Comparison of diffractive Higgs generators

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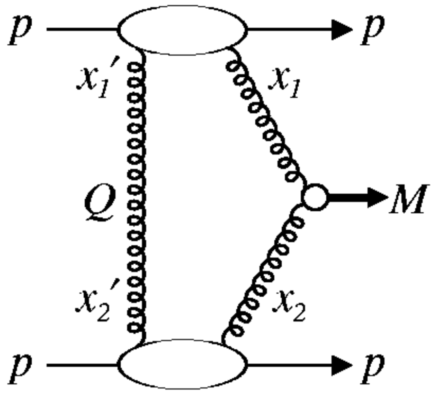
TOTEM Collaboration
http://totem.web.cern.ch/Totem/

- Exclusive Higgs production in DPE
- key distributions from generators
- some experimental implications

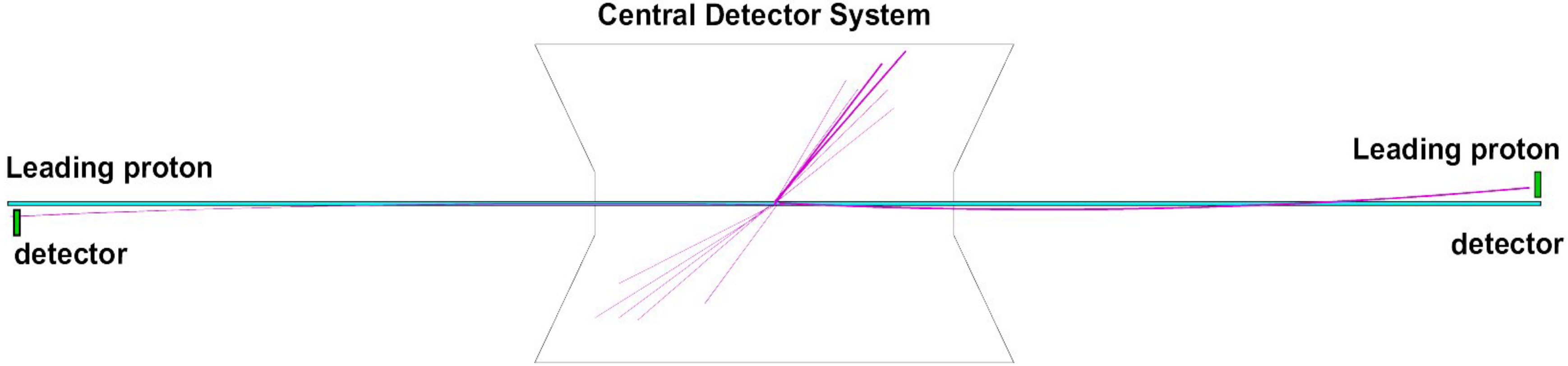
Exclusive Higgs production by DPE



Advantages:

- selection rules: $J^{PC} = 0^{++}, 2^{++},\ldots \Rightarrow$ reduced qq background
- good proton ϕ resolution $\Rightarrow$ determine parity: $P = (-1)^J \Leftrightarrow d\sigma/d\phi \sim 1 + \cos 2\phi$
- good central mass resolution (via protons for larger masses) $\Rightarrow$ further reduction of backgrounds

Measure leading protons accurately with dedicated detectors using the accelerator as a spectrometer & impose 4-vector conservation



Experimental signature: 1 leading proton with small momentum loss / side + a central system. Large rapidity gaps between protons and central system.

Generators compared

- ExHuMe v0.1 – implementation of KMR model (hep-ph 0111078)
- EDDE (R.Ryutin et al., CMS-version)
- modified PHOJET v1.12 DPE + PYTHIA

(used for previously shown acceptance and mass resolution studies)

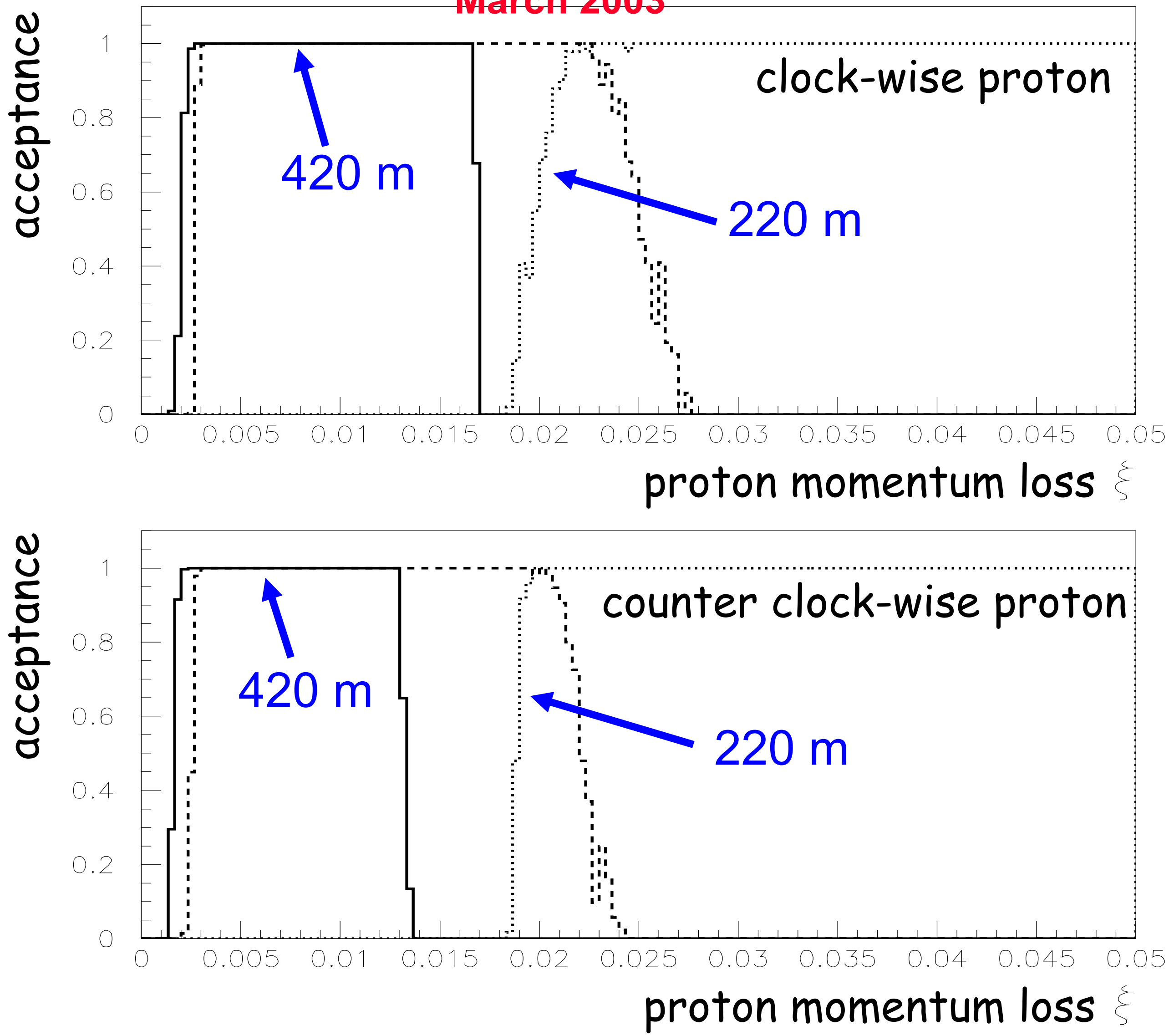
Bench mark process: $pp \to p + H (\to bb) + p$, $m_H = 120$ GeV, $\sqrt{s} = 14$ TeV

Key distributions compared

- Higgs rapidity, y
- Proton momentum loss, ξ
- Proton momentum transfer, t
- E_T of produced b-jets

Leading proton acceptance ($\beta^* = 0.5$ m)

March 2003



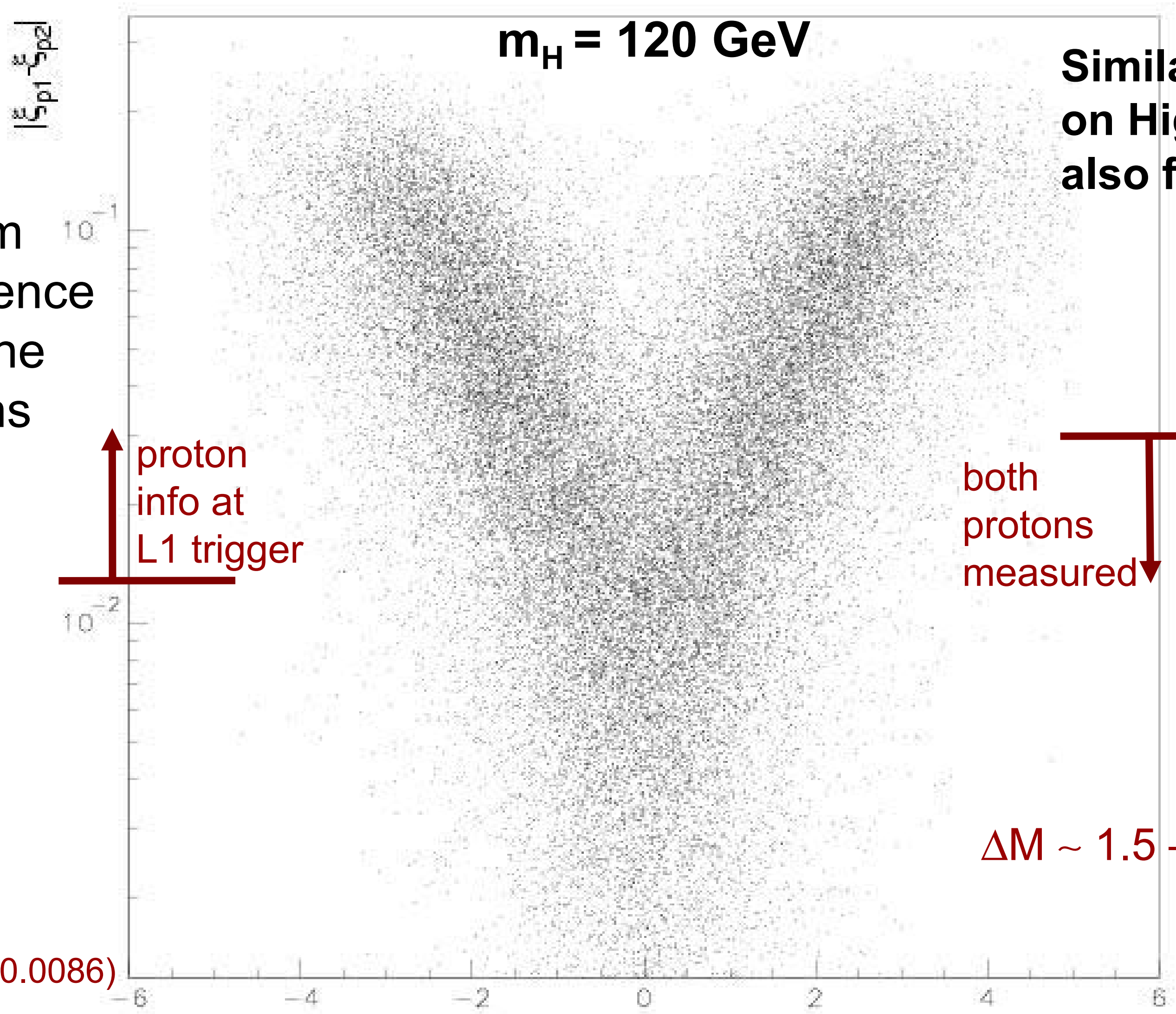
Proton acceptance down to 0.2 % if detectors in the cold region

Only proton info from detectors up to 220 m from IP arrive in time for L1 trigger decision

Higgs rapidity

Similar dependence on Higgs rapidity also for η's of b-jets

Momentum loss difference between the two protons



ΔM ~ 10 GeV

ΔM ~ 1.5 – 2.0 GeV

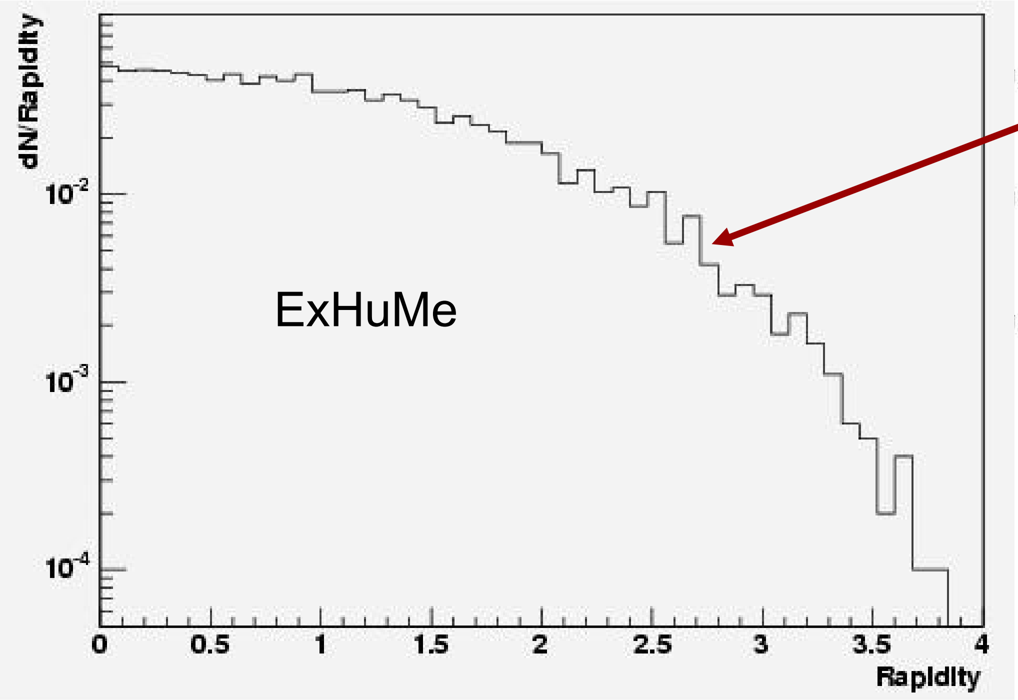
$\xi_{p1} \approx \xi_{p2}$ (≈ 0.0086)

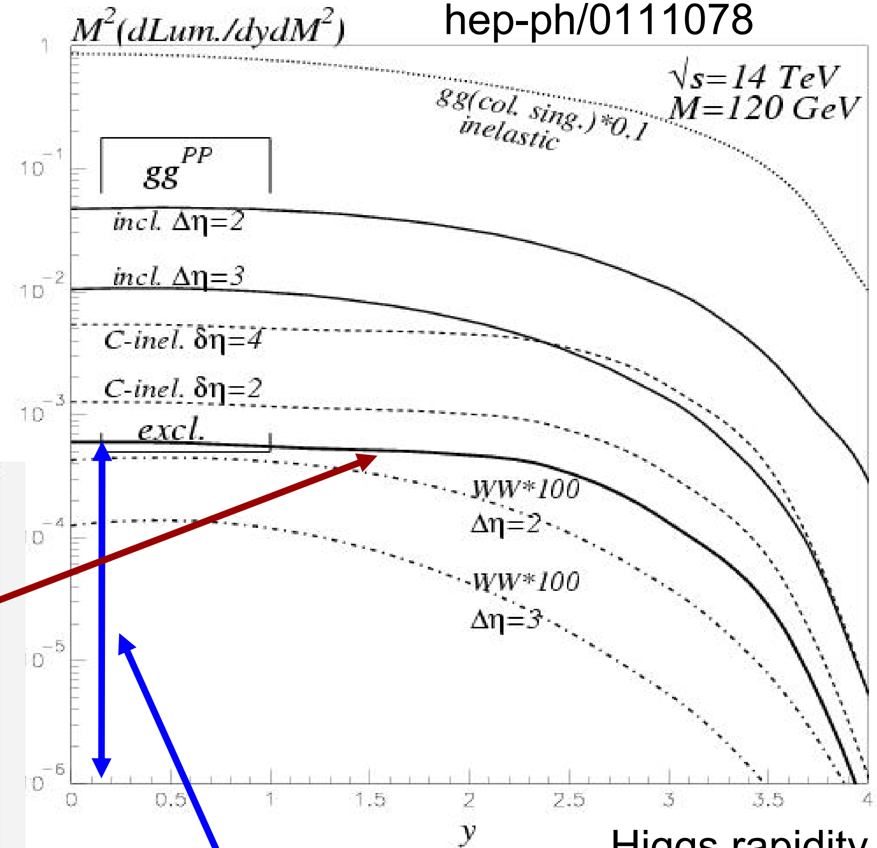
Higgs rapidity

Higgs rapidity

V.A. Khoze, A.D. Martin and M.G. Ryskin, hep-ph/0111078

Acceptable agreement between KMR predictions and ExHuMe output (ExHuMe authors: agreement even better in coming version)

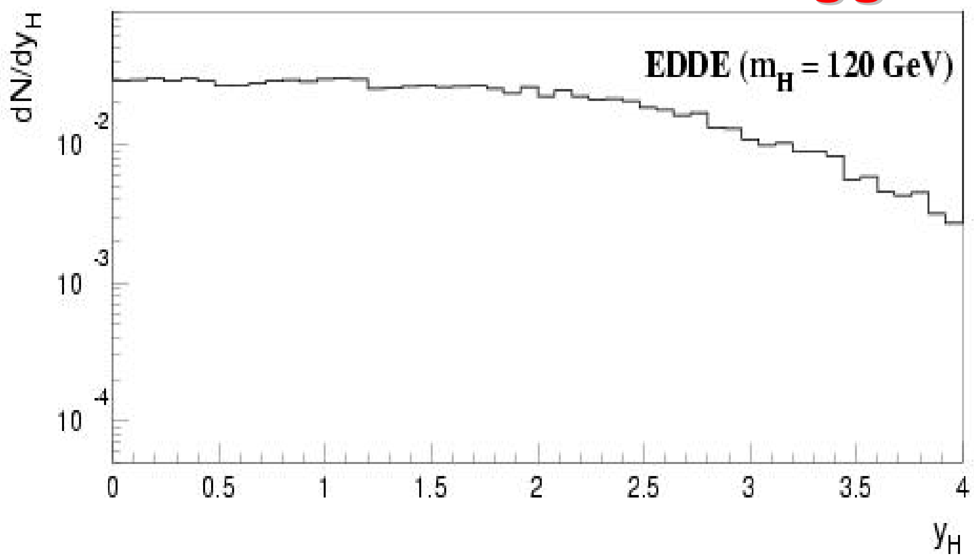


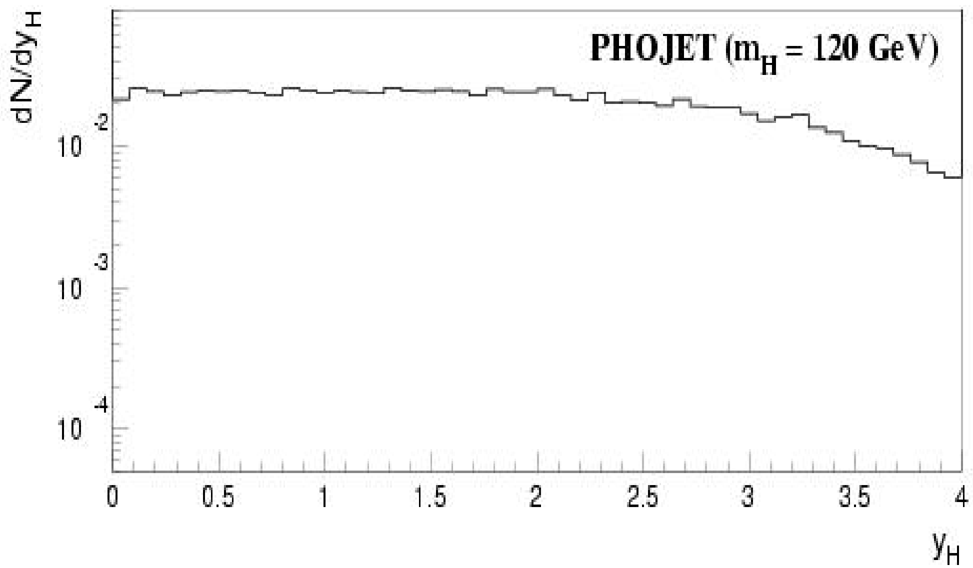


Higgs rapidity

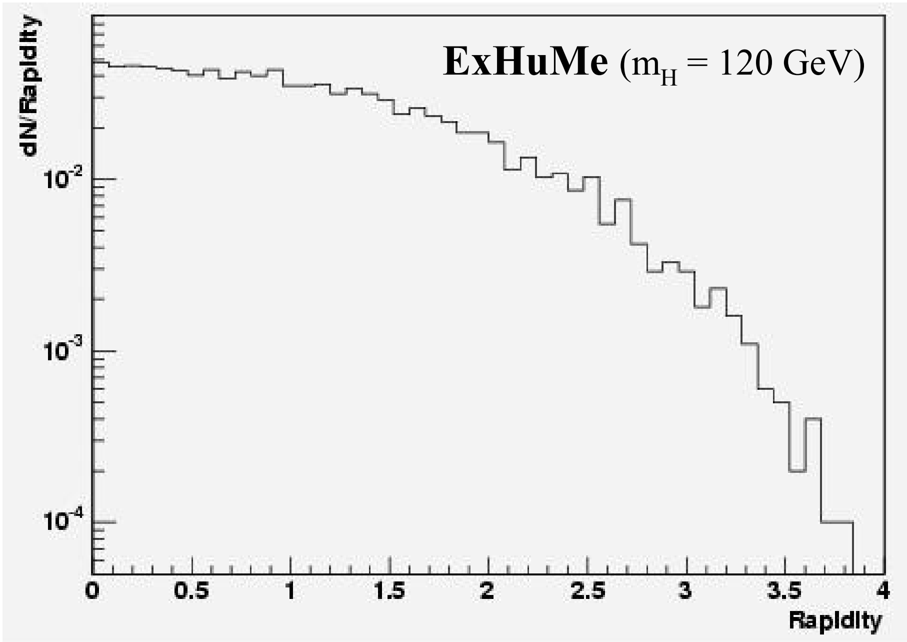
NB! Factor 600 decrease between y = 0 and y = 4

Higgs rapidity



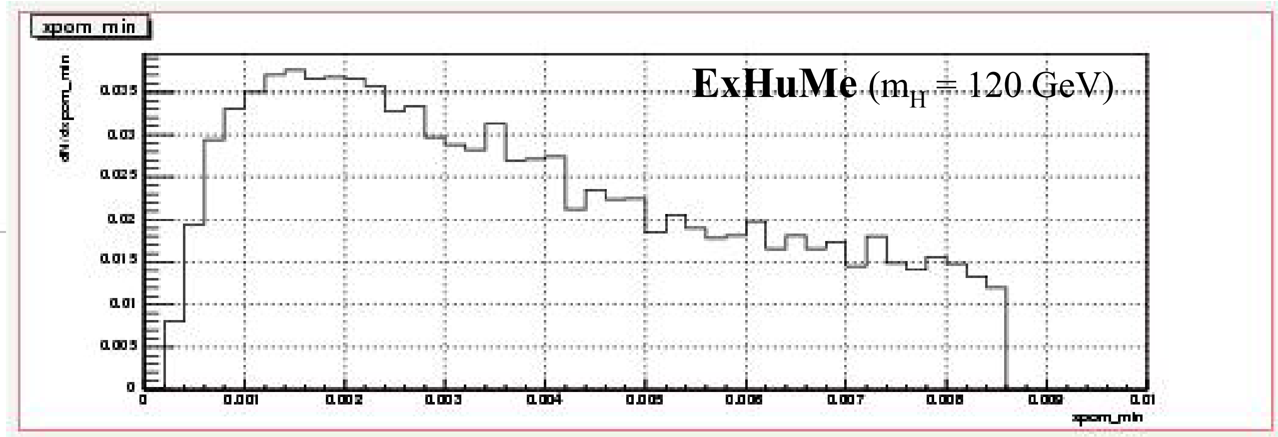


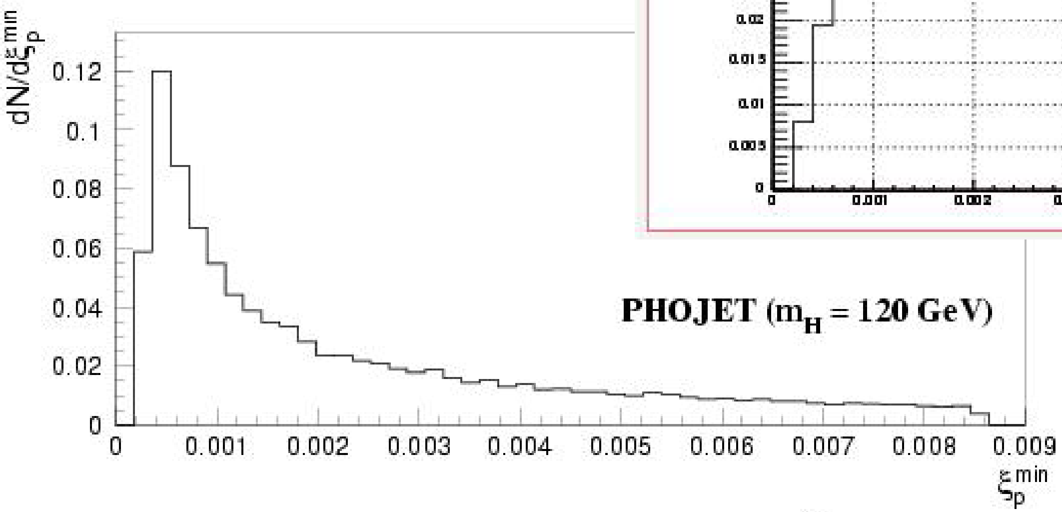
ExHuMe rapidity distribution very different than the other two !!



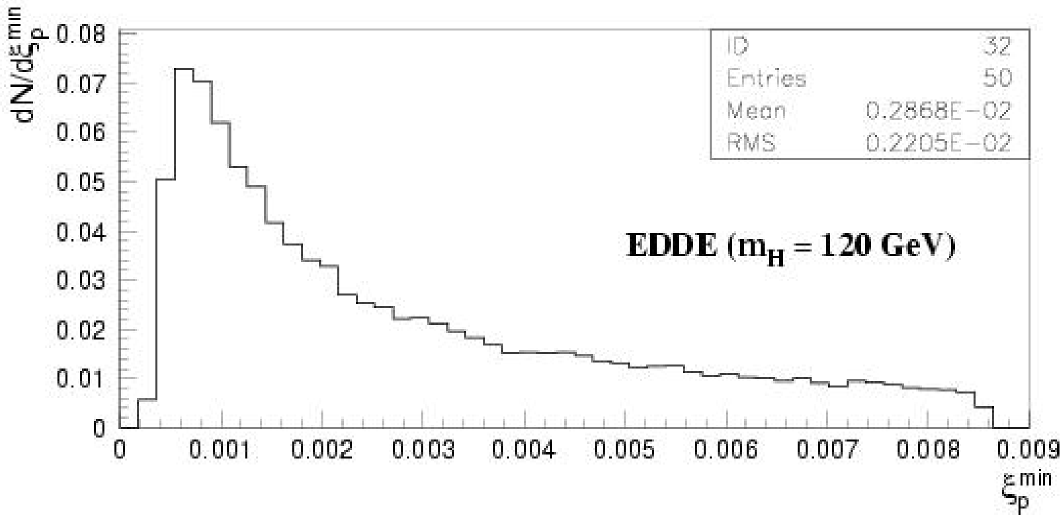
NB! horizontal & vertical scales same

Proton momentum loss



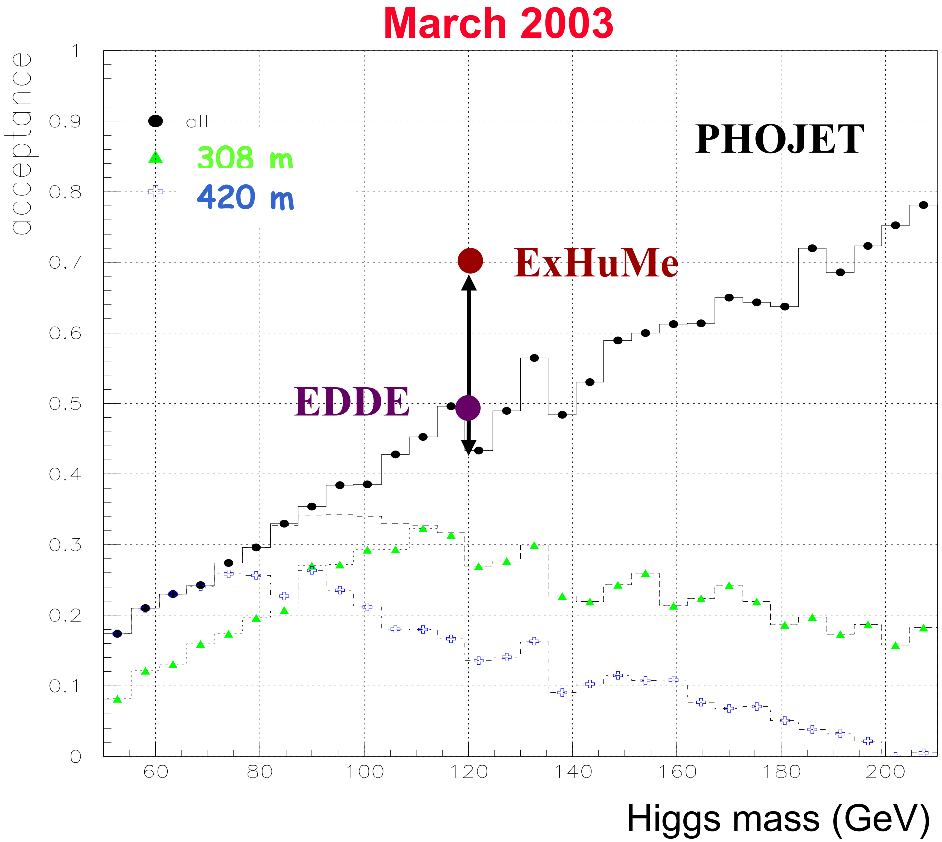


EDDE & PHOJET predicts smaller momentum loss value for proton that looses less momentum of the two

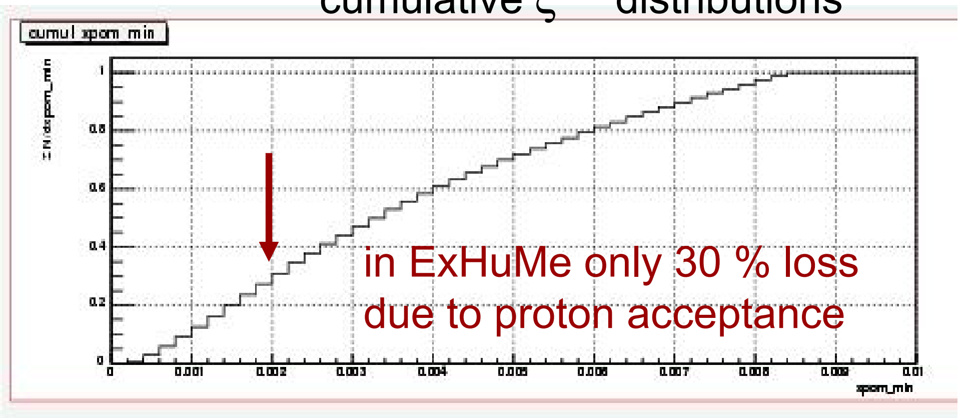


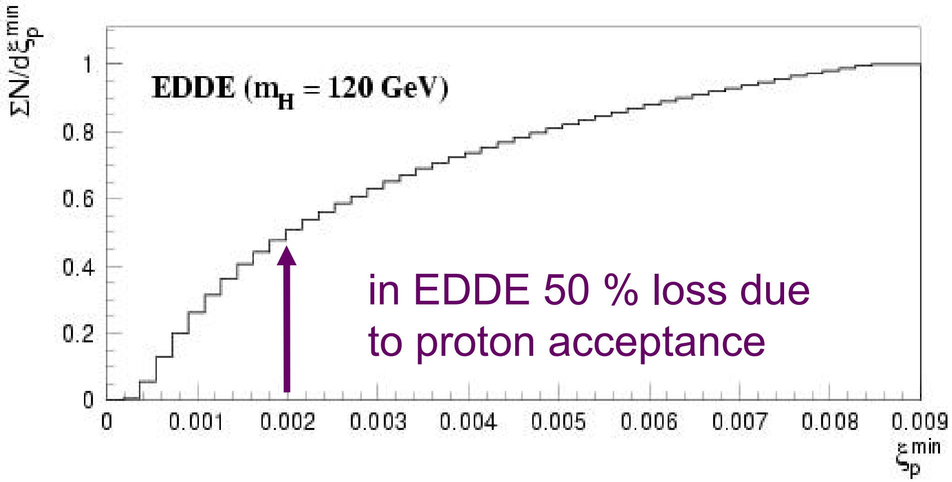
Acceptance vs Higgs mass

Very model dependent !!



cumulative ξ^{min} distributions

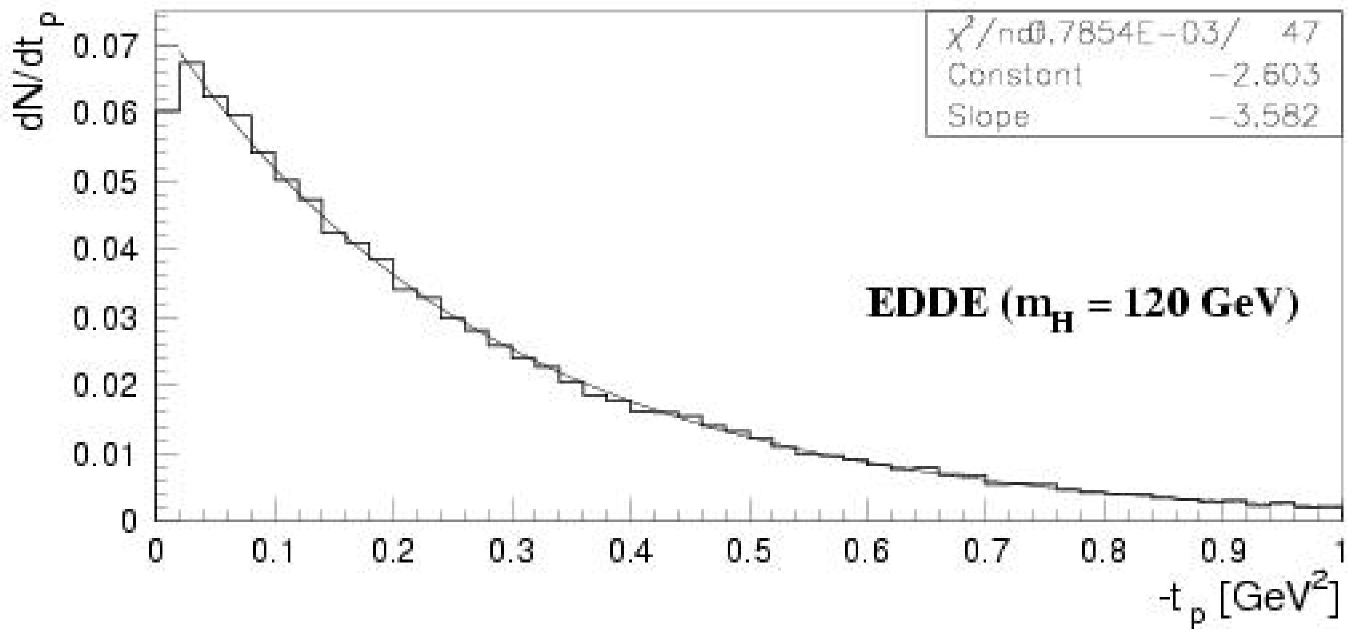




Acceptance refers to being able to measure both protons in 220 m and/or 420 m detectors

Proton momentum transfer

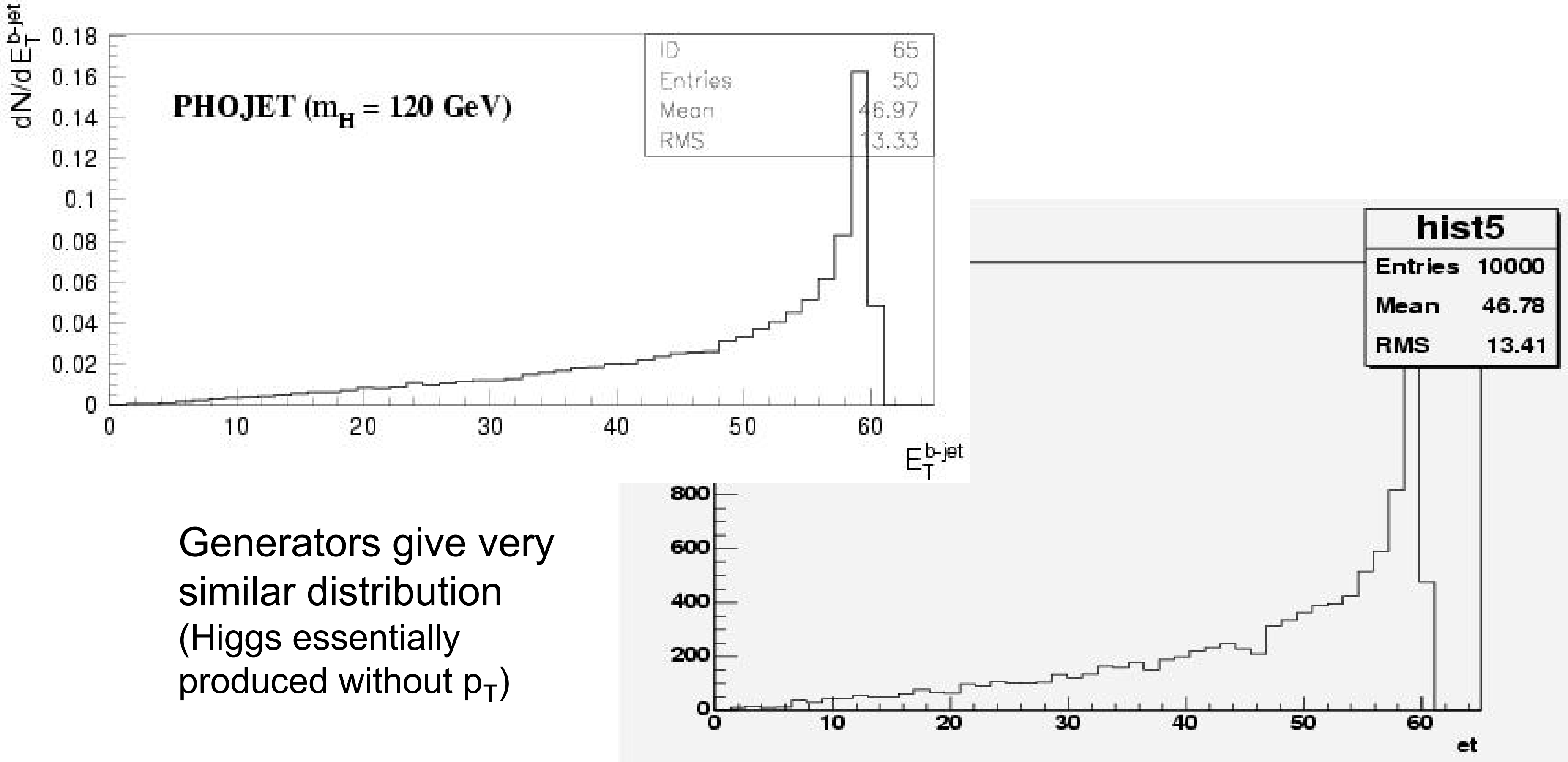
differential cross section: e^{Bt}, B = 3-5



ExHuMe: B ≈ 4.0
EDDE: B ≈ 3.5
PHOJET: B ≈ 5.0

generators give slightly different t-slopes (almost all events have –t < 1 GeV^2)

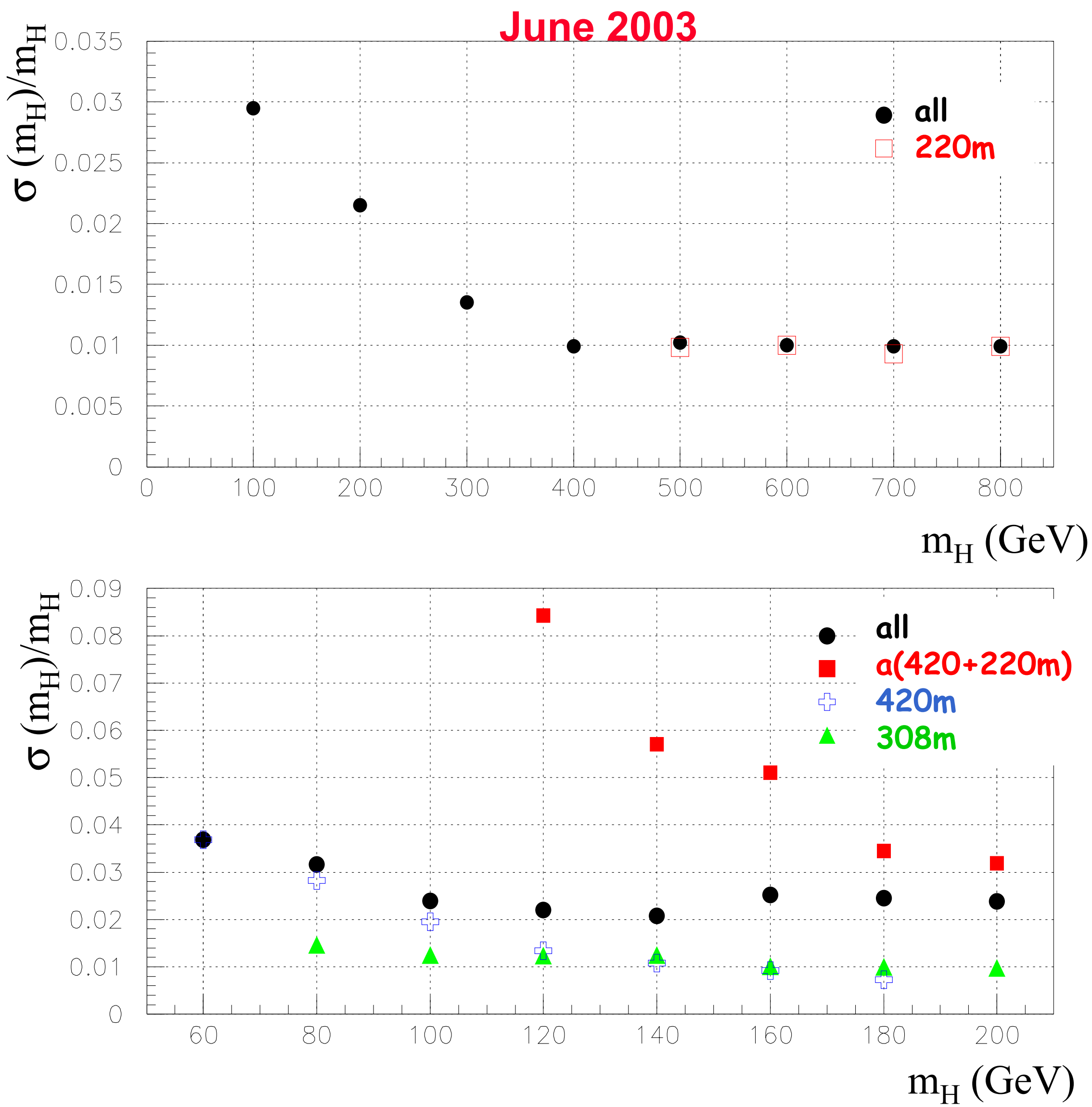
E_T of produced b-jets



Generators give very similar distribution
(Higgs essentially produced without p_T)

In terms of L1 triggering based on Higgs decay products not much difference expected.
NB! the fraction of b-jets with η's in the central region very model dependent.

Mass resolution on Higgs from protons



some model dependence expected also for the mass resolution

HOWEVER

here many other ingredients will play a bigger role!!

uncertainties on

- optical functions
- alignment & position knowledge
- long term stability (E_{beam} ...)

Conclusions

Great to have ExHuMe as an implementation of the KMR model !!
(eagerly awaiting new version with even better Higgs rapidity implementation)

Higgs rapidity distribution important for

- proton acceptancies
- L1 triggering efficiency
- mass resolution of Higgs

What are the uncertainties of the Higgs rapidity distribution?

Rather large model dependencies for proton acceptance,
L1 triggering efficiency and mass resolution !!

Leading proton studies at low β^*

Main motivation: DPE & exclusive new particle production

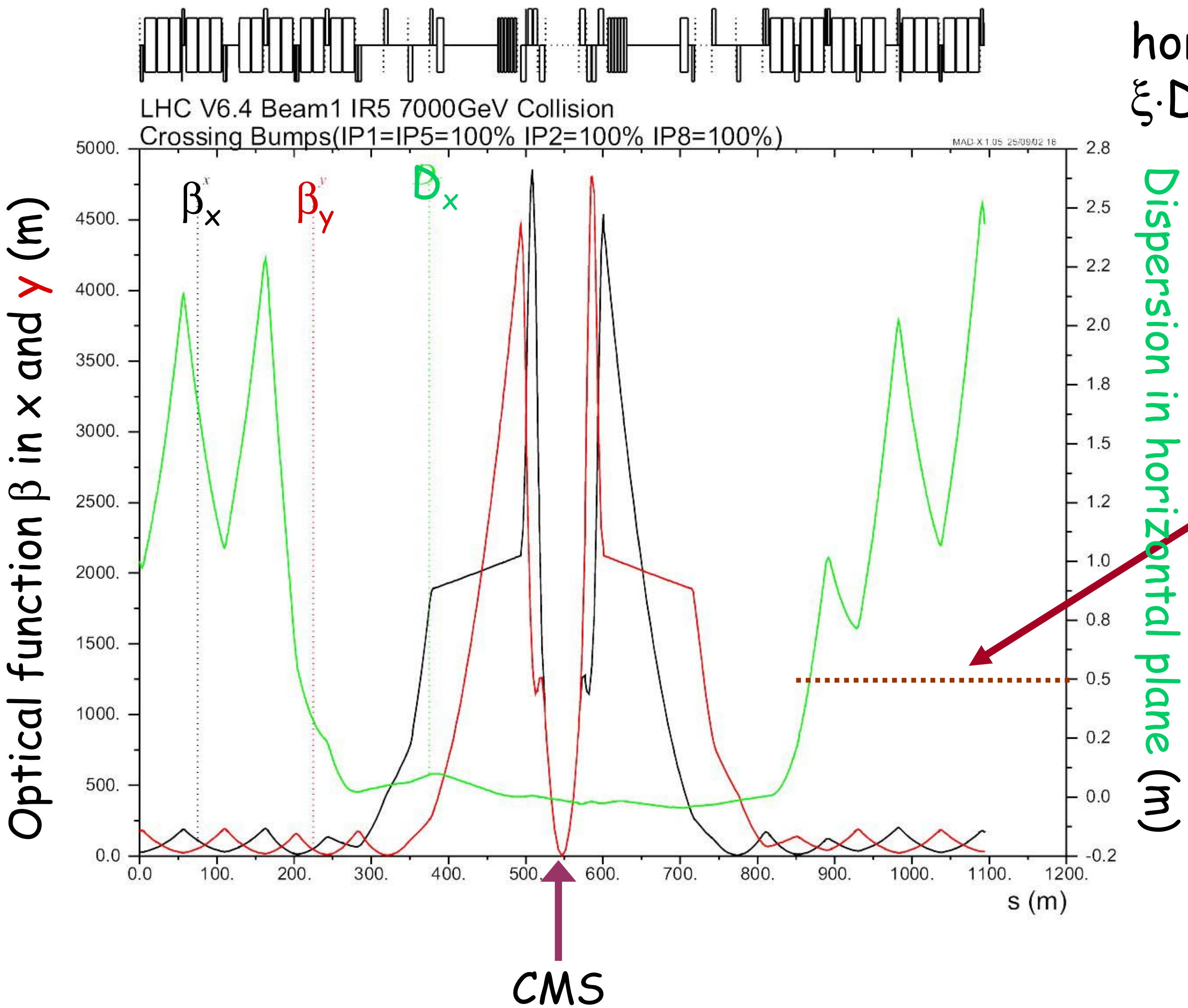
- $\mathcal{L}$ > few $\cdot 10^{32}$ cm^{-2} s^{-1} for cross sections of ~ fb (like Higgs)
- measure both protons to reduce background from non-exclusive
- measure final state in central detector to reduce gg background

Challenges:

- M ~ 100 GeV $\Rightarrow$ need acceptance down to ξ's of a few ‰
- pileup events destroy rapidity gaps $\Rightarrow$ $\mathcal{L}$ < few $\cdot 10^{33}$ cm^{-2} s^{-1}
- sufficently good mass resolution from protons only to overcome reduced cross section w.r.t. standard channels

A study made by the Helsinki group in TOTEM.

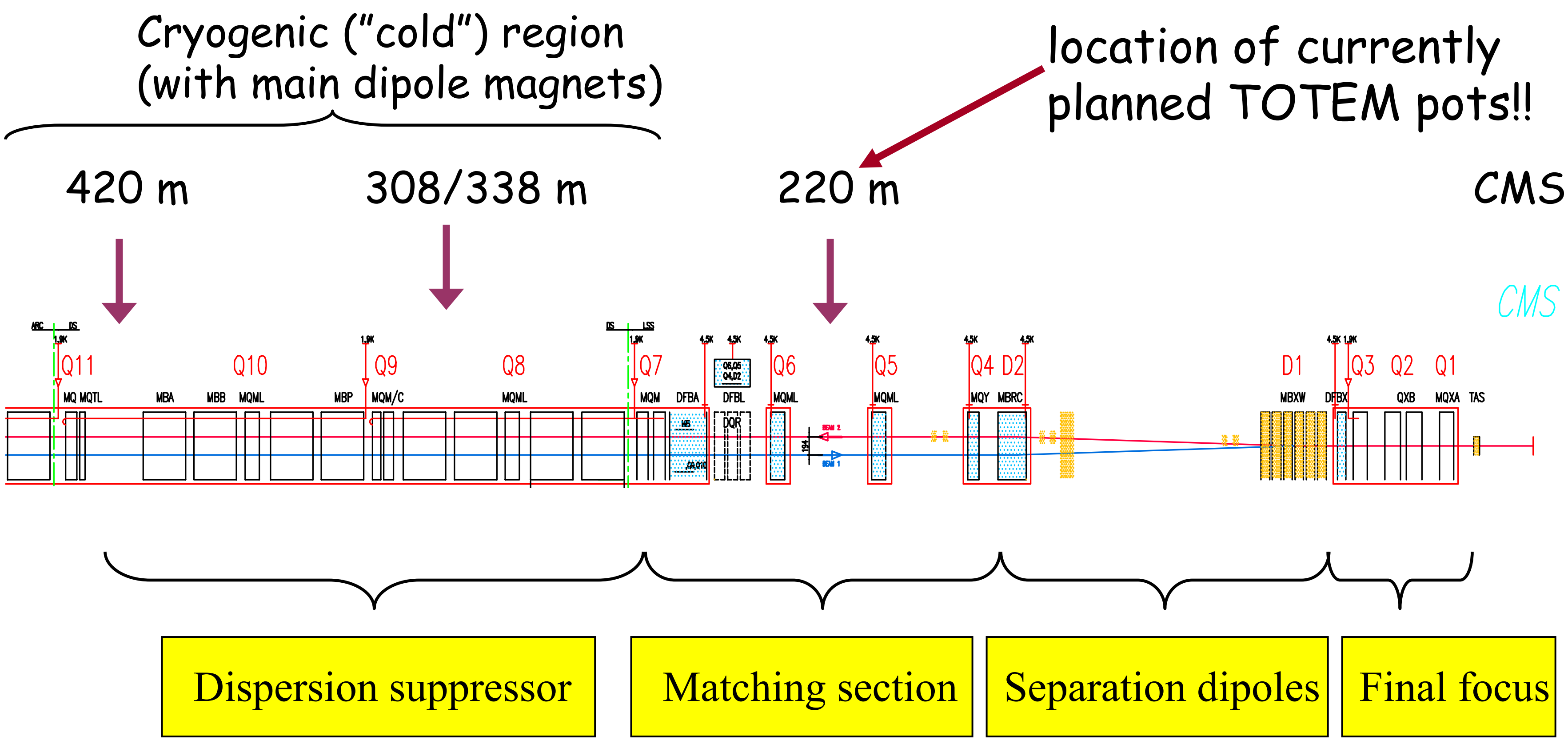
Dispersion function - low β* optics (CMS IR)



horizontal offset = $\xi \cdot D_x$ (ξ = momentum loss)

To get 2.5 mm offset from a $\xi \sim 0.5$ % proton $\Rightarrow$ dispersion $\geq$ 0.5 m $\Rightarrow$ proton taggers located > 250 m from IP i.e. in "cryogenic section" of LHC.

Studied proton detector locations



Leading proton acceptance & resolution studies

- $pp \rightarrow p + X + p$ simulated using PHOJET1.12
- Protons tracked through LHC6.2 optics using MAD8

Simulated experimental leading proton uncertainties:

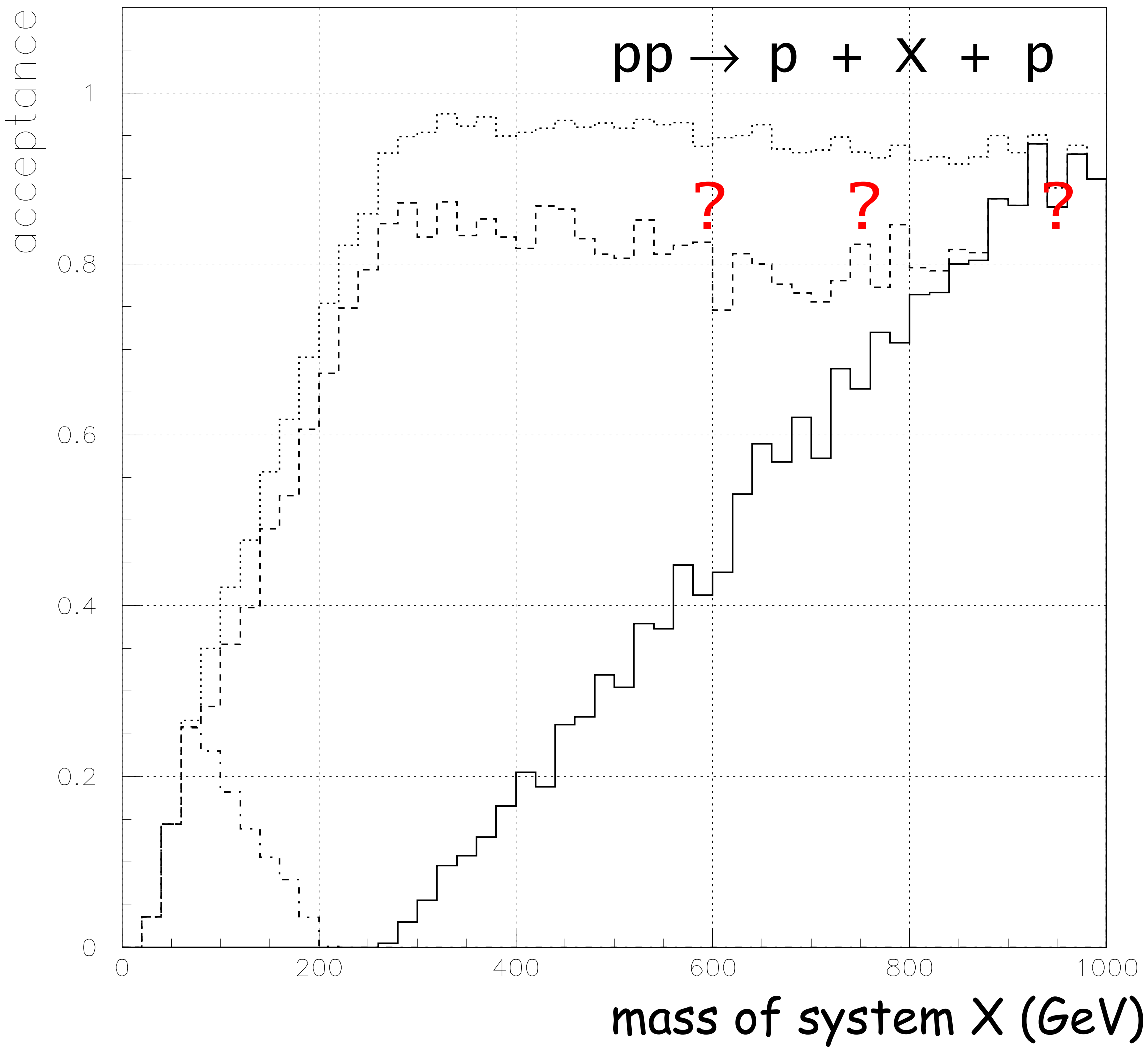
- Initial conditions at interaction point
  - Transverse vertex position ($\sigma_{x,y}$ = 16 μm)
  - Beam energy spread ($\sigma_E = 10^{-4}$)
  - Beam divergence (σ_θ = 30 μrad)

T. Mäki, MSc (eng.)thesis; HIP-2003-11/EXP

- Conditions at detector location
  - Position resolution of detector ($\sigma_{x,y}$ = 10 μm)
  - Resolution of beam position determination ($\sigma_{x,y}$ = 5 μm)

Also systematic offsets at detector locations has been studied.

Mass acceptance central system

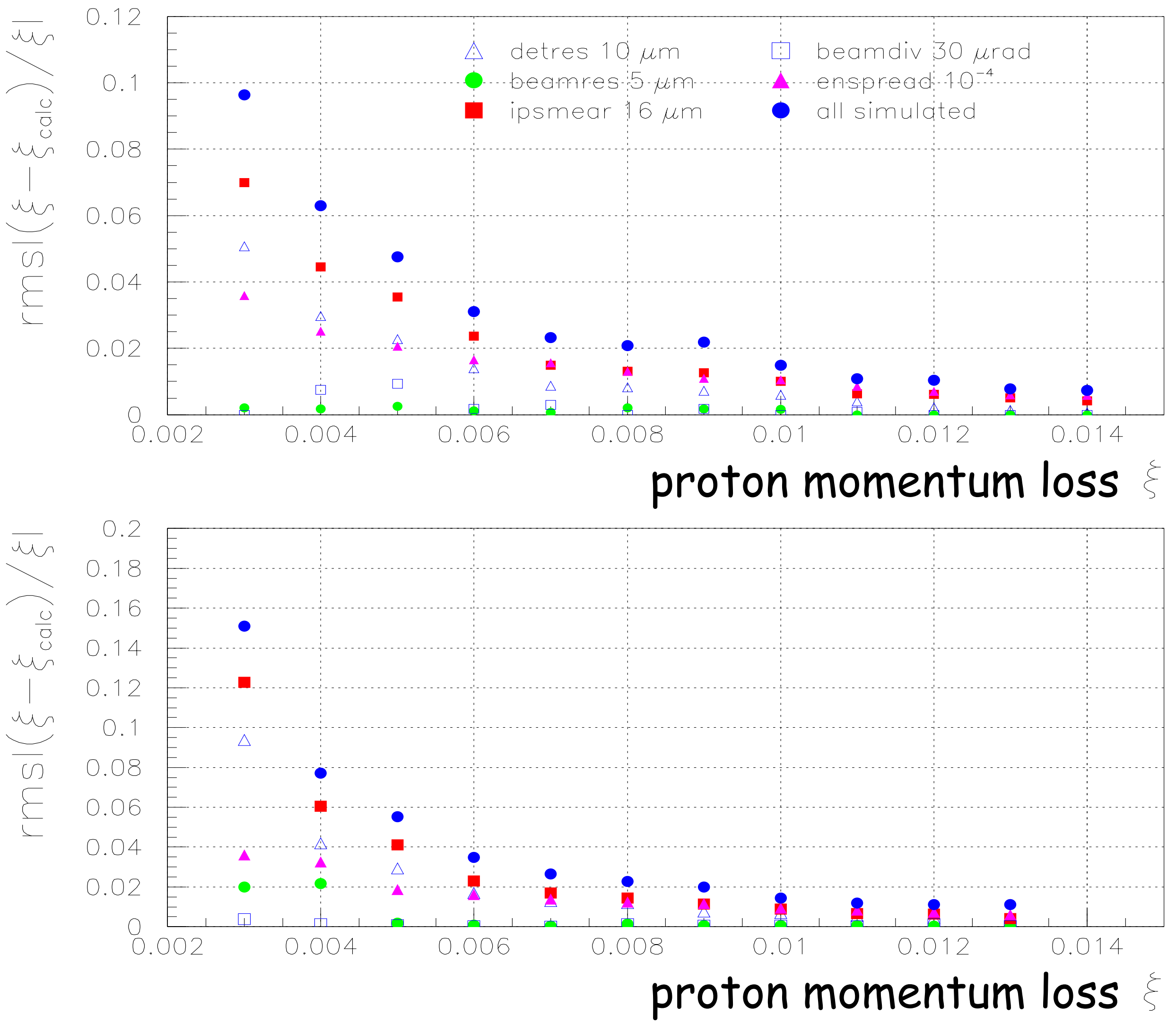


Combined acceptance of

- all locations (dotted)
- 420 m + 220 m (dashed)
- 220 m alone (solid)
- 420 m alone (dash-dotted)

(caveat: PHOJET limits ξ to 25 % so acceptance over-estimated at higher masses)

Momentum loss resolution at 420 m



Resolution improves with increasing momentum loss

<u>Dominant source: transverse vertex position</u> (at small momentum loss) and <u>beam energy spread</u> (at large momentum loss, 420 m)/<u>detector resolution</u> (at large momentum loss, 215 m & 308/338 m)

Triggering diffractive events at low β^*

Constraints on triggering diffractive events:

• At level 1 leading proton info available only from detectors < 220 m from IP (CMS trigger latency, ATLAS worse!!) + asymmetric events have bad mass resolution $\Rightarrow$ for new particle masses $\leq \sim 180$ GeV, level 1 trigger must be based on central detector info only !!

• Level 1 trigger based on calorimetry & muon chambers only.

• E_T threshold of inclusive jet trigger is too high to be useful.

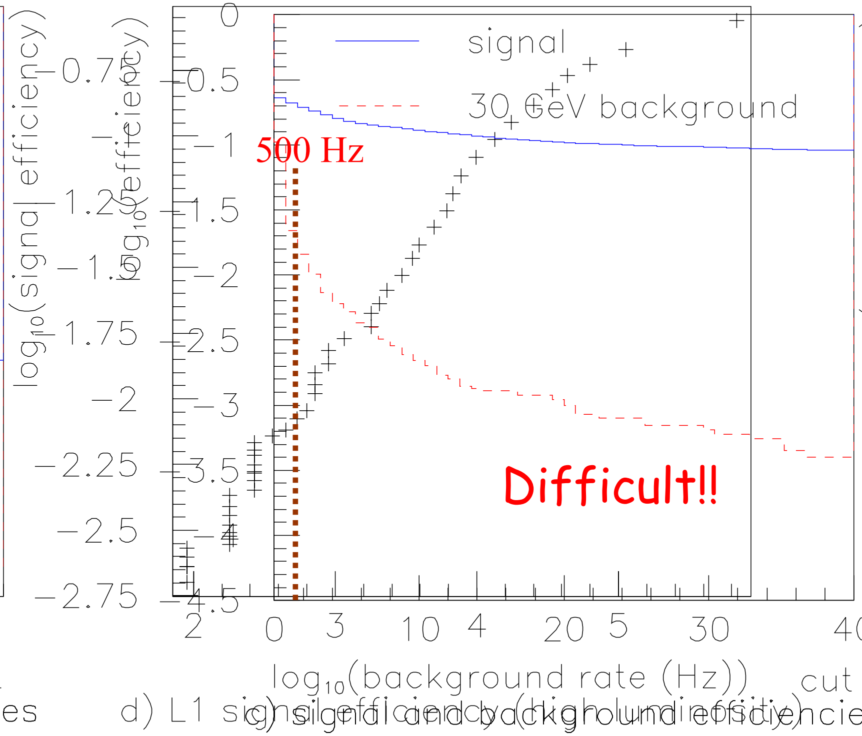
• Pileup will destroy some rapidity gaps (~2(20) inelastic events at $10^{33}(10^{34})$ cm^{-2} s^{-1}) + cause accidental 2 leading proton events (SD+SD)

• Allowed level 1 trigger rate for a special diffractive new particle trigger could be ~500 Hz (?)(out of 100 kHz, no prescaling!!)
MinBias ($E_T > 30$ GeV) ~ 0.22 mb $\Rightarrow$ $10^3/10^4$ suppression at $10^{33}/10^{34}$ cm^{-2} s^{-1}

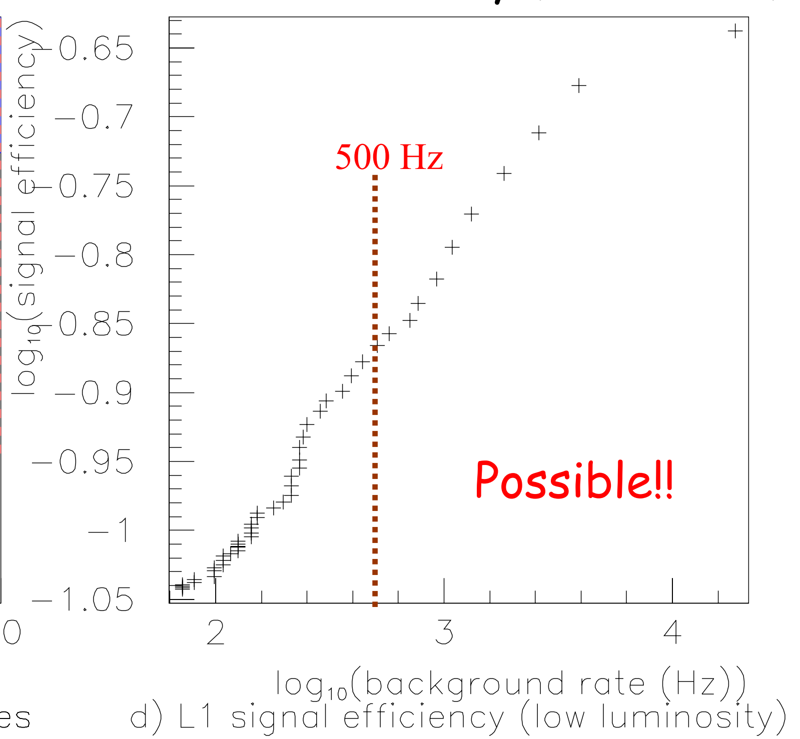
Case study for a 120 GeV Higgs using topological variables (forward E_T, jet E_T's, η's & ϕ-angles) of the 2-jet final state with a "CMS-like" L1 calorimetry trigger.

Preliminary results on L1 triggering of a 120 GeV Higgs

"High" luminosity ($10^{34}cm^{-2}s^{-1}$)



"Low" luminosity ($10^{33}cm^{-2}s^{-1}$)



Efficiency includes "usefulness" cuts (protons & b-jets seen) !!

Will be repeated with complete CMS trigger simulation !!

Improvements should be possible by using also T2 & CASTOR !!