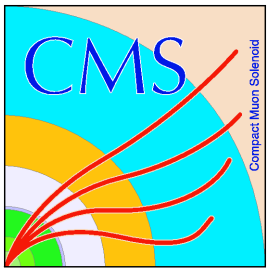


QCD for LHC start-up with CMS

CMS Collaboration
Klaus Rabbertz
University of Karlsruhe

Content

- Scope of this talk
- LHC start-up
- CMS performance expectations
- CMS analyses so far
- Next steps
- Summary

Scope 1/2

- New CMS management in place (Jan. 2007)
- Not presenting final wisdom but first thoughts, suggestions welcome!
- Focus in 2007 will be on the up to $1fb^{-1}$ limit
- Preparing for CMS start-up with focus on:
  - Commissioning of the CMS detector
  - Low luminosity measurements
  - Re-establishing the Standard Model with CMS and, of course, exploiting the new physics reach!

Scope 2/2

- CMS has now five physics analysis groups dealing predominantly with SM physics:
  - Diffraction, QCD, Electroweak, top and B physics
  - In addition: Heavy Ions
- As a responsible for QCD:
  - Restricting to topics not attributed to other groups
    - Exact coverage of physics areas not defined yet
    - So e.g. not discussing diffractive/forward physics or heavy quarks

LHC reaches CMS

23. October 2006

D. Barney, CERN

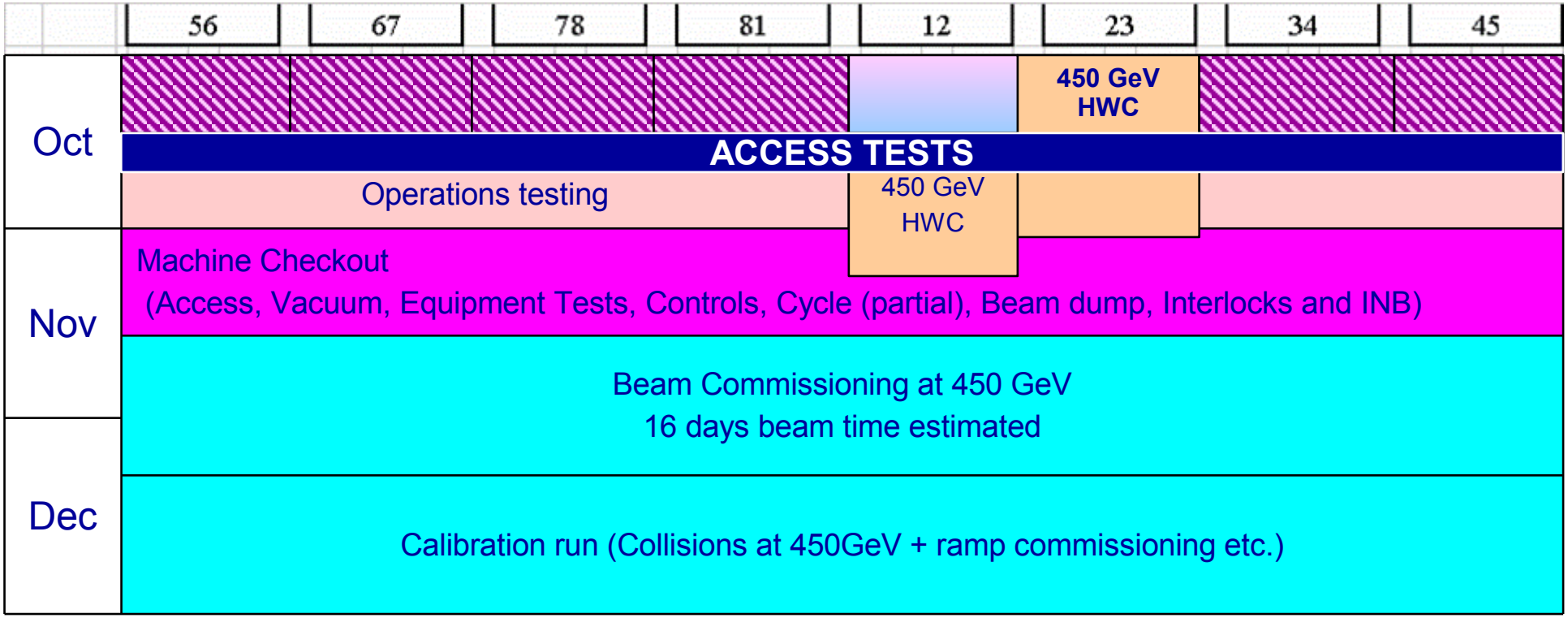
and CMS as well ...

YE+2
endcap disc
12.12.2006

More pictures and an actual movie can be found here: CMS Times

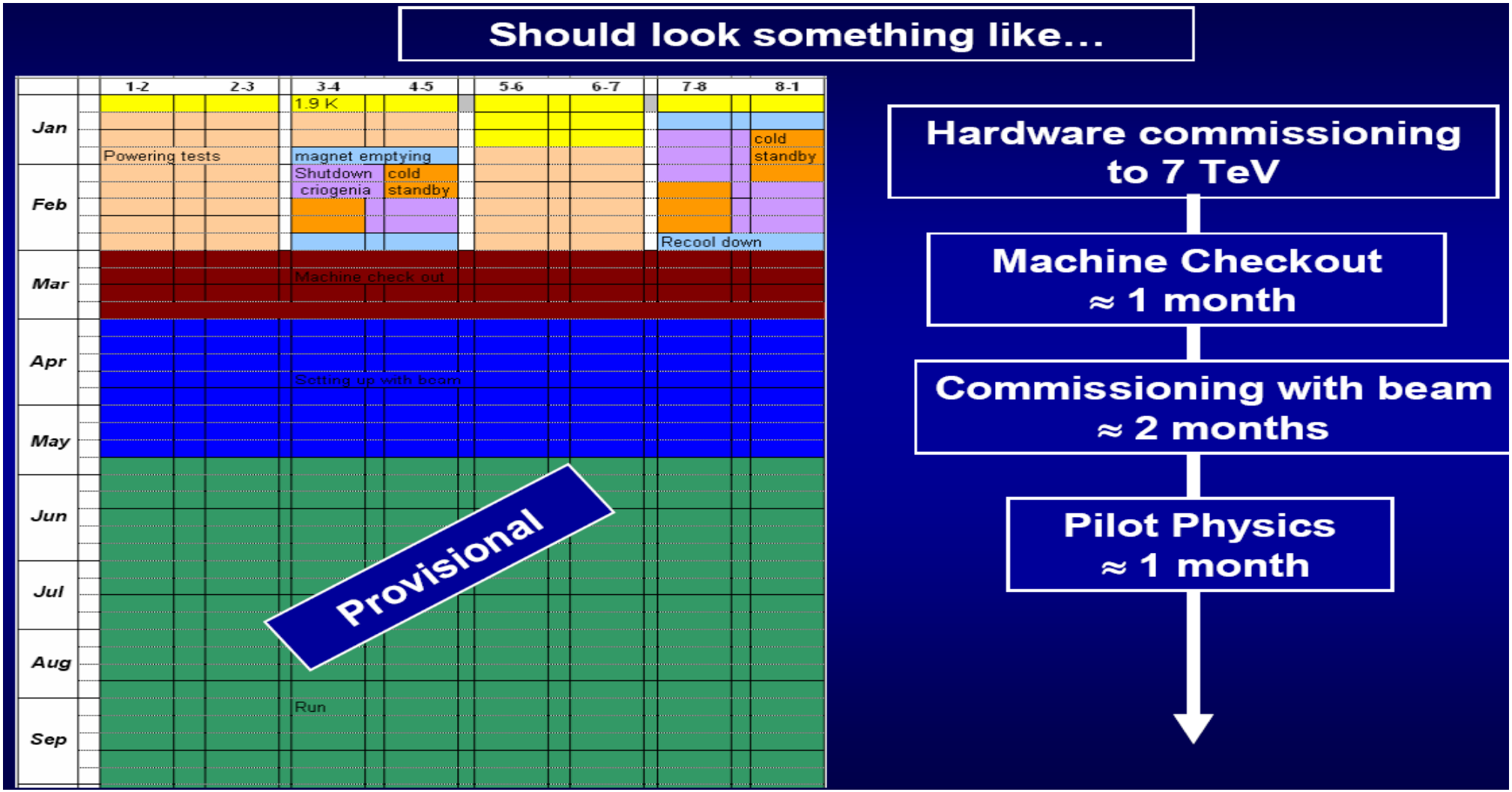
LHC Start-up, 2007

- M. Lamont, September 2006:
  - Calibration run 2007: 3 weeks collisions with:
  - $L \approx 1.2\ 10^{28} – 2.6\ 10^{29}\ cm^{-2}s^{-1}$, $E_{beam} = 450$ GeV

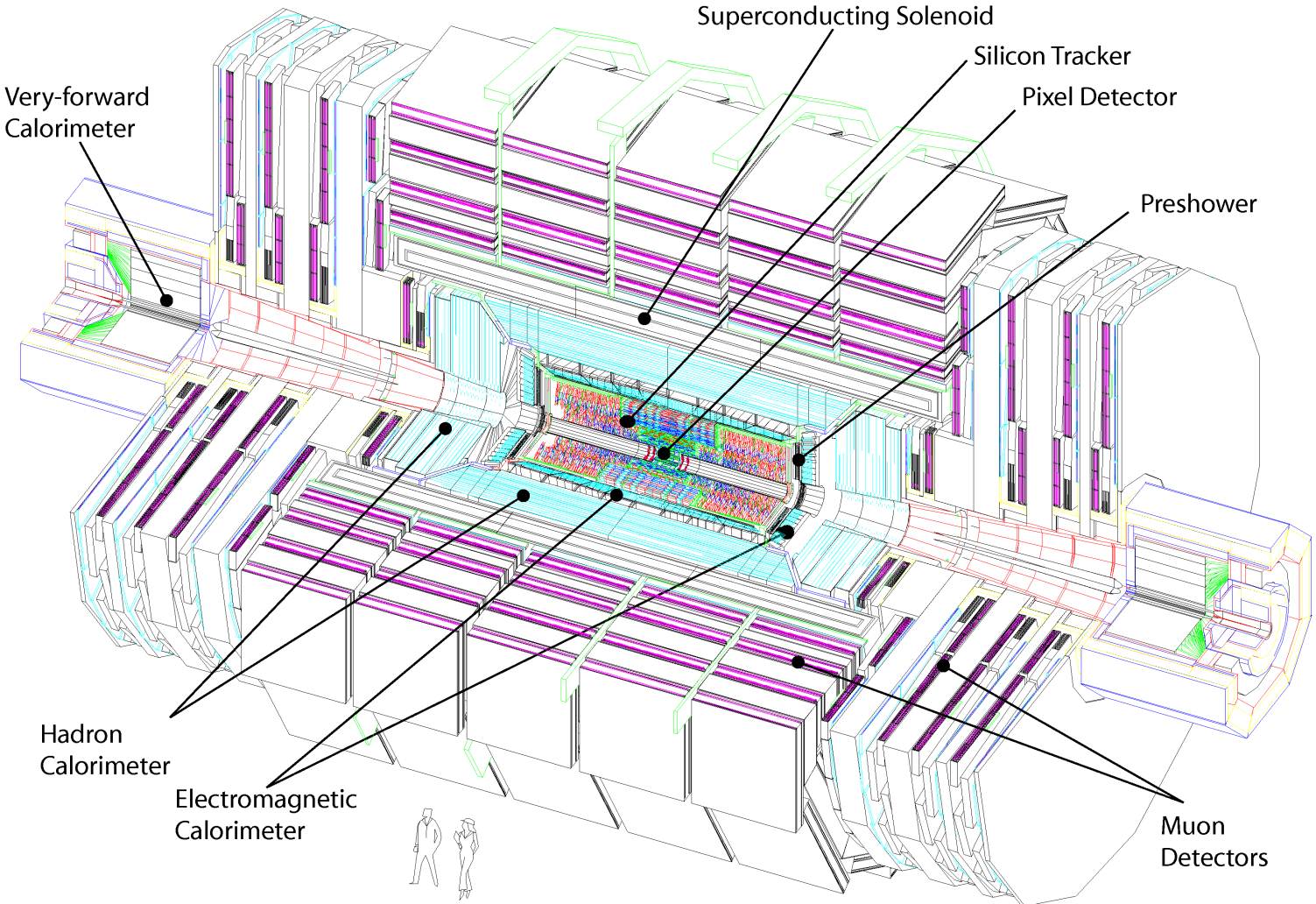


LHC Start-up, 2008

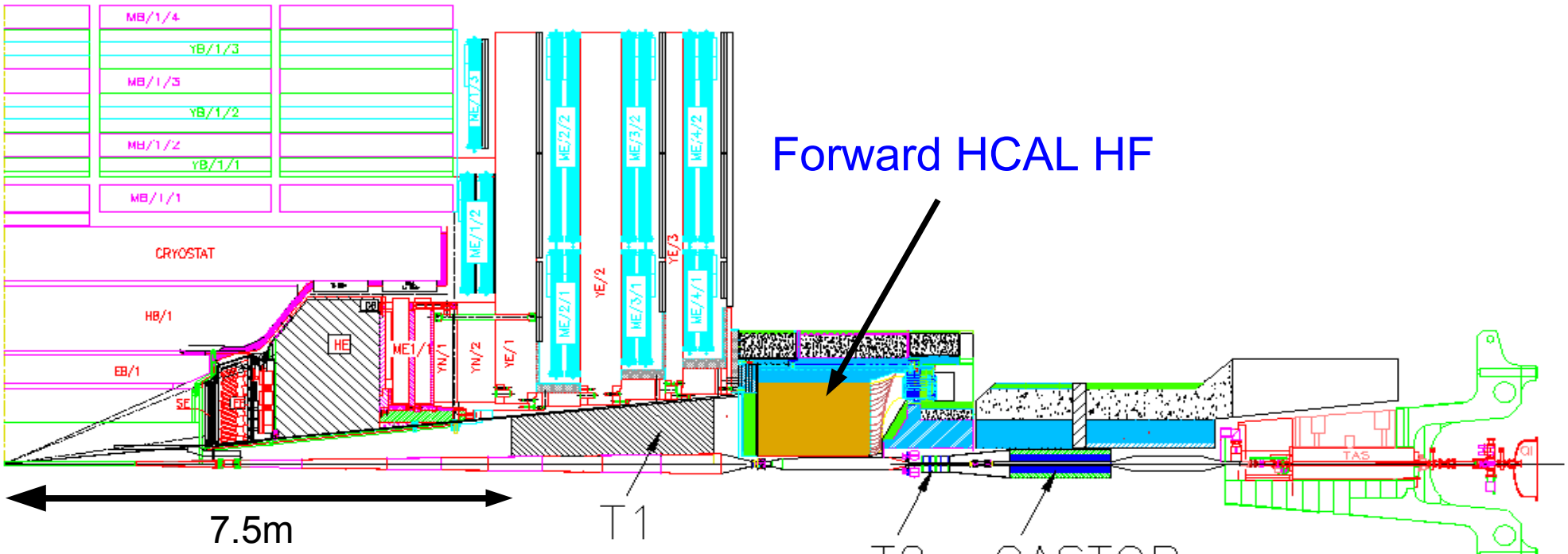
M. Lamont, September 2006



CMS Detector 3d



CMS & TOTEM



Forward HCAL HF

TOTEM Forward Trackers T1 and T2

CMS CASTOR calorimeter

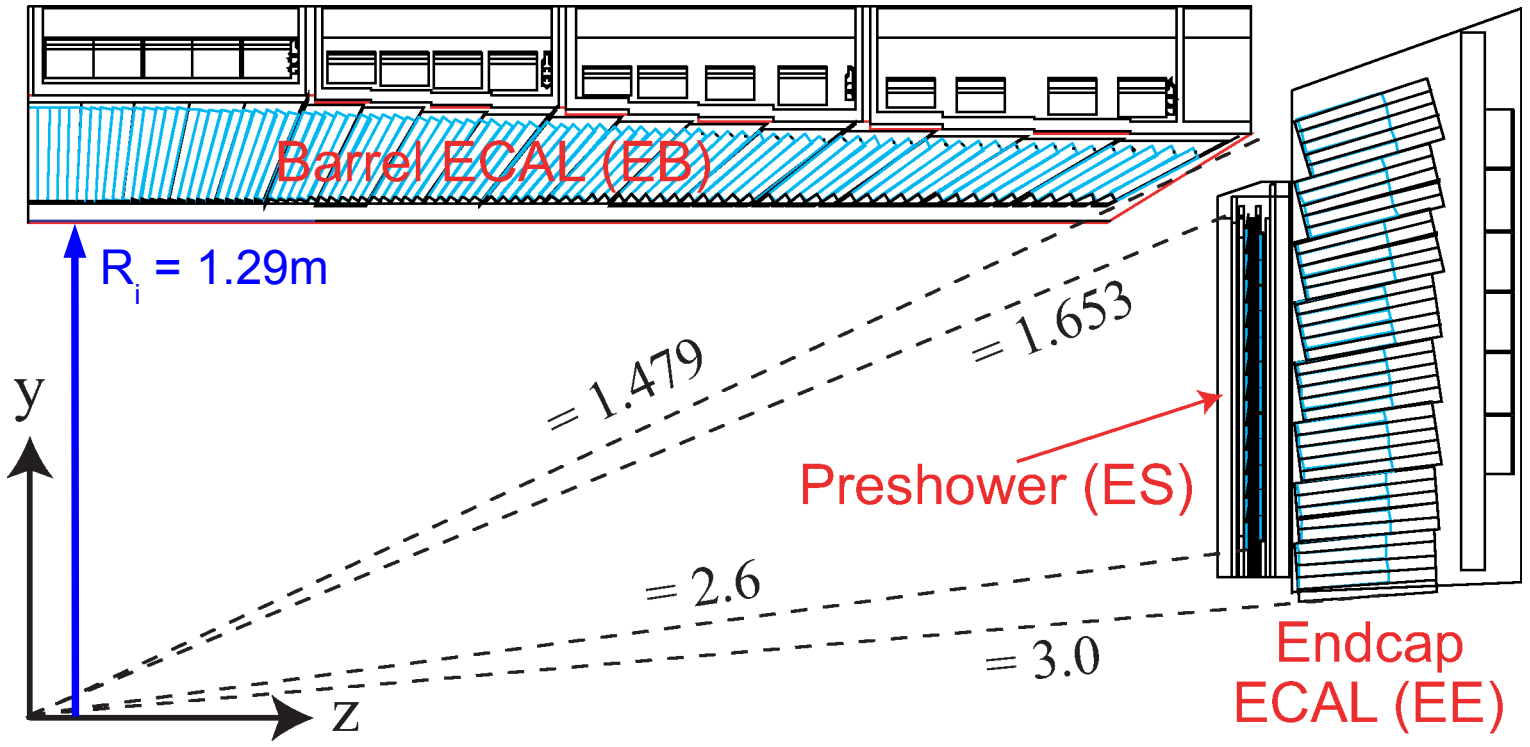
Plus TOTEM Roman pots
at 147 and 220 m

References

- If not stated otherwise all following results are extracted from the references:
  - CMS Physics TDR, Volume 1, CERN-LHCC-2006-001
  - CMS Physics TDR, Volume 2, CERN-LHCC-2006-021
  - CMS Notes: 2006/013, /067, /069
- Additional reading: New!
  - CMS/TOTEM report on diffractive and forward physics at the LHC, CERN-LHCC-2006-039

Electromagnetic Calorimeter

Barrel (EB):
- η segments: 2x85
- φ segments: 360
→ 61200 crystals ($PbWO_4$, 26 X_0)
→ Δη x Δφ ≈ 0.0174 x 0.0174



Energy resolution from test beam:
S = 3.63%, N = 124 MeV, C = 0.26%

$$\left(\frac{\sigma}{E}\right)^2 = \left(\frac{S}{\sqrt{E}}\right)^2 + \left(\frac{N}{E}\right)^2 + C^2$$

Endcaps (EE):
- (x,y) grid on two halfs
- front face 28 x 28 mm^2
→ 2 x 2 x 3662 crystals = 14648 ($PbWO_4$, 25 X_0)

Hadronic Calorimeter

HCAL (tower structure):

- Barrel (HB): $|\eta| < 1.4$, 2304 towers
- Endcaps (HE): $1.3 < |\eta| < 3.0$, „ towers
- Outside coil (HO): $|\eta| < 1.26$ (tail catcher)

→ 4608 towers (Plastic scintillator tiles, ≈ 10 λ_N)

→ $\Delta\eta \times \Delta\varphi \approx 0.087 \times 0.087 \rightarrow 0.350 \times 0.175$

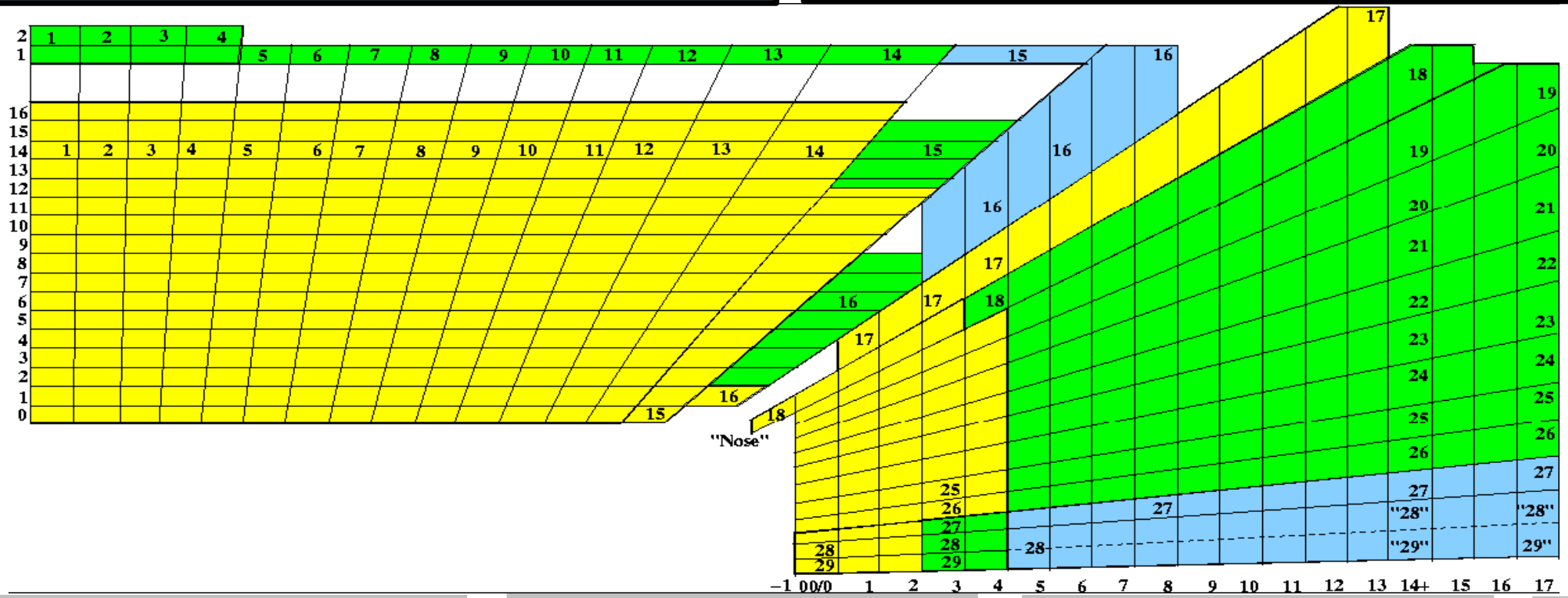
- Forward (HF): $2.9 < |\eta| < 5.0$ (not shown)

→ 2 x 900 towers (Quartz fibers, ≈ 10 λ_N)

→ $\Delta\eta \times \Delta\varphi \approx 0.111 \times 0.175 \rightarrow 0.302 \times 0.350$

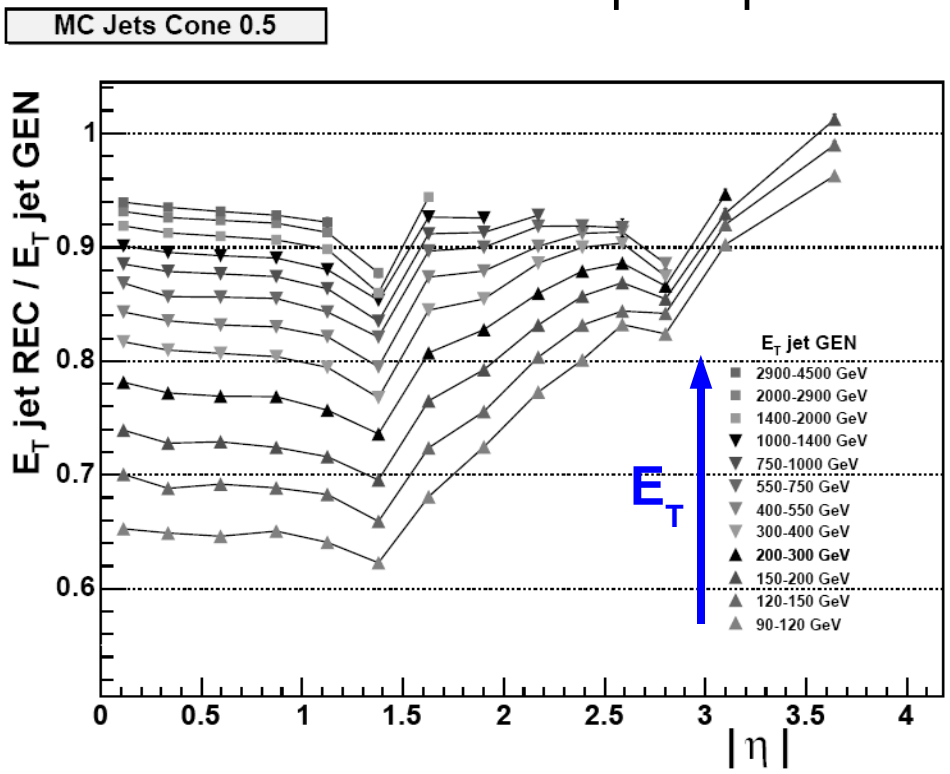
CASTOR calorimeter (not shown):

- $5.1 < |\eta| < 6.5$, ≈ 22 X_0, ≈ 10 λ_N

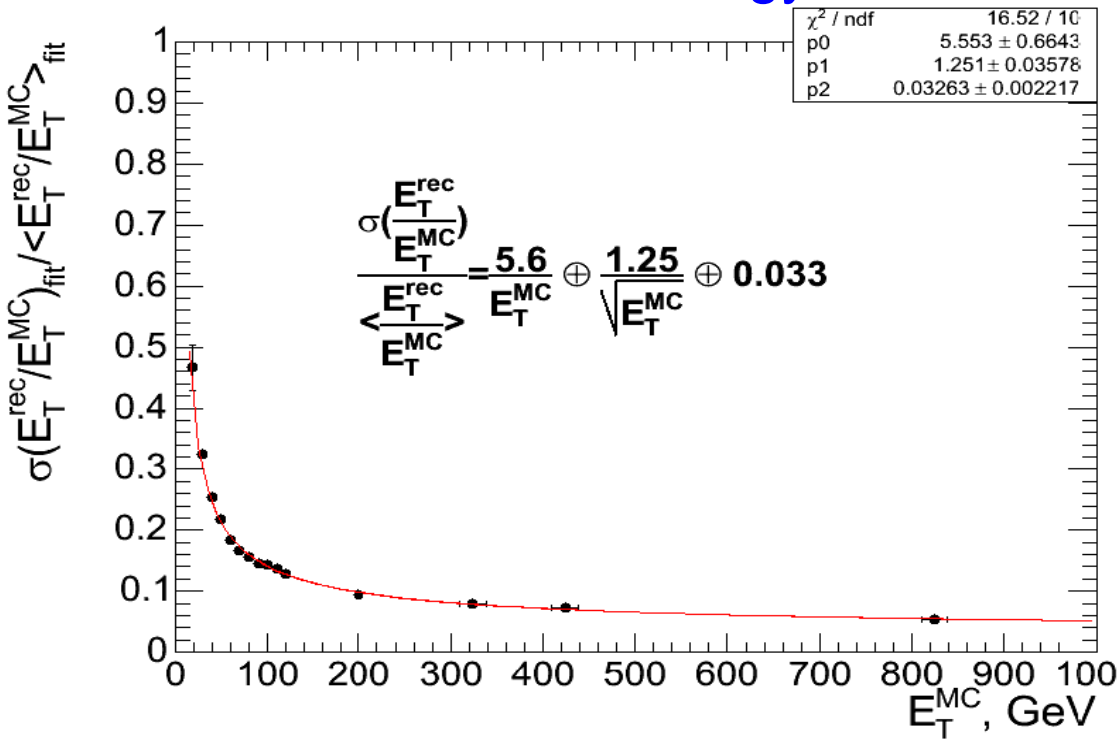


Jet Energy Calibration 1

- Complements initial calo calibrations, e.g. via radiation sources for HCAL
- Finer ECAL crystals merged into HCAL towers for total energy
- Start-up: Model dependent MC calibration technique using fully simulated events
  - Matching of reconstructed and particle level jets
  - Different input schemes/cuts (E_T > 0.5 GeV, E > 0.8 GeV, cell-based thresholds) to tackle noise and pile-up



Jet transverse energy resolution

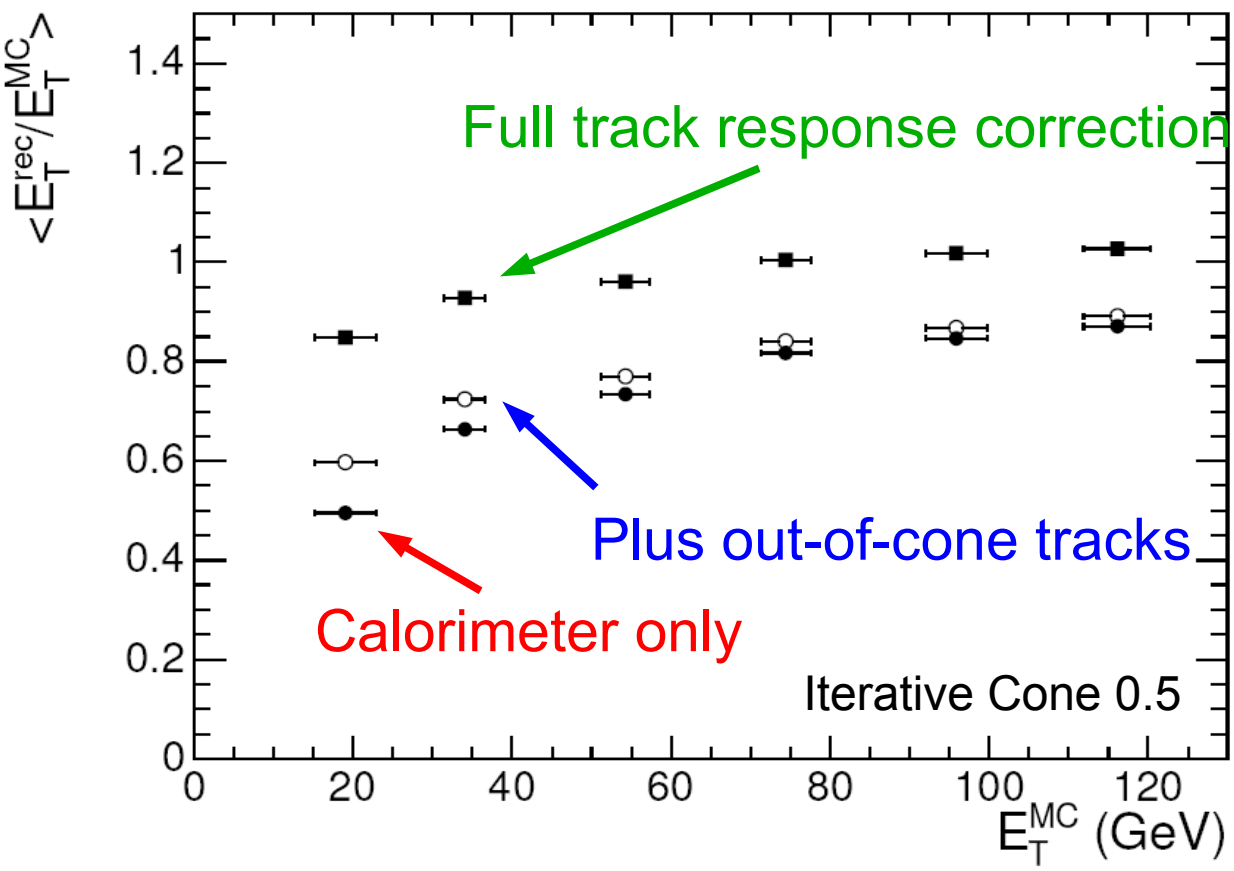


Jet Energy Calibration 2

- Better: Data driven strategies:
  - Dijet balancing (rel. calibr.)
  - Photon + jet events (calibration against ECAL)
  - W boson mass constraint in top events
  - Charged track response to correct calorimeter energies

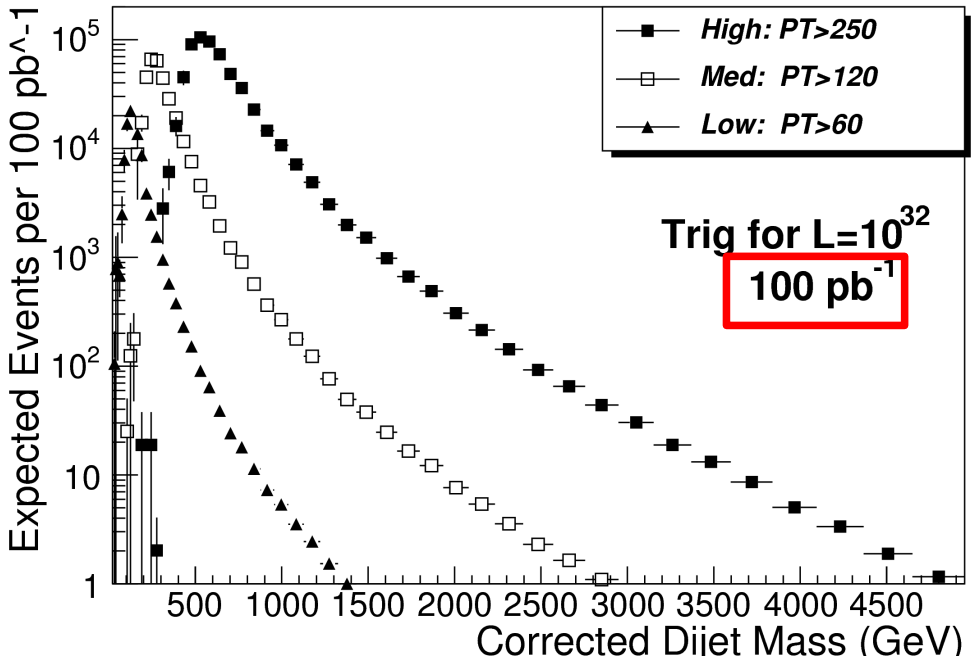
Much more details probably just seen in Sven Menkes presentation ... :-)

Ratio of rec. and gen jet E_T vs. E_T

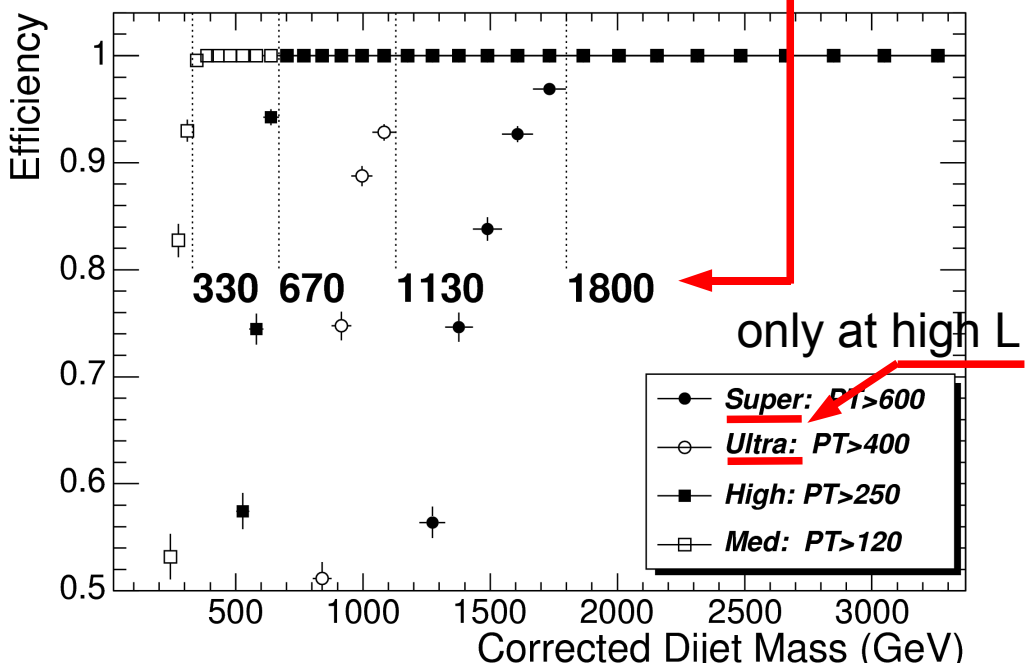


Dijet Analysis 1

- Expected no. of events and trigger efficiency for different trigger thresh.
- Iterative Cone, R = 0.5 in (η,φ)
- Dijet mass $m = \sqrt{(E_1 + E_2)^2 - (\vec{P}_1 + \vec{P}_2)^2}$
- Corrected using MC calibration technique

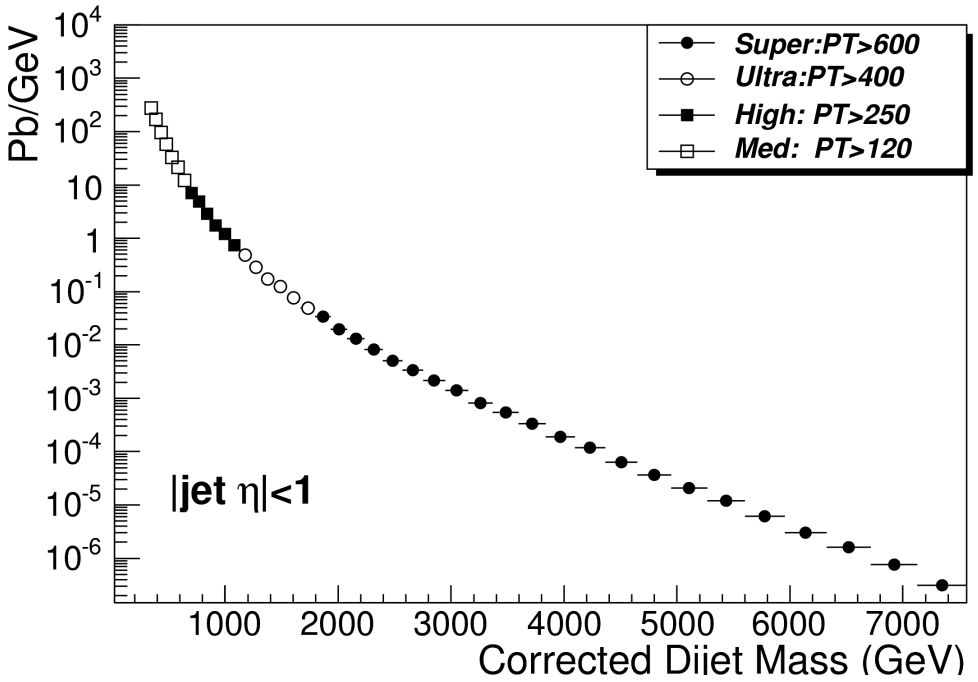


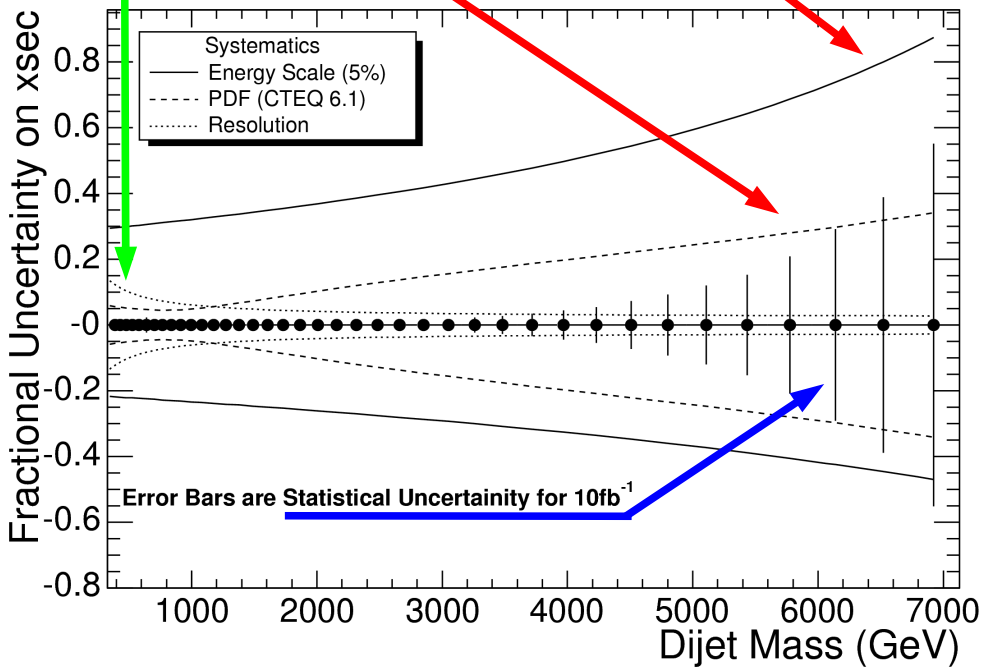
Fully eff. dijet mass cuts



Dijet Analysis 2

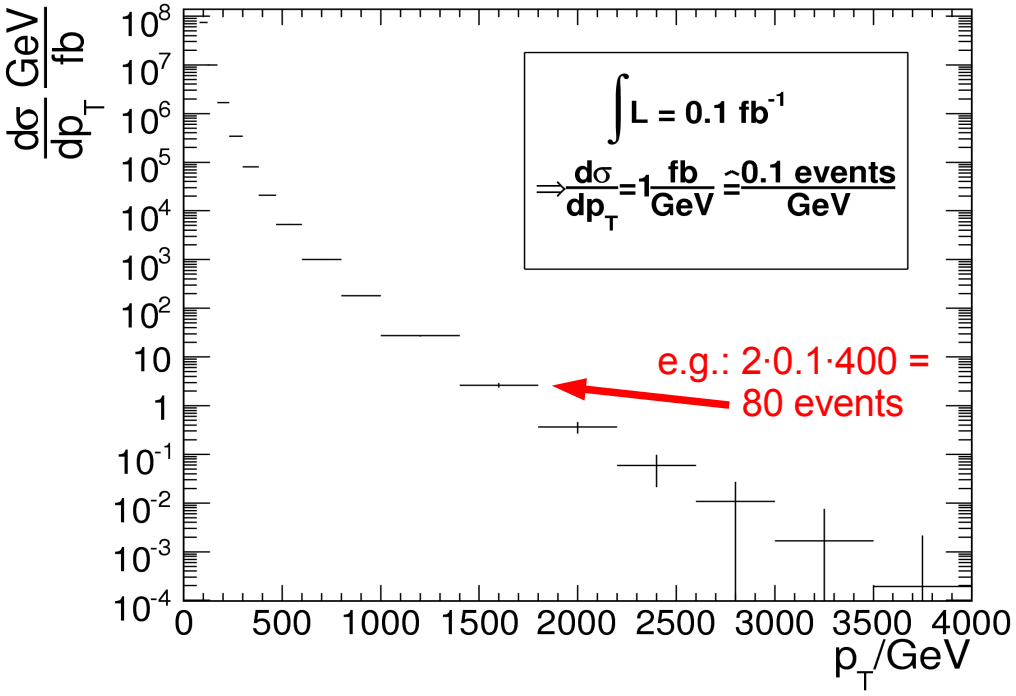
- Measurable x-section, to be compared to models of new physics
- Alternatively: Dijet ratios for diff. η regions, angles
- Systematic uncertainties: - Abs. jet energy scale (±5%)
  - PDFs (CTEQ6.1)
  - Calorimeter smearing (resolution)



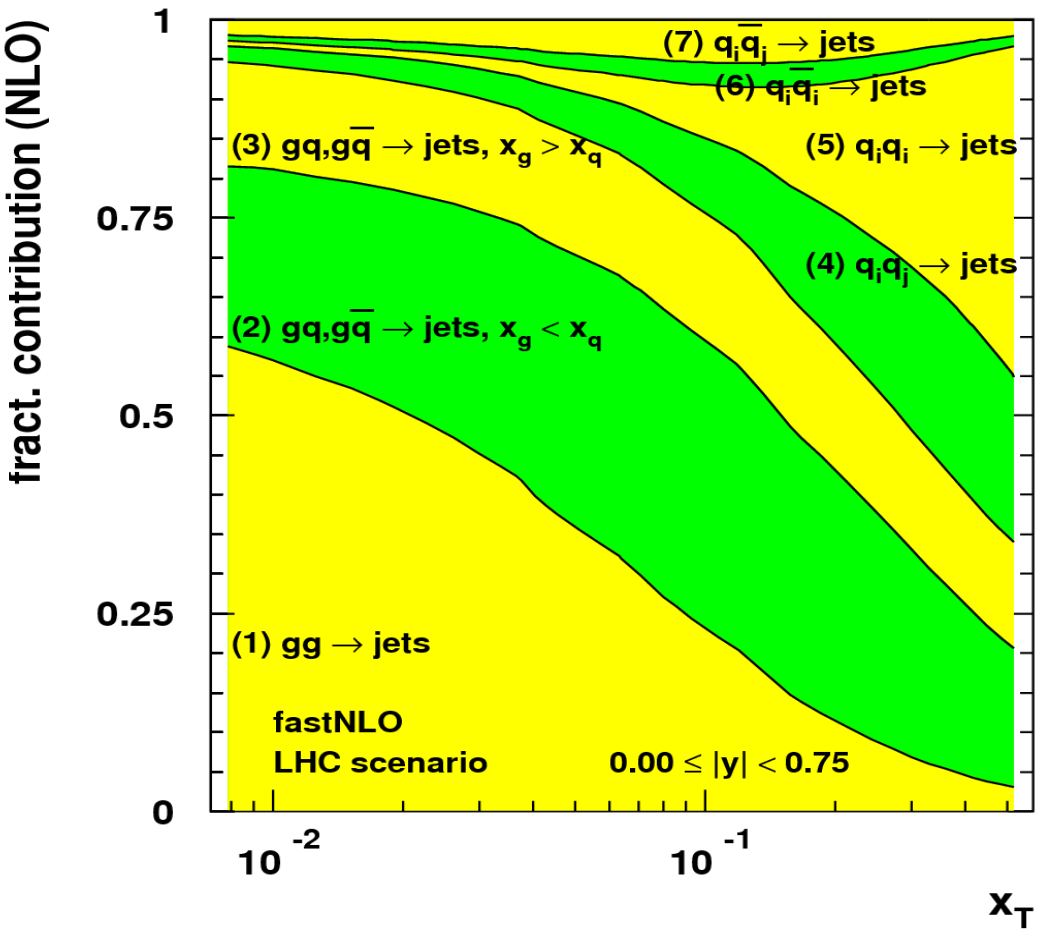


Inclusive Jets 1

- Expected statistics for L_{int} of 0.1 fb^{-1} (LO Pythia, all y)
- Inclusive k_T, ΔR scheme, D = 1.0 in (y,φ)



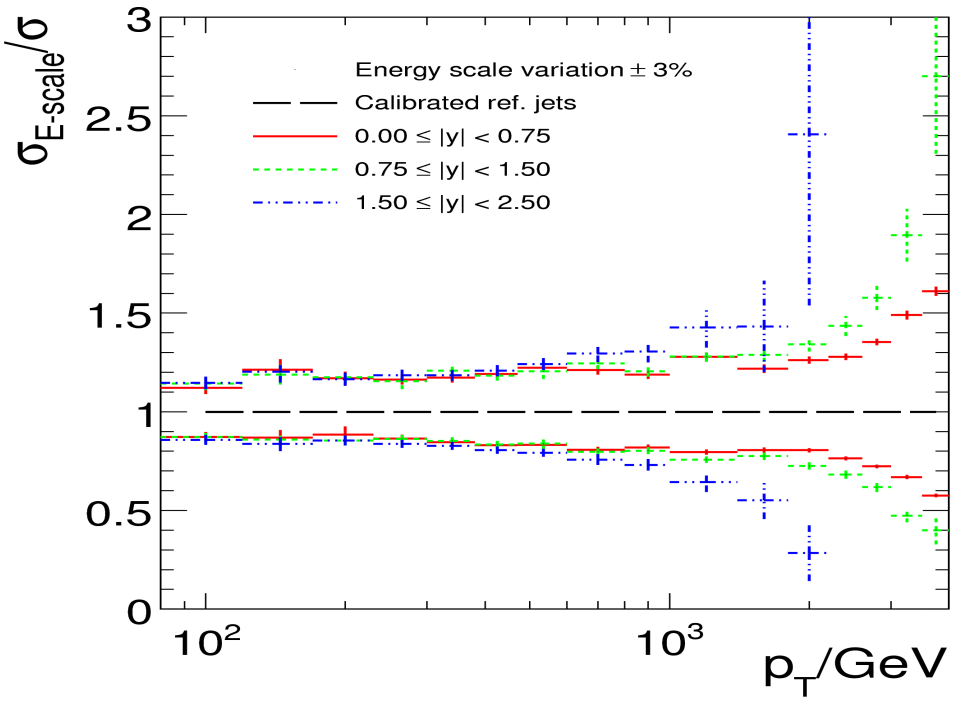
- pp → jets subprocess decomposition at LHC (NLO) vs. $x_T = 2p_T/\sqrt{s}$



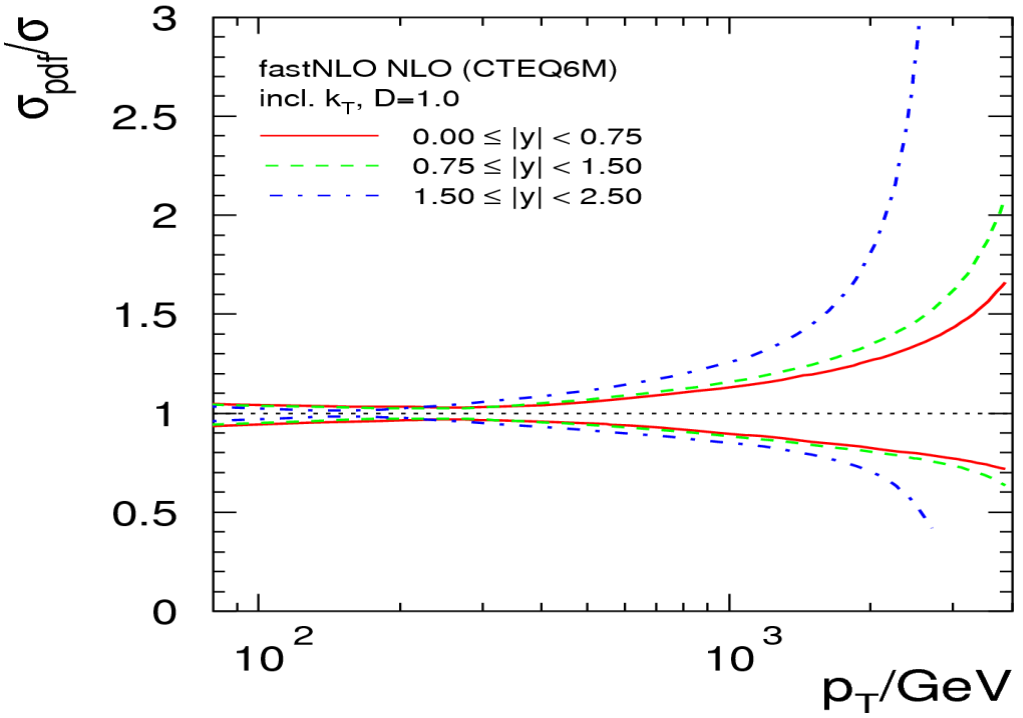
Inclusive Jets 2

- Dominant systematic uncertainties in 3 ranges of rapidity:
  $0.00 \le |y| < 0.75$, $0.75 \le |y| < 1.50$, $1.50 \le |y| < 2.00$
- Underlying Event and hadronization influence under investigation,
  eager to hear news in Gavins talk :-)

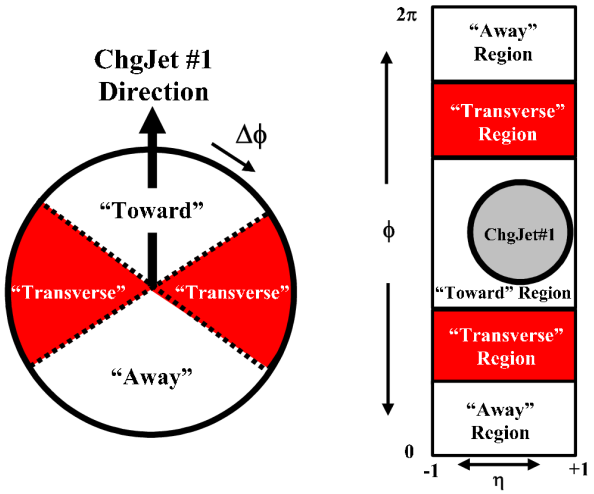
Abs. jet energy scale (±3%)



PDFs (CTEQ6.1) in NLO



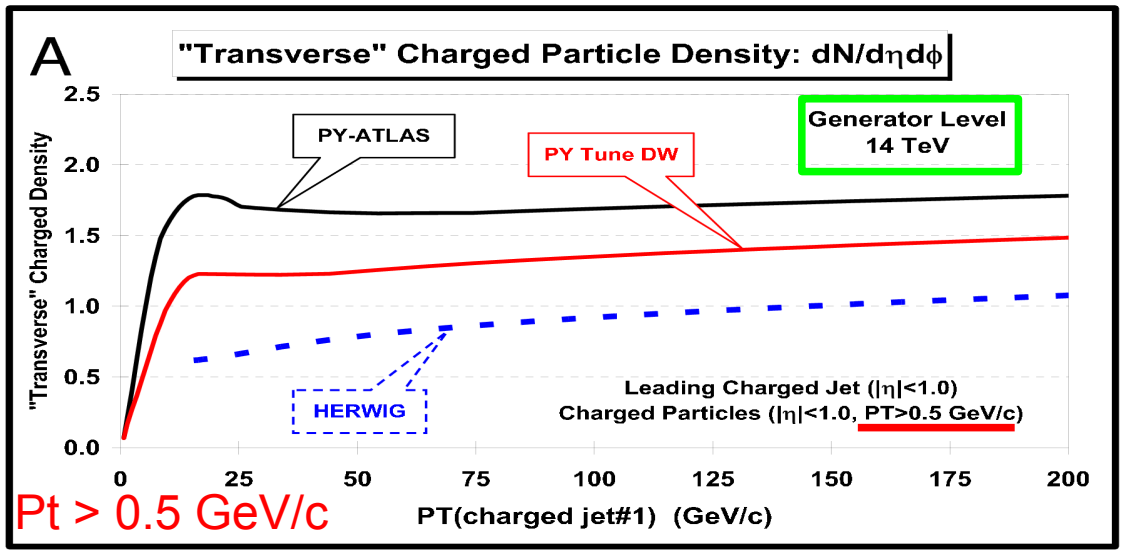
Underlying Event Studies 1

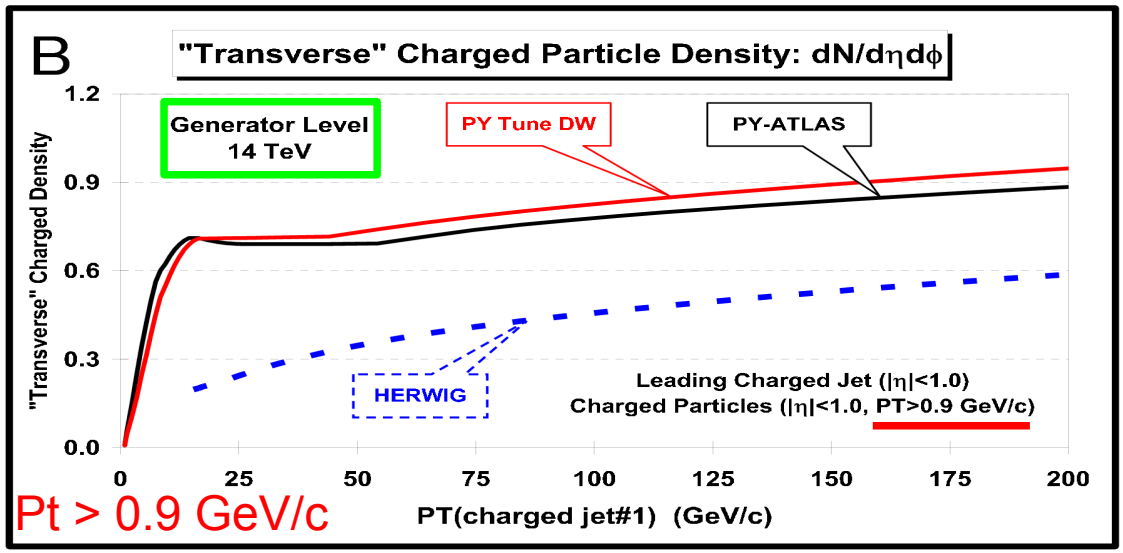


MC comparison for two different Pythia tunes of multiple interactions:
- PY ATLAS
- PY Tune DW by R. Field fitting CDF Run 1 and 2 UE data

and HERWIG

- MI energy dependence parameter PARP(90) = 0.16 (ATLAS), 0.25 (DW)
- „Softer“ charged part. Spectrum for ATLAS tune



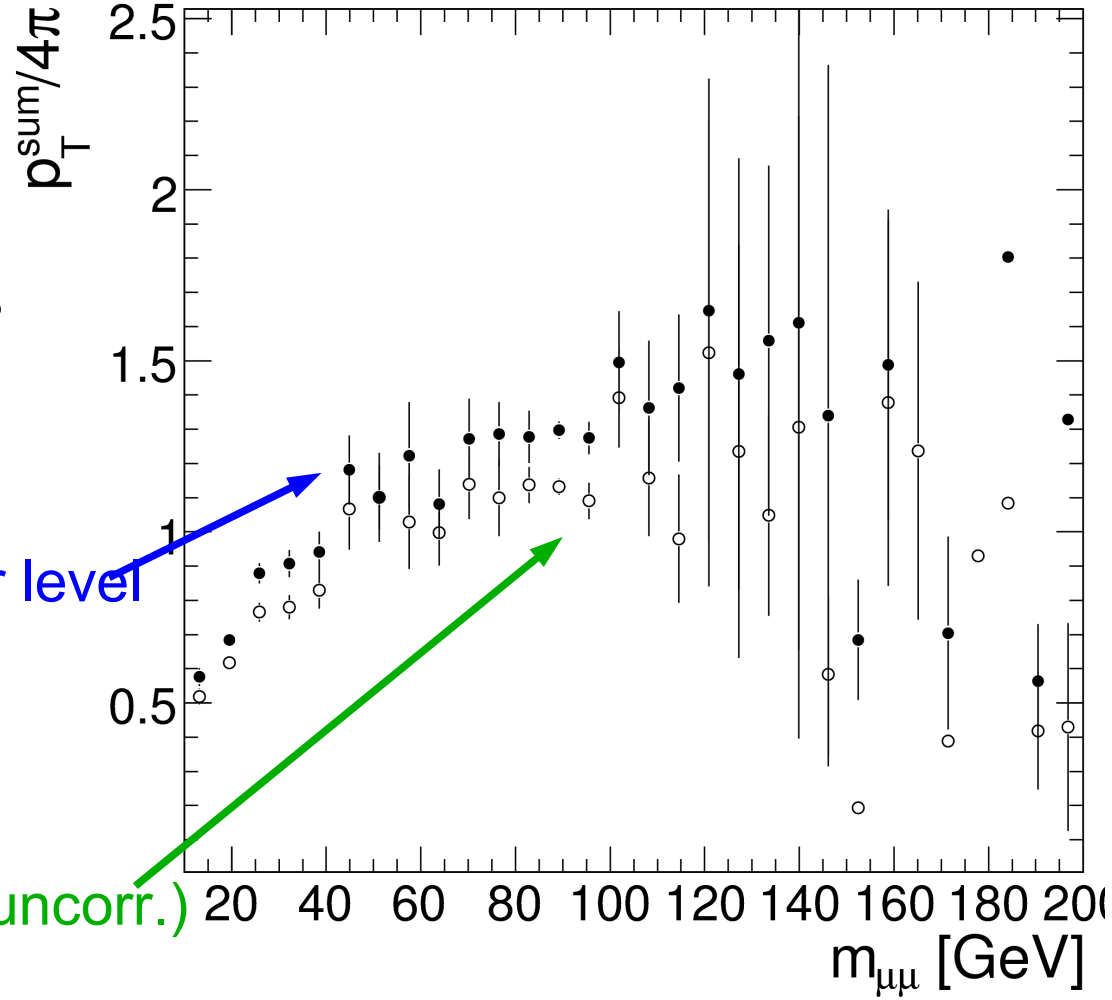


Underlying Event Studies 2

Mean Pt sum density (without μ's) for:
- Pt > 0.9 GeV/c
- |η| < 1

vs. inv. mass of Drell-Yan μ pairs

Reflects the UE activity in the event

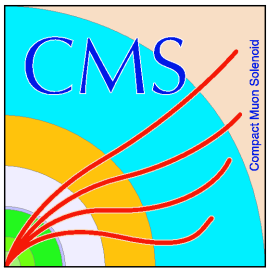


full circles: generator level

open circles: reconstr. level (uncorr.)

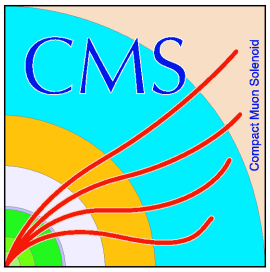
Current Activities and Next Steps

- Complete validation of new CMS software framework
  - Means also quite some MC events to reproduce
  - Very active groups for jet calibration and UE+MB business
  - Currently integrating fastjet kt algorithm (G. Salam, M. Cacciari)
- Demonstrate high level trigger plan
- Prepare analyses for 2008 physics runs
  - Special QCD concern:
    - Some topics not well covered yet (event shapes, jet rates, ...)
    - The jet calibration is a huge task for our Jet&Missing ETgroup
- Planning for LHC calibration run (900 GeV) data



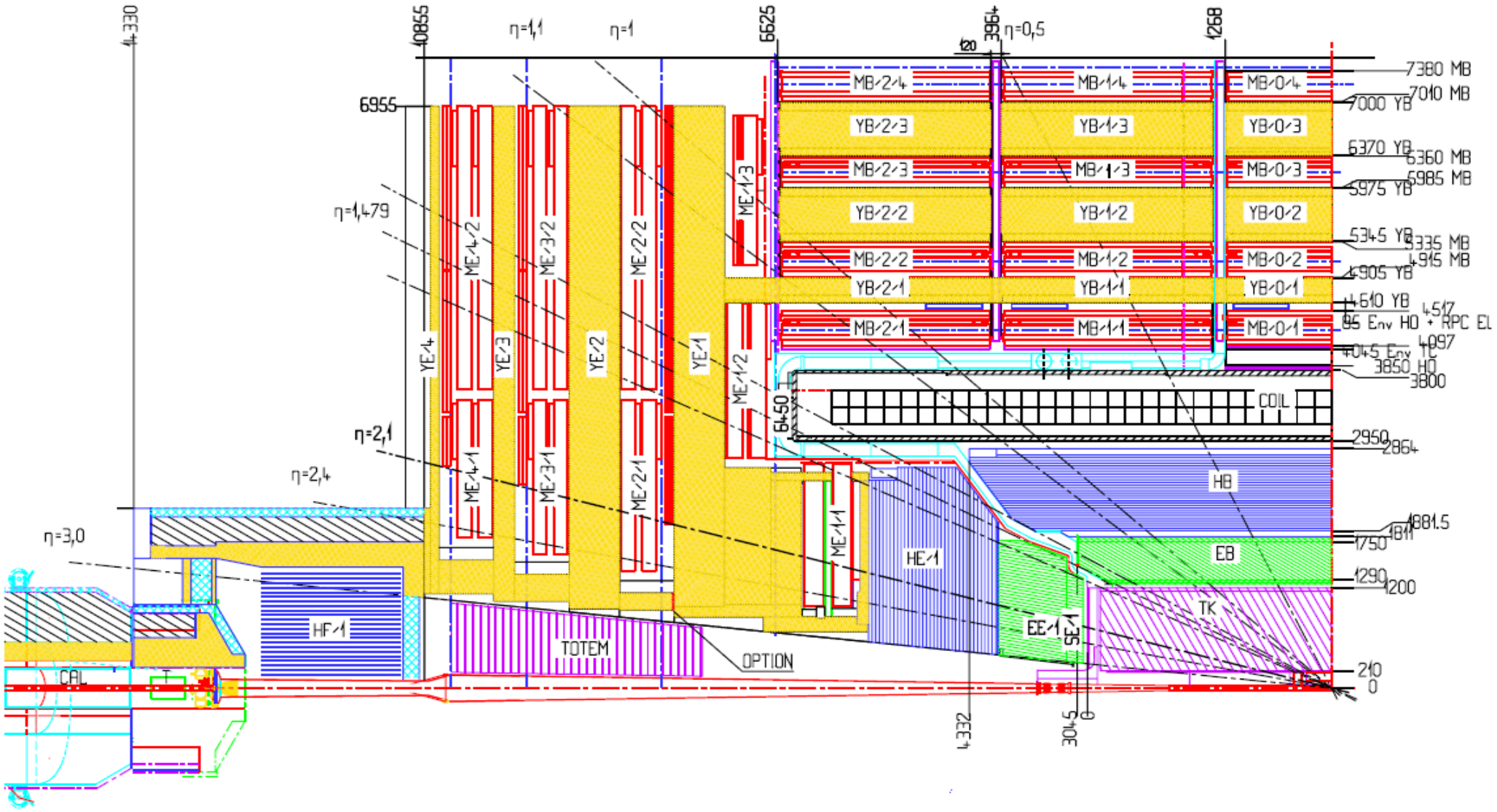
Summary/Remarks

- A long way ahead of us and much to learn for physics runs
- Input from theorists welcome, e.g. to tackle systematic uncertainties (UE, ...)
- ATLAS and CMS should strive to agree on some common definitions, at least on generator level, e.g. to avoid diverging jet algorithms like with CDF and D0 (→ Les Houches)
- The discussion is opened ...

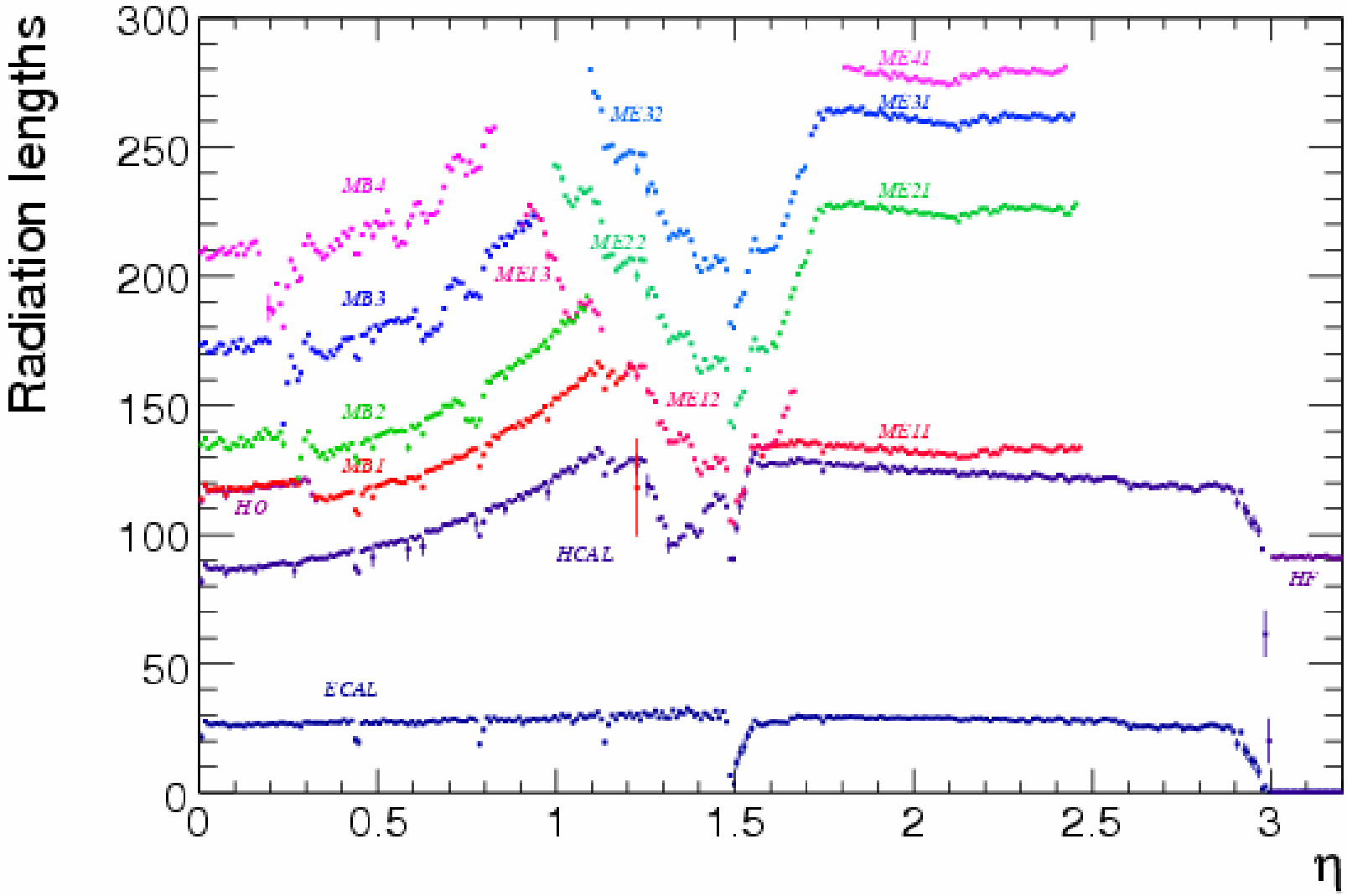


Backup

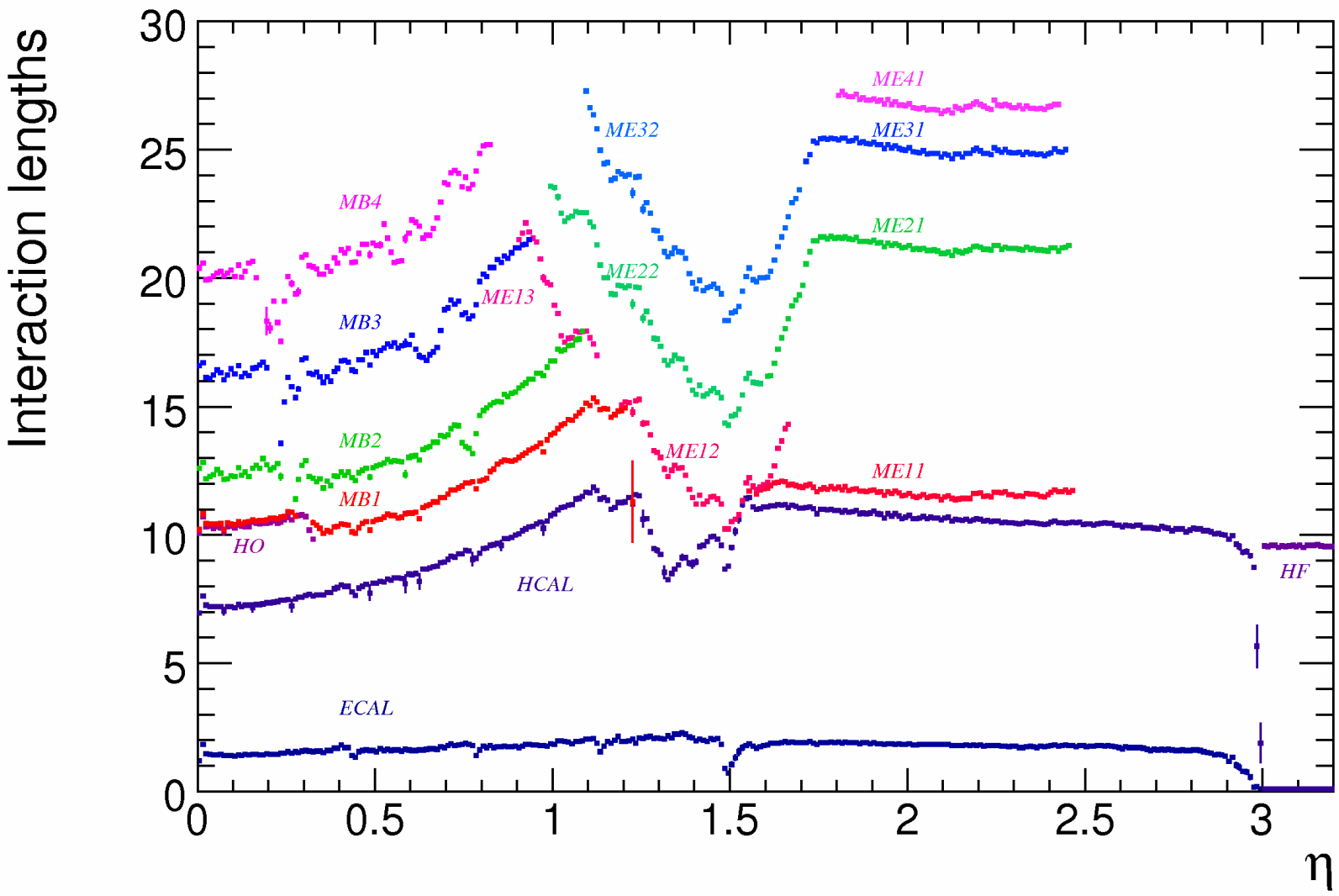
CMS Detector



Material Depth in X_0



Material Depth in λ_N



Process Decomposition