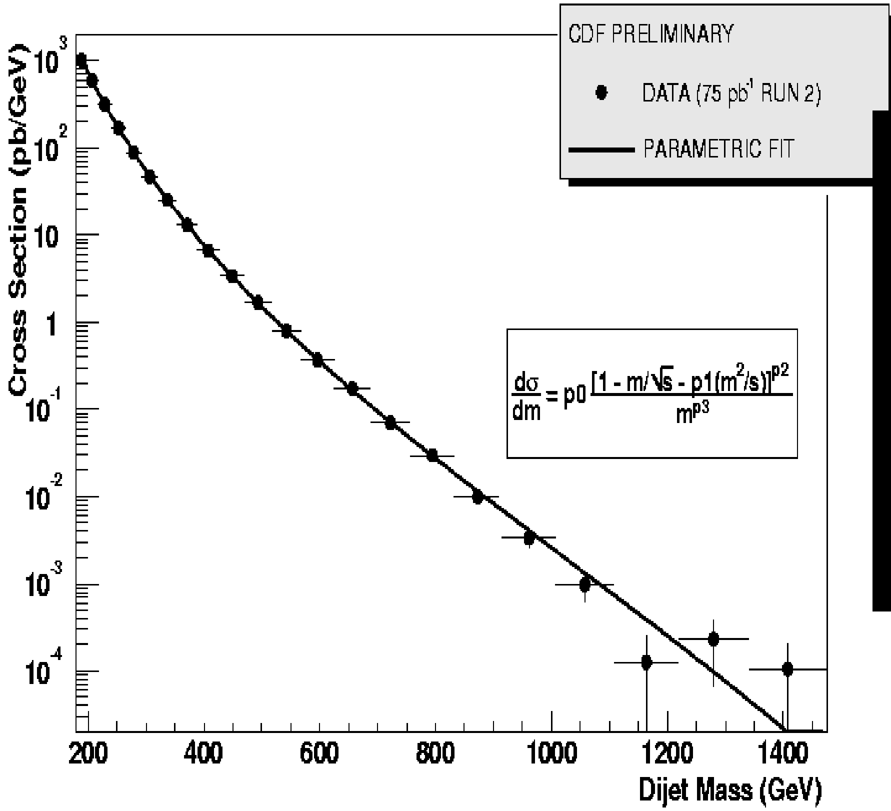
and with the recently improved DØ Run I result

$$m_{top} = 180.1 \pm 3.6 \pm 4.0 \text{ GeV} / c^2$$

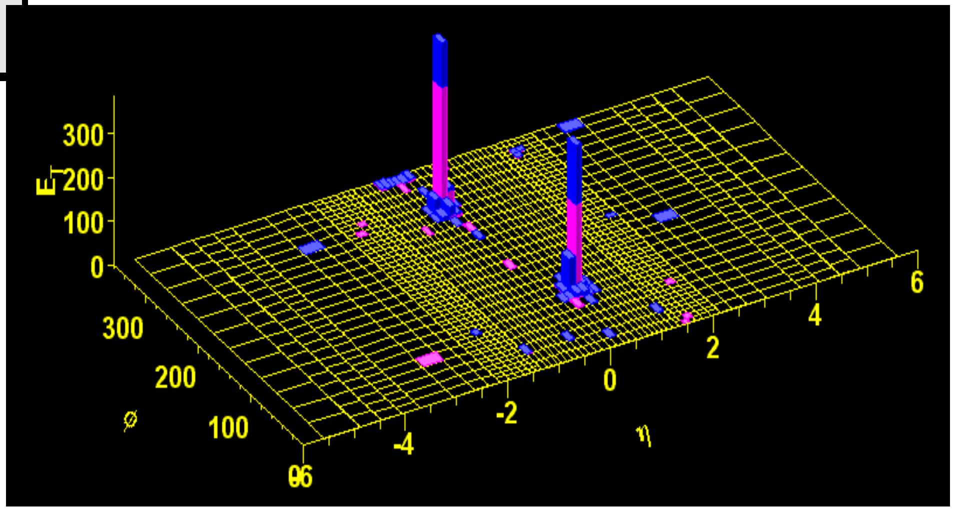


Dijet Mass Distribution

- Dijet mass distribution is a tool for QCD test and is also sensitive to high mass resonances.
- Both CDF and DØ have measured dijet cross section in Run II. The distributions agree well with the expectations.



CDF high mass dijet event



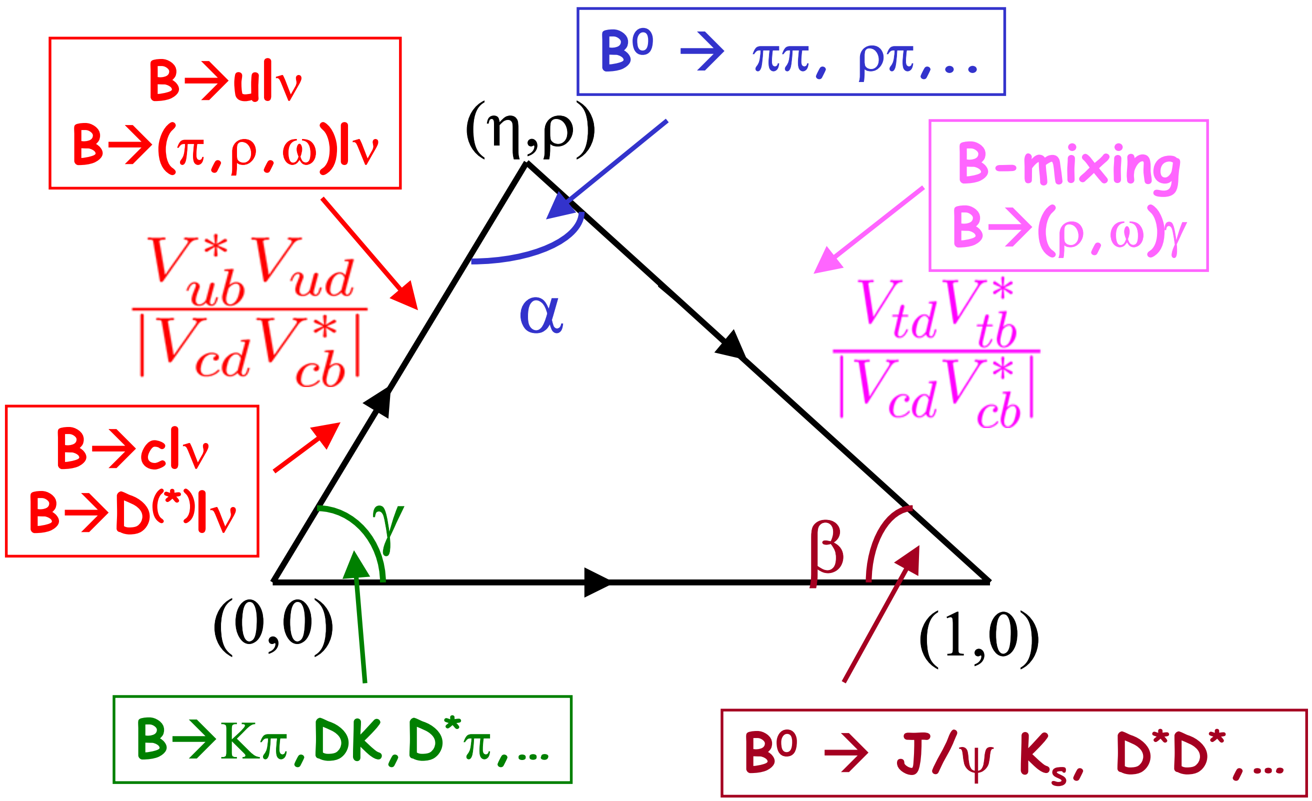
Dijet Mass: 1364 GeV

~ 70% of $p\bar{p}$ energy
$\langle x \rangle \sim 0.85$

B-Physics

Results from B-factories
Tevatron results & prospects
LHC Prospects

B-Physics and the Unitarity Triangle



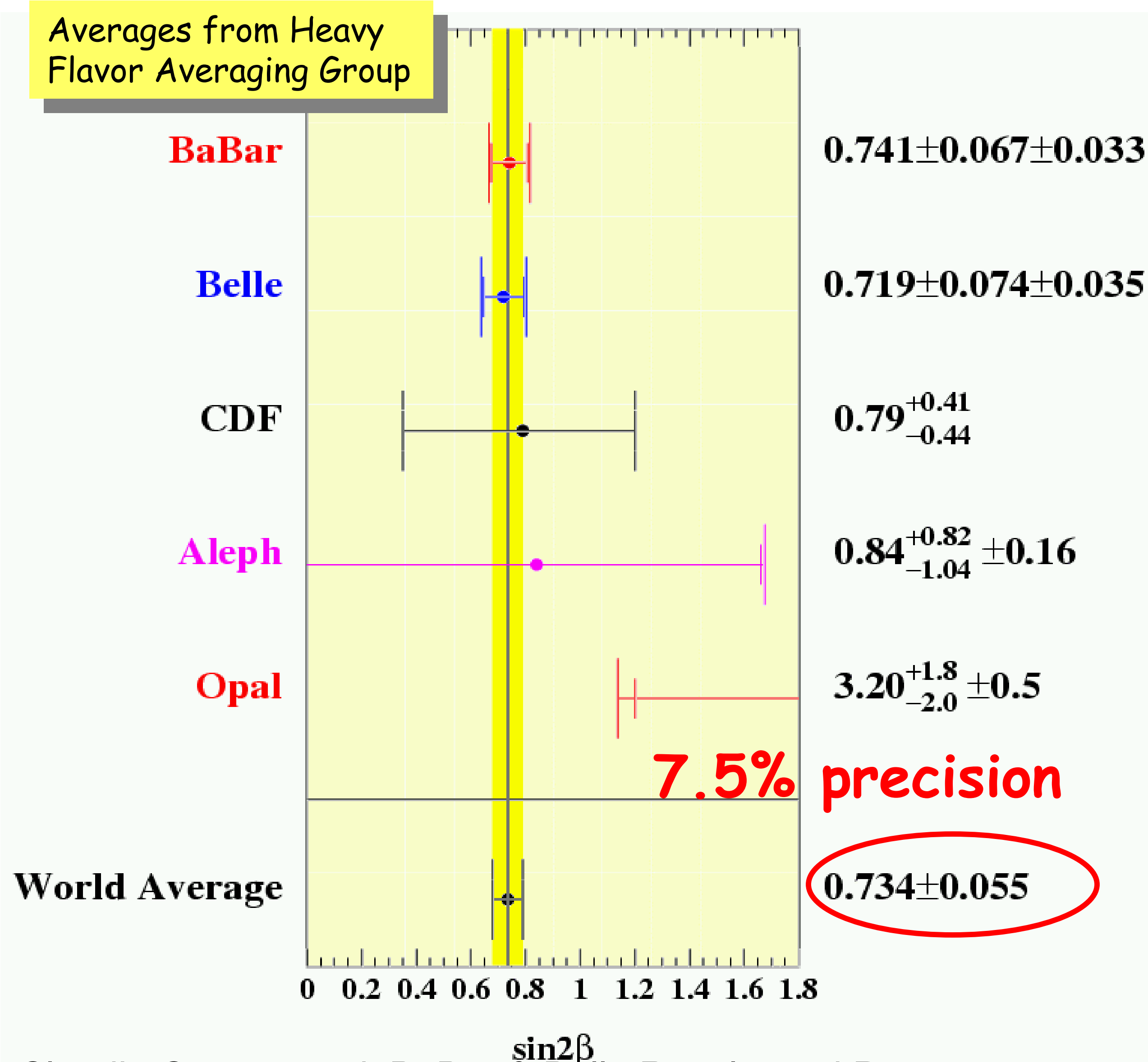
Results shown:

- Luminosity BaBar and Belle
- Lifetimes and mixing
- Sin2β results
- Working towards sin2α
- Comments on γ
- V_{ub}

B-factories

- Now ~100 fb^{-1} per experiment
- Should have ~500 fb^{-1} by 2005-2006, 1000-2000 fb^{-1} by end of decade

Summary sin2β in $b \rightarrow c\bar{c}s$

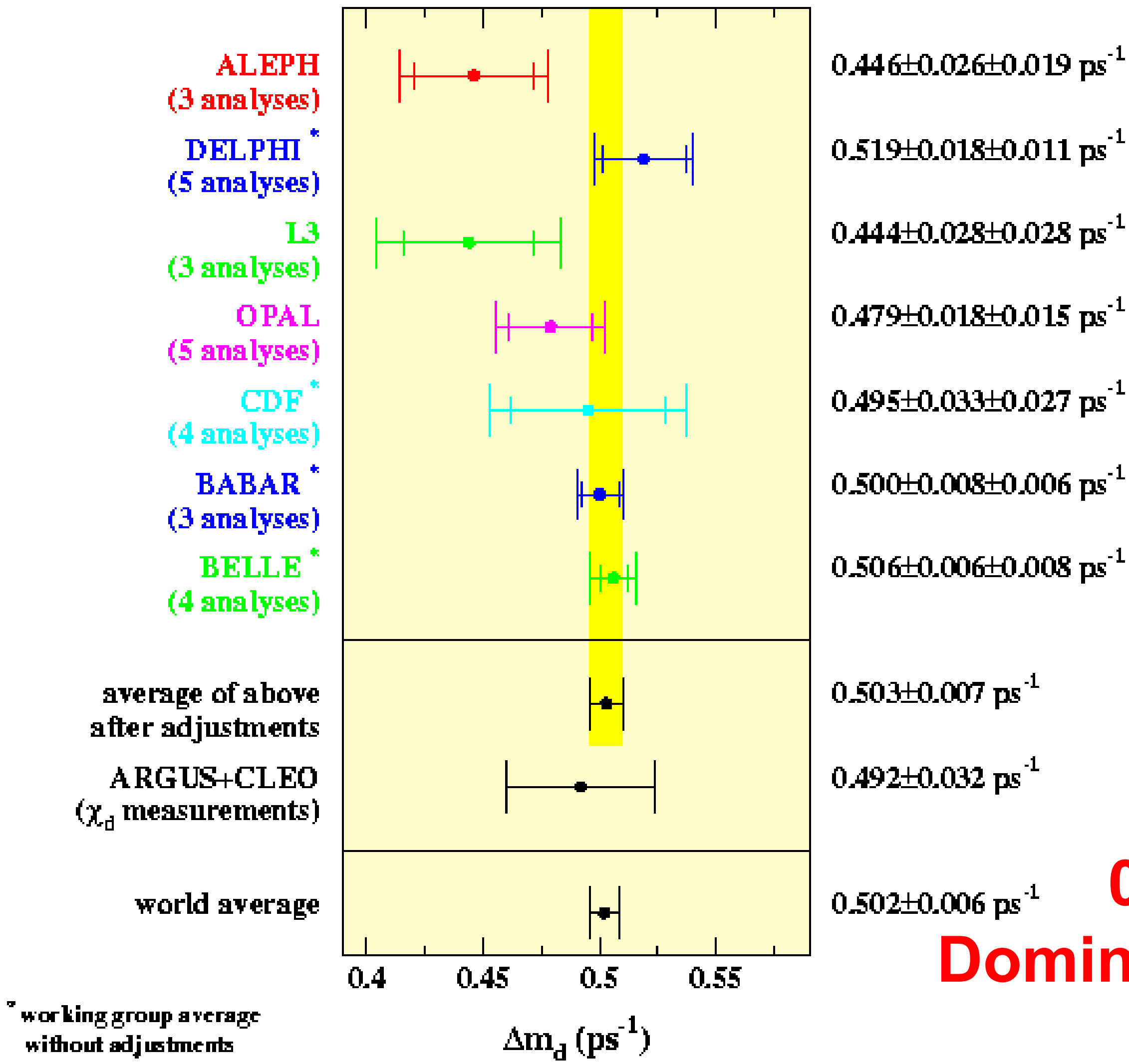


Prospects:

- Already a precision measurement
  - **But still statistically limited**
  - **Will be improved**
- Measurements in other modes will improve as √luminosity
  - **Maybe faster, as techniques improve**
- Improved results in the $b \rightarrow s$ modes will be particularly interesting!

Mixing results summary

Partial averages from F. Ronga CKM Workshop03



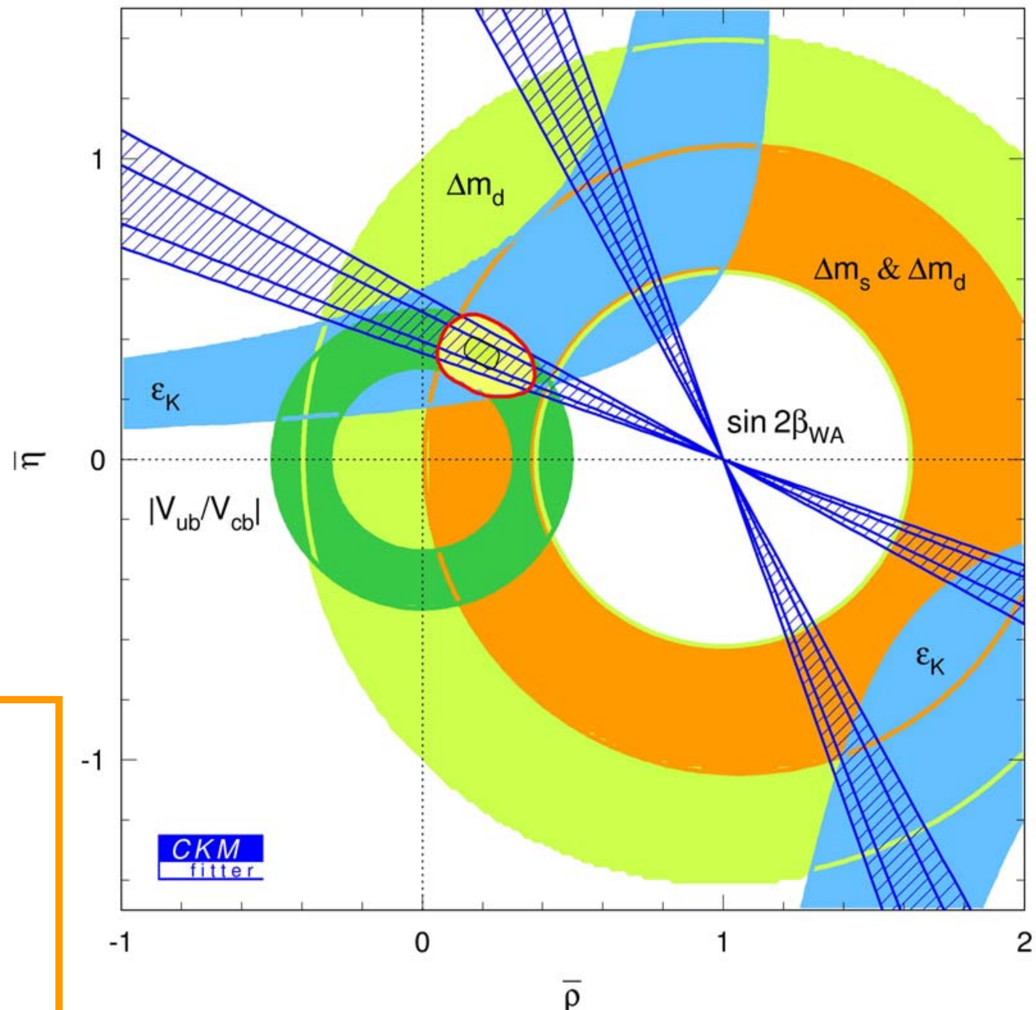
LEP+CDF
0.497 ± 0.014 ps^{-1}

BaBar + Belle
0.502±0.006 ps^{-1}

World Average
0.502 ± 0.006 ps^{-1}
Dominated by BaBar & Belle
3% precision!

B-Factories: Conclusions

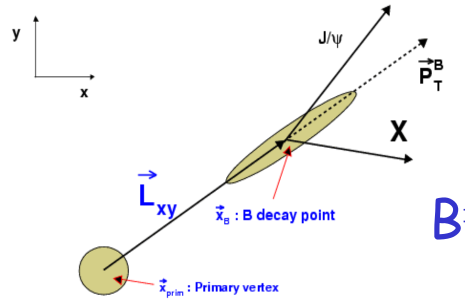
- The B-factories have gone through a very successful first three years
- Today I showed you only a small fraction of their physics program, there is much more
- We are looking forward to increases in luminosity, eventually x10-20 more data
- The SM is still alive and well, but we'll continue poking at it



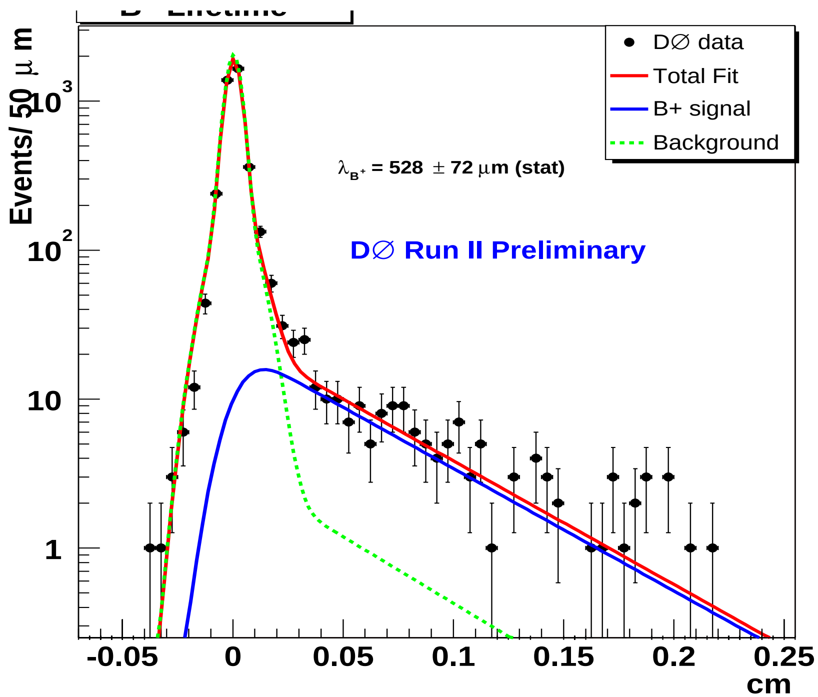
Some B-physics better done at hadron machines (angle γ, Bs, etc.)

Hadronic B-factories: CDF, D0, LHCb, ATLAS, CMS

Heavy Flavor at Tevatron

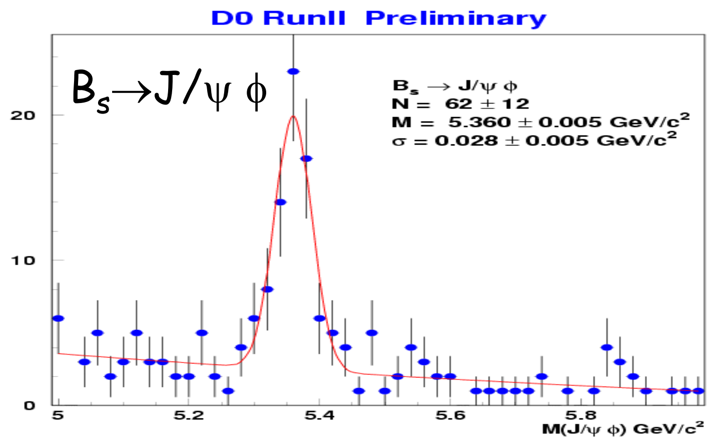


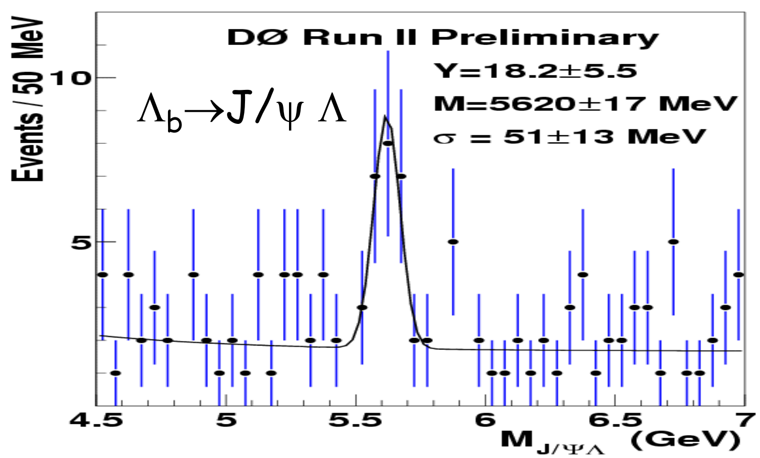
$B^\pm \to J/\psi\, K^\pm$



$\tau = 1.76 \pm 0.24$ (stat) ps

New in the game, but is catching up quickly…





Expect a lot more for the summer…

CDF B-Physics

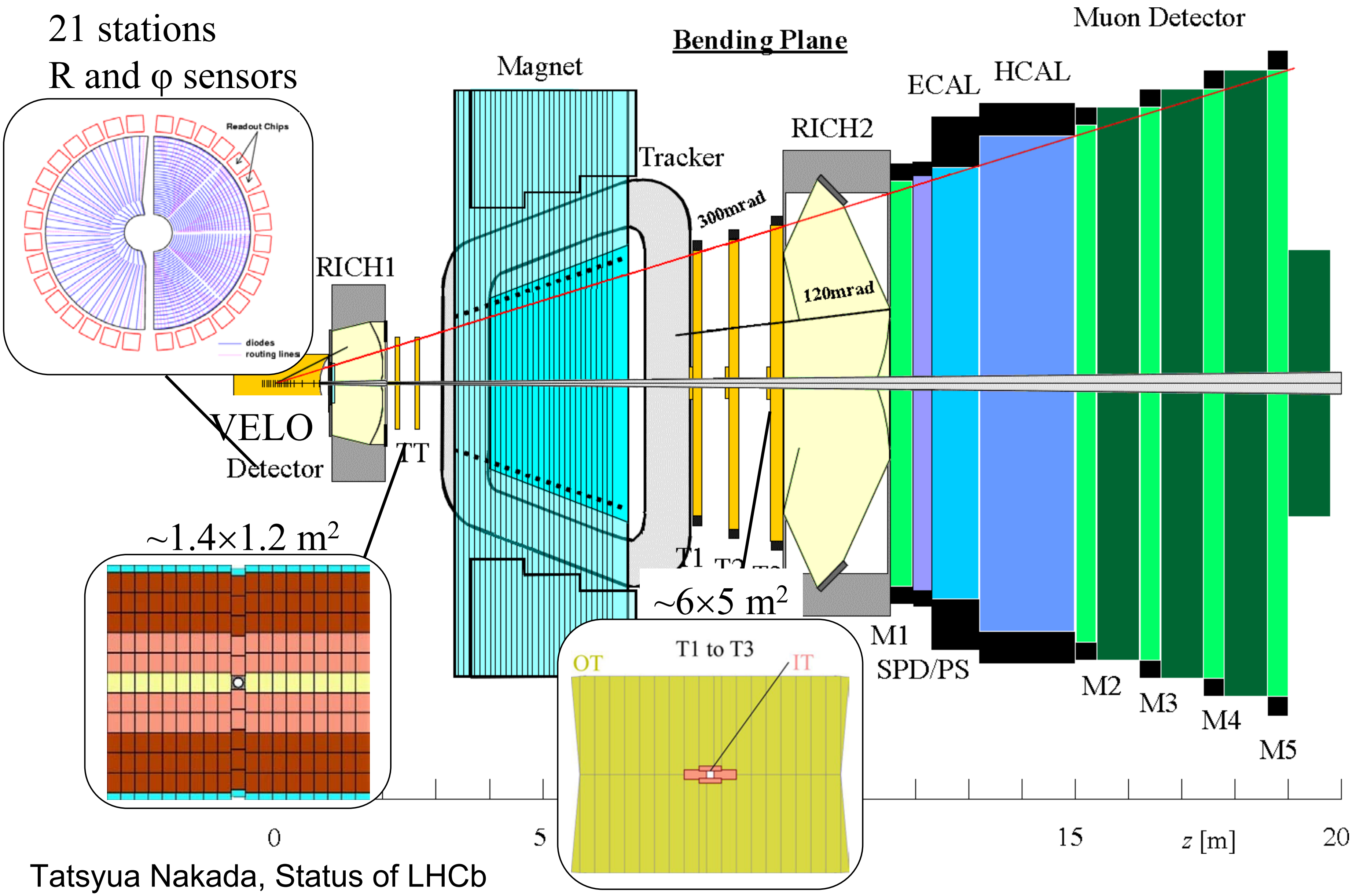
- **Key triggers and detector performances** well understood. Better triggers and larger kinematic coverage compared to Run I.

- **Masses, lifetimes, BRs:** Worlds best B_s mass, lifetime and worlds largest sample of Λ_b with ONLY 65 pb^{-1}. Current best limit on FCNC $D^0 \rightarrow \mu\,\mu$ decay.

- **CKM matrix physics:** Key hadronic signals $B_s \rightarrow D_s^* \pi$ and $B \rightarrow h^+ h^-$ established.

Particle	Measured mass [MeV/c^2]
B^+	5280.6 ± 1.7 (stat) ± 1.1 (syst)
B^0	5279.8 ± 1.9 (stat) ± 1.4 (syst)
B_s^0	5360.3 ± 3.8 (stat) + 2.1 – 2.9 (syst)
$M(D_s^\pm) - m(D^\pm)$	99.41 ± 0.38 (stat) ± 0.21 (syst)
Particle	**Lifetime**
B_s	1.26 ± 0.20 (stat) ± 0.02 (syst) ps
Λ_b	xxx ± 0.13 (stat) ± 0.07 (syst) ps
Decay	**Branching fraction**
$D^0 \rightarrow \mu\,\mu$	≤2.4 x 10^{-6} @ 90% C.L.

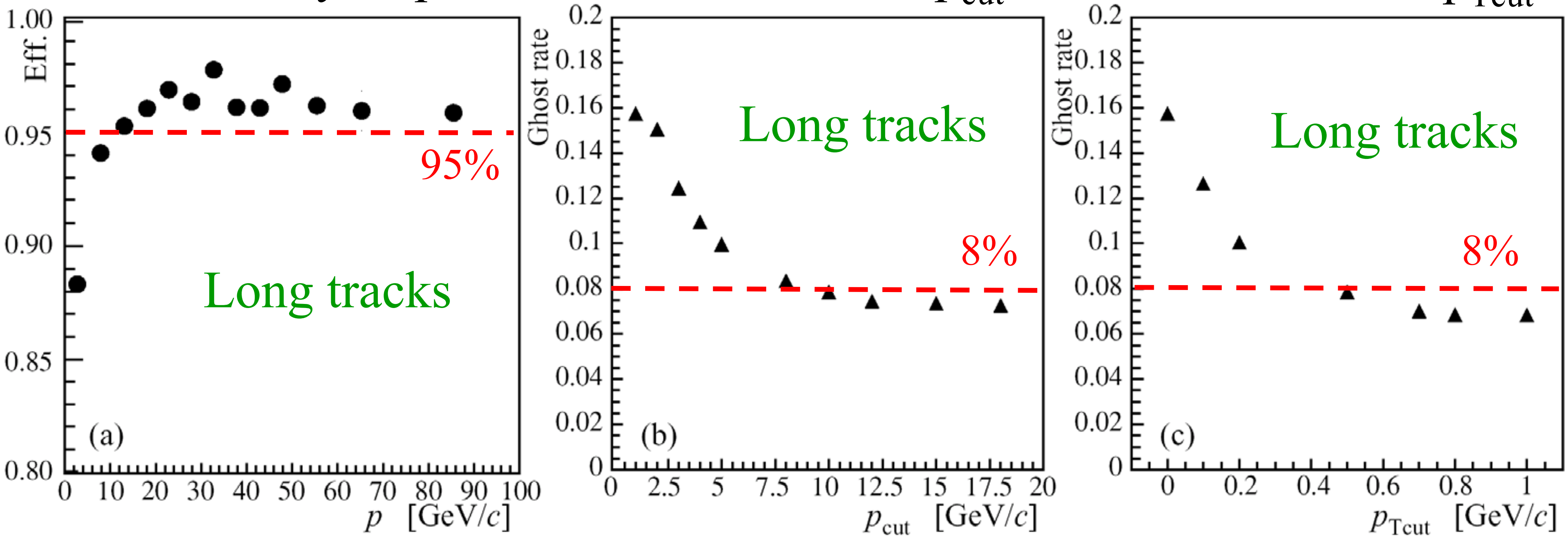
The Next Generation: LHCb Re-Optimization



Tatsyua Nakada, Status of LHCb

Tracking Performance still good

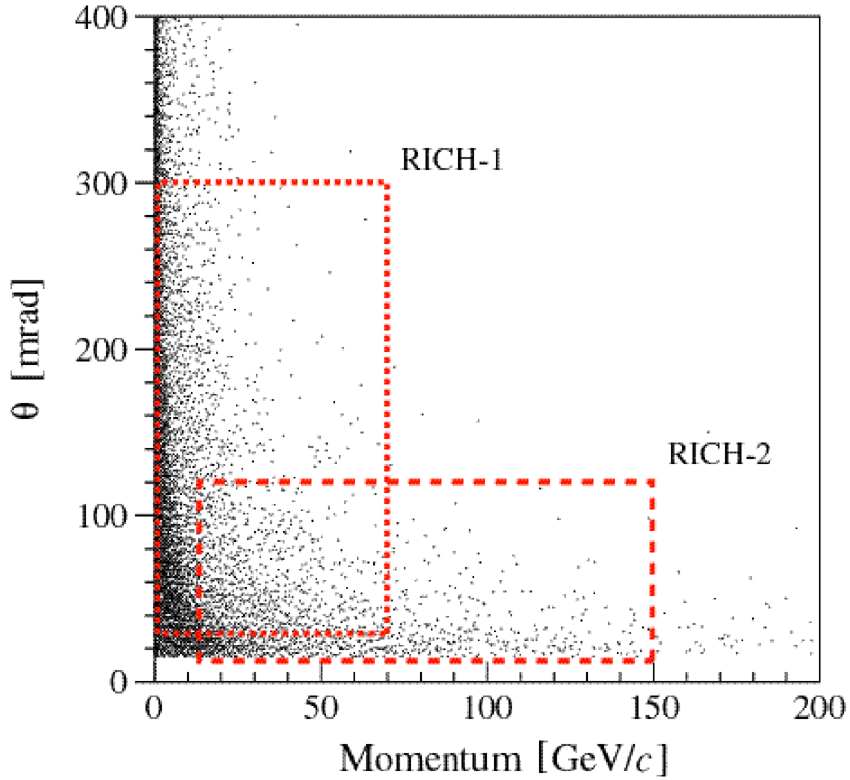
Efficiency vs p | Ghost rate vs p_{cut} | Ghost rate vs p_{Tcut}



Average efficiency = 92 %
Efficiency for p>5GeV > 95%

Total ghost rate = 16%
Ghost rate p_T>0.5 GeV ~ 8%.
Large event to event fluctuations.

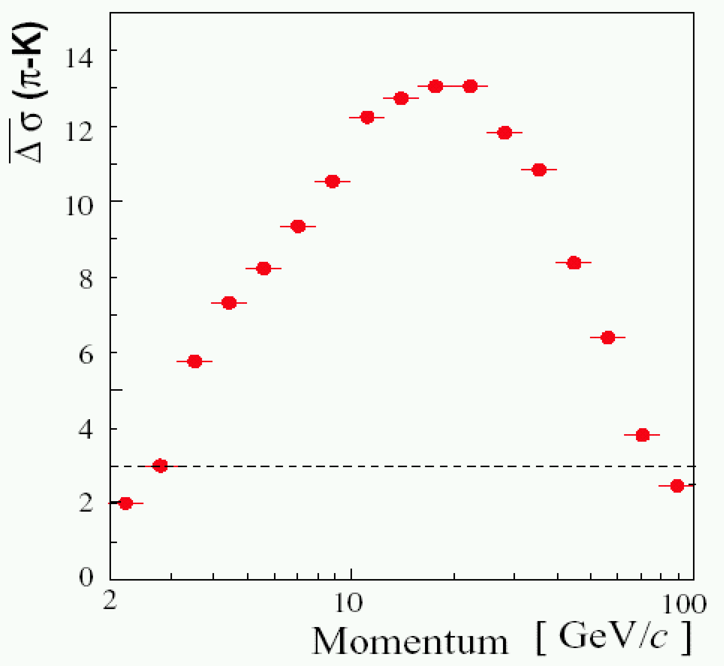
Physics with Hadron Identification



- Two independent detectors
  - "RICH1" : Aerogel and C_4F_{10}
  - "RICH2" : CF_4

$$\cos(\theta_c) = \frac{1}{n \cdot v/c}$$

- Require π/K separation for 1-150 GeV/c
- Overall the 3 radiators provide excellent π/K separation over the full momentum range

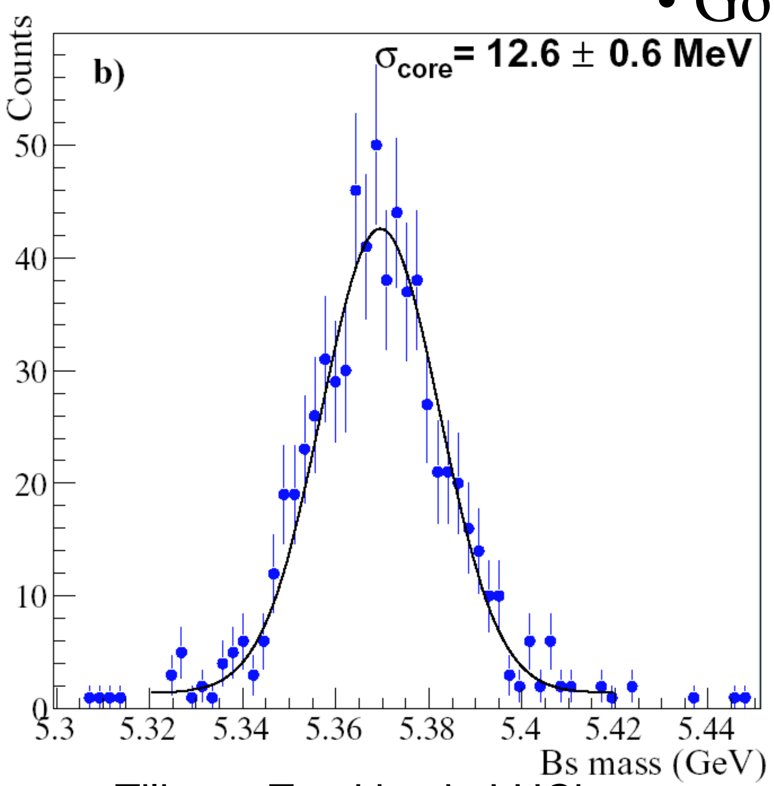


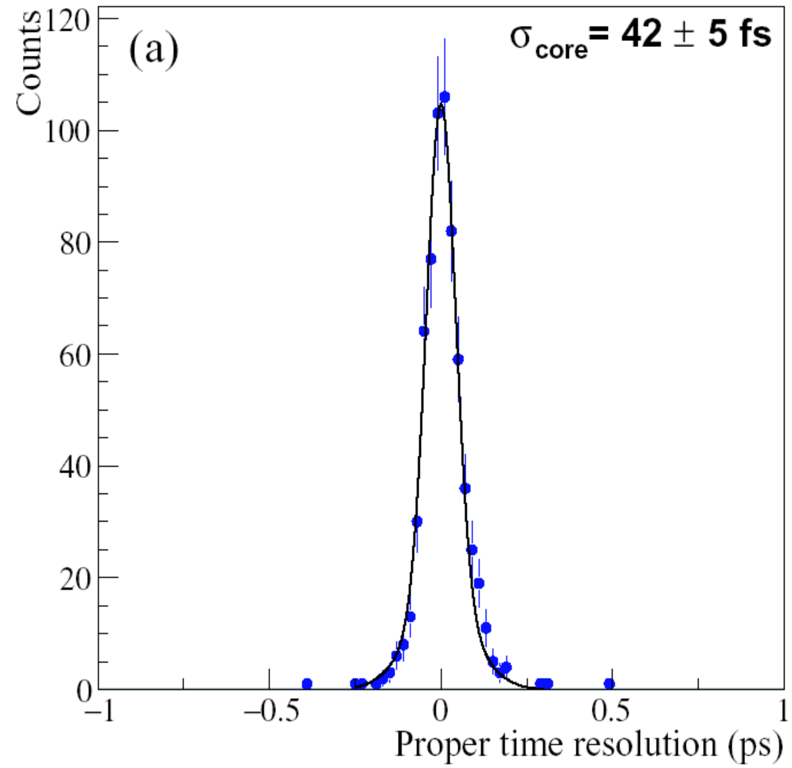
Final State Reconstruction is maintained

Good tracking performance essential input for physics analysis:

<u>Decay channel</u>:
$B_s \rightarrow D_s^-(\rightarrow KK\pi)\ \pi^+$

- 4-prong *prompt* decay → all long tracks.
- Total tracking efficiency 84.6±0.5 % (= 95.6 % per track)
- Good resolutions:





LHCb Physics

By measuring CP violation in B_d and B_s systems, we will determine:

- phase of the B_d-$\overline{B}_d$ oscillation with an improved accuracy

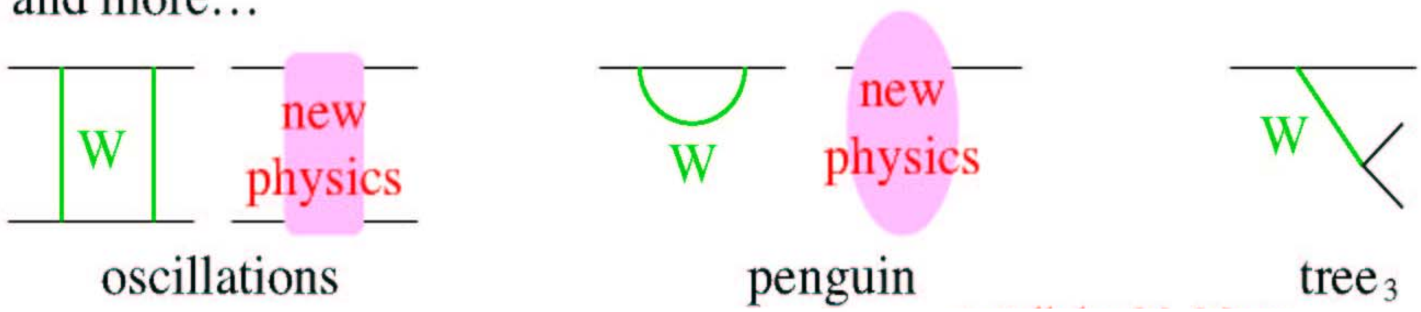
$$\sigma\ (\sin 2\beta \text{ LHCb one year}) = \int^{2006} \text{Babar+Belle+Tevatron } dt$$

- phase of the B_s-$\overline{B}_s$ oscillation
- phase of the $b \to s$ penguin decay
- phase of the $b \to d$ penguin decay

→ Search for New Physics

- phase of the $b \to u + W^-$ tree decay → Determination of the CKM

and more…



Necessary final states

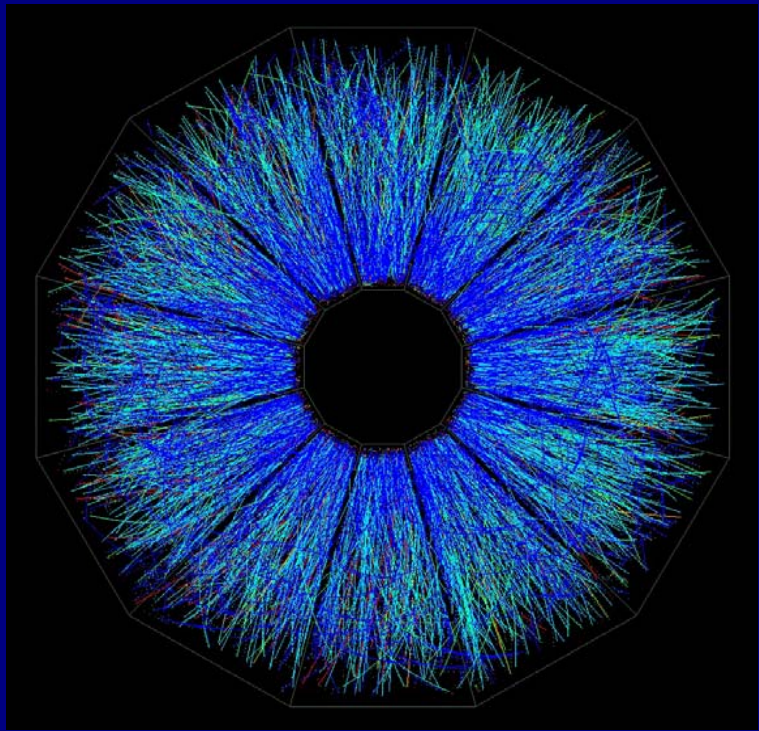
$B_s \to J/\psi\ \phi,\ J/\psi\ \eta,\ D_s\ K,\ K^+K^-,\ \phi\ \phi\ ,\ \phi\ \gamma,\ \phi\ K_S,\ \phi\ K^{*0}, \ldots$

$B_d \to D^*\ \pi,\ K^\pm\ \pi^\mp,\ \pi^+\ \pi^-,\ K^{*0}\ \gamma,\ \phi\ K_S,\ \phi\ K^{*0},\ K^{*0}\ \overline{K}^{*0}, \ldots$

LHC Both B_d and B_s

LHCb Hadron PID, trigger sensitive to hadronic states, excellent σ_t

Heavy Ion Physics



Results from RHIC
ALICE Performance & Physics
ATLAS, CMS HI Programme

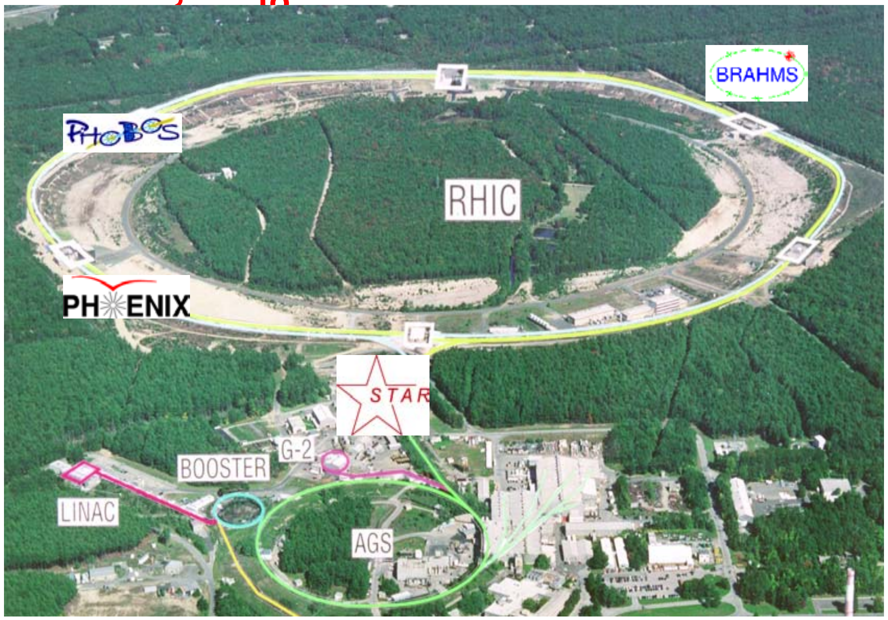
Bulk Particle Production @ RHIC

1. **Initial Conditions/Energy Density:** > 5 GeV/fm^3
2. **Thermalization:** ✓
3. **Hadrochemistry:** $T_{ch} \sim 180$ MeV, $m_B \sim 25$MeV
4. **Expansion Dynamics:** $T_{th} \sim 110$ MeV, $\langle b_T \rangle \sim 0.6c$

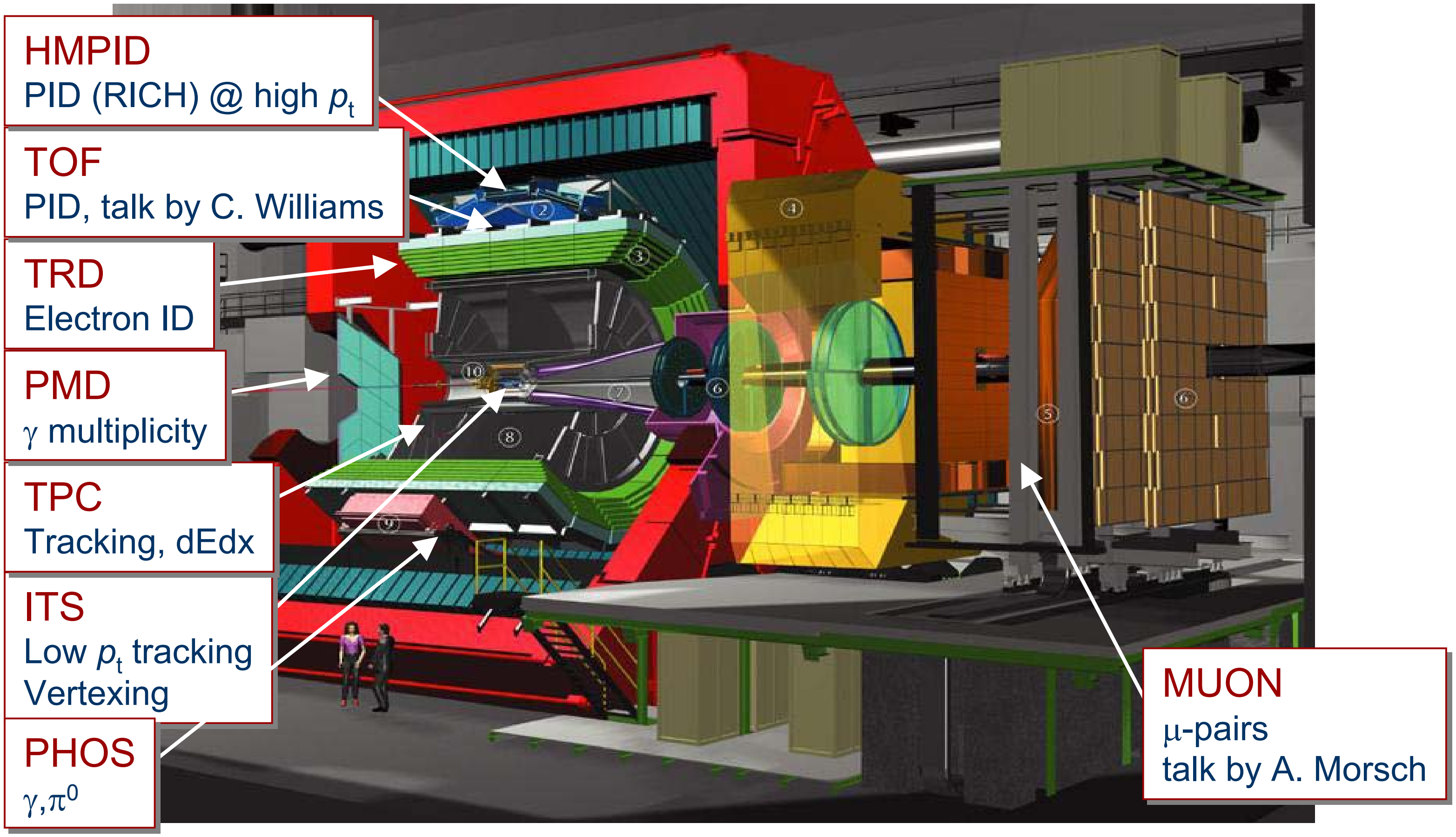
   $\langle t_{fo} \rangle \sim 10$ fm/c, $Dt_{fo} \sim 0\text{-}3$ fm/c

Consistent *Description* of Final State

But we're missing a picture of *Dynamical Evolution*



LHC Heavy Ion Presentations



1. ALICE Physics Reach	**C. Blume**
2. Muon Spectrometer	**A. Morsch**
3. TOF System	**C. Williams**
4. Jet Physics in ALICE	**T. Cormier**

ATLAS + CMS
Heavy Ion
Programme

ALICE Physics

Soft Regime

p_t = 0–2 GeV/c
non-perturbative

- Particle yields
  → chem. freeze-out
- HBT interferometry
  → thermal freeze-out
- Flow
  → expansion

Semi-hard Regime

p_t = 2–5/10 GeV/c

- Thermal photons
  → temp. evolution
- Open charm, J/Ψ
  → plasma screening
- p_t-Spectra
  → mini-jets

Hard Regime

p_t > 10 GeV/c
perturbative

- Hard photons
- Open beauty, Υ
- Jets

→ initial collisions

→ ALICE will cover the transition from the soft (hadronic) to the hard (partonic) regime

→ Correlations between soft and hard probes only possible within ALICE

Summary of LHC 2003 Symposium

A long road, worth the journey.

We will see familiar landscape with new peaks.

Conference participants in front of the Wilson hall.