Physics benchmarks, FCC-hh detector specifications

Michele Selvaggi
(on behalf of the FCChh group)

CERN

Outline

- Physics Benchmarks
- Object performance
- Detector baseline

Motivations for FCC-hh

- **Ultimate discovery machine**
  - **directly** probe new physics up to **unprecendented** scale
  - discover/exclude: [1606.00947]
    - heavy resonances "strong" m(q*) ≈ 50 TeV,
      "weak" m(Z') ≈ 30TeV,
    - SUSY m(gluino) ≈ 10 TeV,
      m(stop). ≈ 5 TeV
- **Precision machine**
  - probe Higgs **self-coupling** to few % level, and %-level precision for top yukawa and rare decays [1606.09408]
  - measure **SM parameters** with high precision
  - exploit **complementarity with e^+e^-** by probing **high dim.operators** in **extreme kinematic** regimes

Goals for CDR:

- Define a set of key **physics benchmarks**
- Evaluate — **optimize detector performance** by maximising physics reach for such benchmarks

Physics Benchmarks

Higgs Physics

- γ, leptons, p_T, η acc
- b/tau tagging performance
- fwd jet tagging
- id efficiencies and fake rates

- Higgs self-coupling ($bb\gamma\gamma$, $bb\tau\tau$, bb+leptons)
- Top-Yukawa:
  - ttH, $H \rightarrow \gamma\gamma$ (threshold), $H \rightarrow b b$ (boosted)
- Rare Higgs decays ($H \rightarrow cc$, $H \rightarrow \mu\mu$, $H \rightarrow Z\gamma$)
- "Big Five": Higgs decays ($H \rightarrow 4l, WW, \gamma\gamma, \tau\tau, bb$) see talk tomorrow
- VBF (VBS)
- BSM Higgs ($H^{+/-} \rightarrow tb$)

At **threshold** , **20×10^9** ggH events are produced at 30 ab^{-1}
With **pT(H) > 1 TeV** , **10^6 H events at disposal.**

Large statistics allow to these measurements to be performed in the **"boosted" regime**.

Extreme kinematics (large pT(H), m(VH)) enhance sensitivity to modifications of SM coupling through **anomalous couplings** / high dim. operators.

These can be nice **complementary precision** measurements to e^+e^-

Top physics

Top physics couplings:

- tt ɣ /Z
- ttH/ttZ ratio? [1507.08169]
- tWb (single top s-channel)
- g t t
- FCNCs, rare decays

Orhan Cakir

At **threshold** , 10^{12} top pairs events are produced at 30 ab^{-1}
With **pT(top) > 1 TeV** , **500 10^6 top pairs events at disposal.**

Same comments as for the Higgs apply here.

Key Experimental issues to be addressed in Higgs and Top studies are sensitivity to:

- final state pT, η acceptance (especially for VBF) and resolution
- tagging efficiencies and mistag rates (c, b , top , higgs)
- id efficiencies and fake rates

Benchmarks analyses (BSM)

"Strong" SUSY:

- gluinos, squarks: jets + MET, s.s dileptons + jets + MET:
  - M_g = 12 TeV, M_{LSP} = 100 GeV
  - M_g = 8 TeV, M_{LSP} = 7.8 TeV (compressed region)

- stops: 0/1 leptons + jets + MET:
  - Ms_{top} = 9 TeV, M_{LSP} = 100 GeV
  - Ms_{top} = 5 TeV, M_{LSP} = 4.8 TeV (compressed region)

Key aspects are:

- lepton pT thresholds in compressed scenarios
- MET resolution
- tracking/ calo granularity in boosted regions
- lepton id requirements in boosted leptonic top decays

Benchmarks analyses (BSM)

"Weak SUSY/ DM":

- EW-ino: 3/4 leptons + MET
- Higgsino (disappearing tracks) Ryu Sawada
- Dark Matter Phil Harris

Key experimental challenges:

- lepton id, lepton threshold in compressed regions?
- MET tails
- disappearing tracks

"Heavy Resonances":

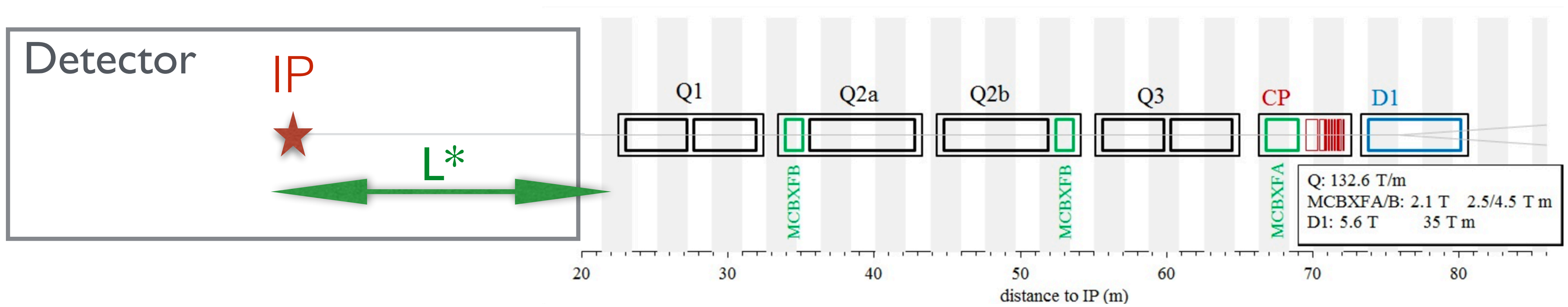
- → K_{factor} = 1.3
- Z' → tt, jj, ee/μμ:
  M_Z = 5, 30 TeV

Key aspects are:

- boosted tops
- high pT electron/muon resolution

Luminosity, Pile-Up scenari

- $L^* = 45$ m



  - Distance between **triplet and IP**
  - determines overall **longitudinal size** of detector

- Luminosity = [5×10^{34} - 30×10^{34}] $cm^2 s^{-1}$
  - low lumi , N_{PU} = 170 (25ns)
  - high lumi , N_{PU} = **1020** (25ns) - 204 (5ns)

radiation

Ilaria Besana

z_{vtx} resolution
CPU time
timing detector?

Zbynek Drasal

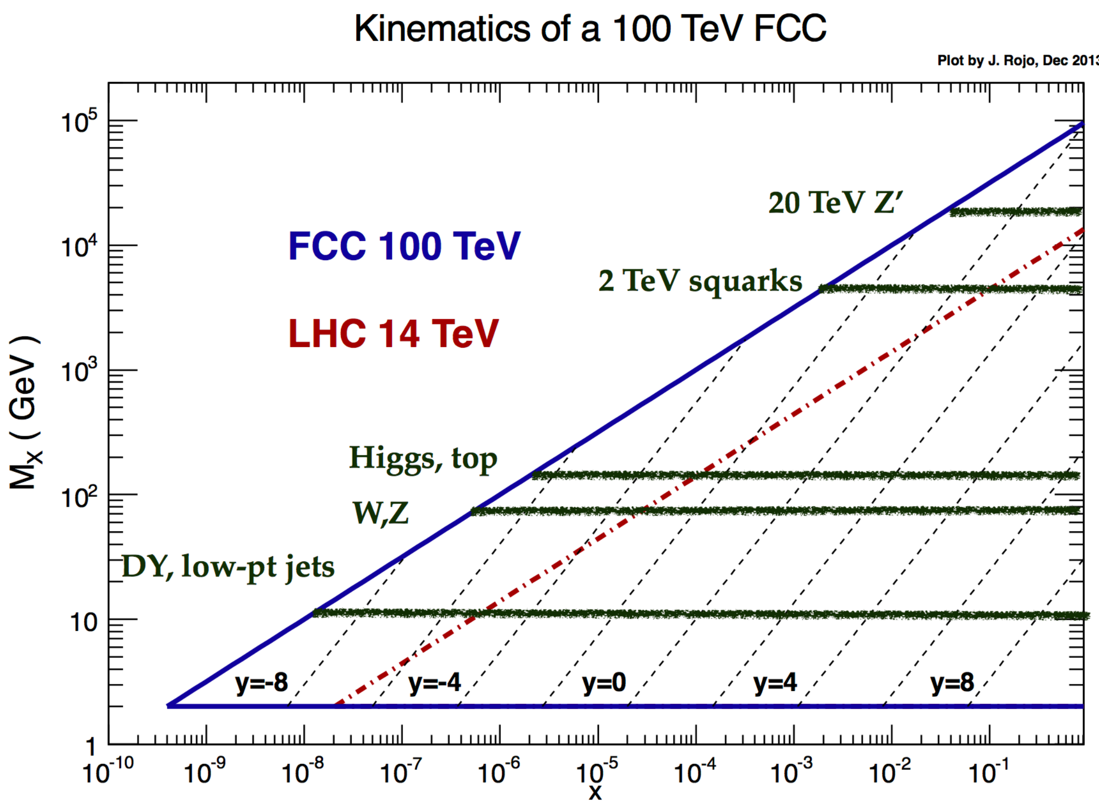
better for Tracking

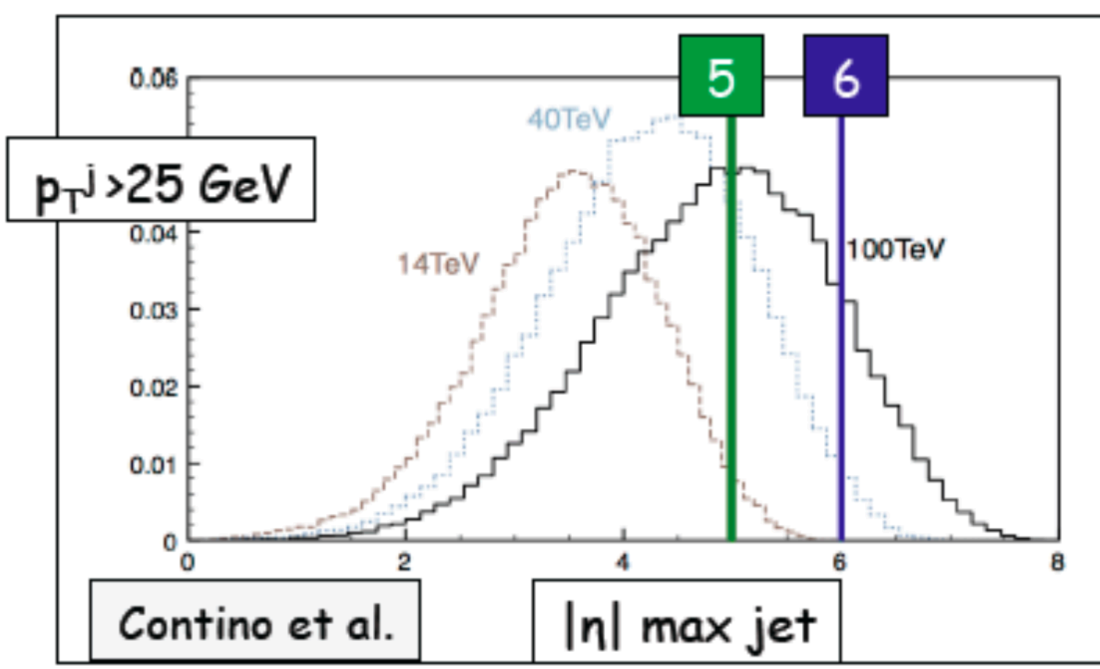
Towards defining the FCChh detector

Physics constraints

- **Physics will be more forward**
  - less for "high pT" physics
  - more for "low pT" physics (W/Z/Higgs, top)
  - in order to maintain sensitivity in need **large rapidity** (with tracking) and **low pT** coverage

→ Can we deal with 1k pile-up will at large rapidities?





Towards defining the FCChh detector

Physics constraints

- **Physics objects will be more boosted**

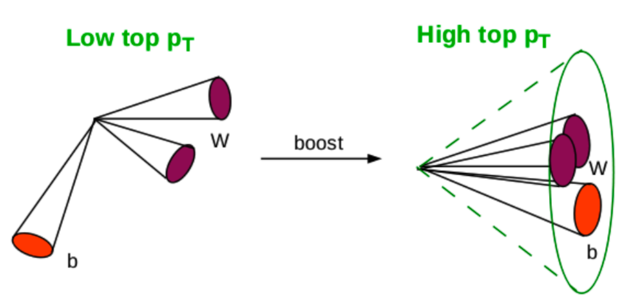
Tracking: $$\frac{\sigma(p)}{p} \approx \frac{p\sigma_x}{BL^2}$$

calorimeters: $$\frac{\sigma(E)}{E} \approx \frac{A}{\sqrt{E}} \bigoplus B$$

- **Tracking** target : achieve **σ / p = 10-20% @10 TeV** Zbynek Drasal
- **Muons** target: **σ / p = 5% @10 TeV** Werner Riegler
- Keep calorimeter **constant term** as small as possible. Jana Faltova, Coralie Neubuser, Tony Price
- Long-lived particles live **longer**:

ex: 1 TeV **b-Hadron** travels **10 cm** before decaying
1 TeV **tau lepton** travels **2 cm** before decaying

→ re-think reconstruction, include **dE/dx ?** Estel Perez Codina



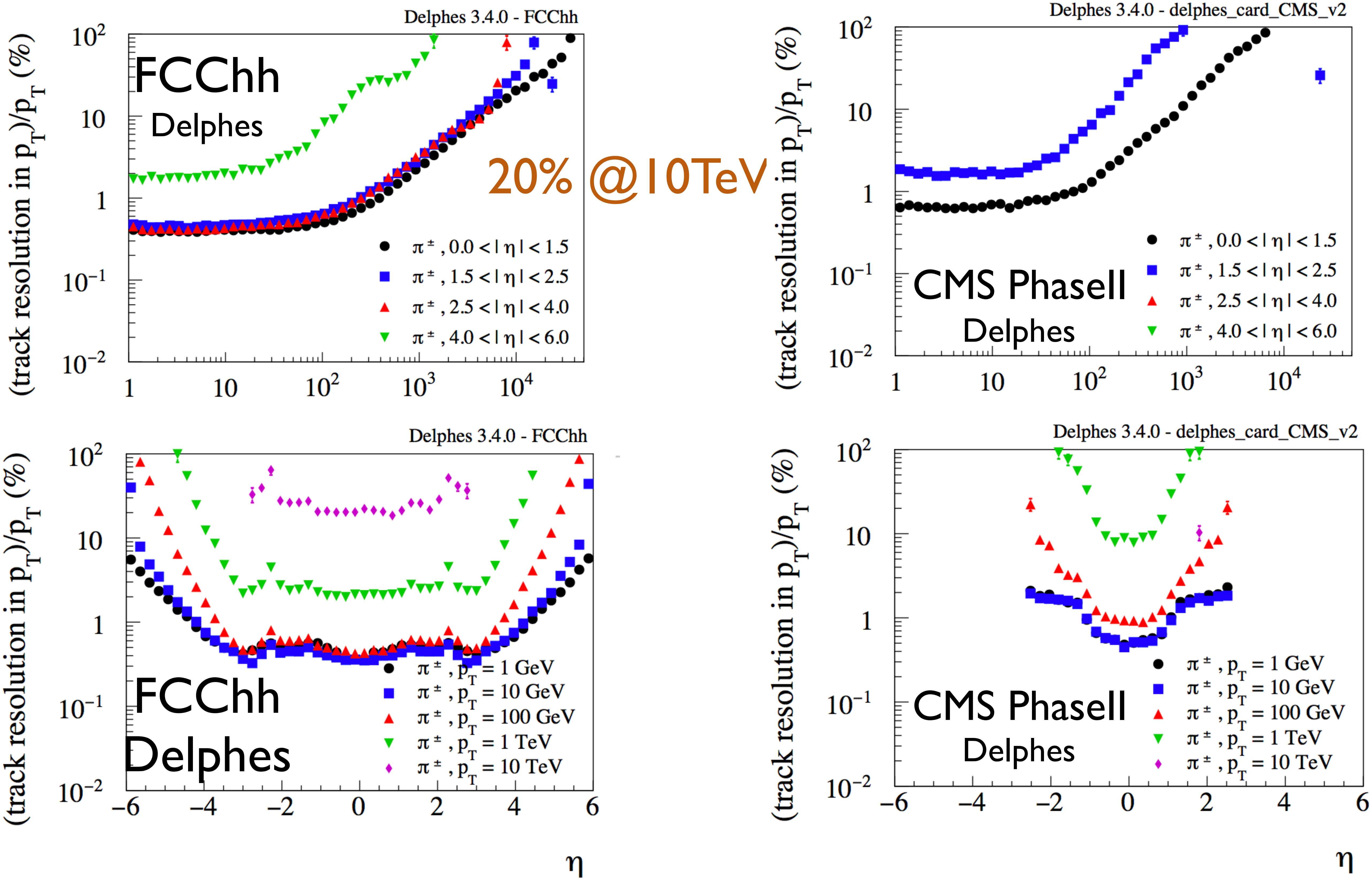
Require **high granularity** (both in tracker and calos):

ex: W(p_T **= 10 TeV**) will have **decay products** separated by **ΔR = 0.01**

Object parameterisation for Physics

Performance

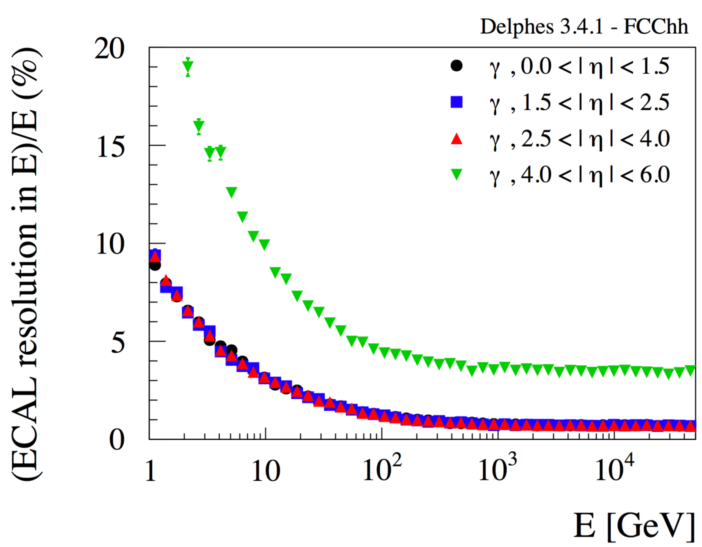
Tracking

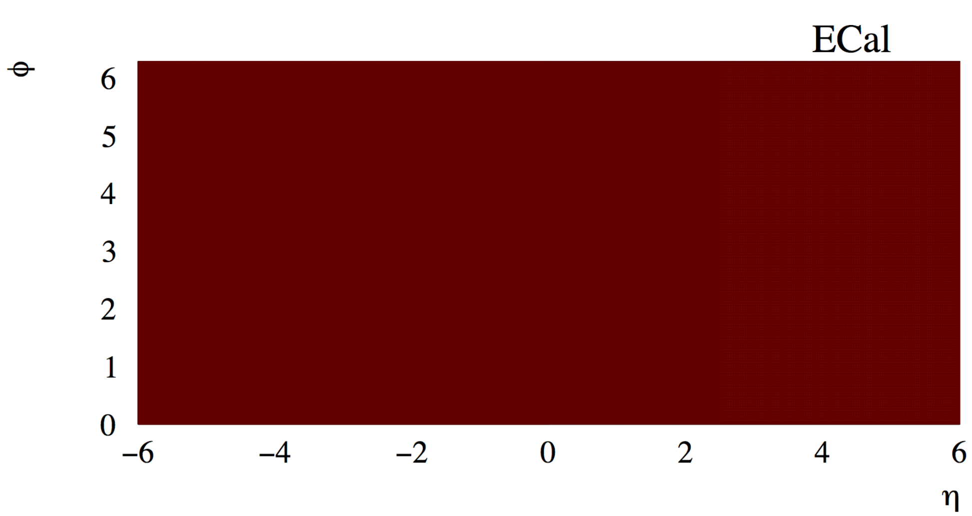


Performance
ECAL

FCChh Delphes

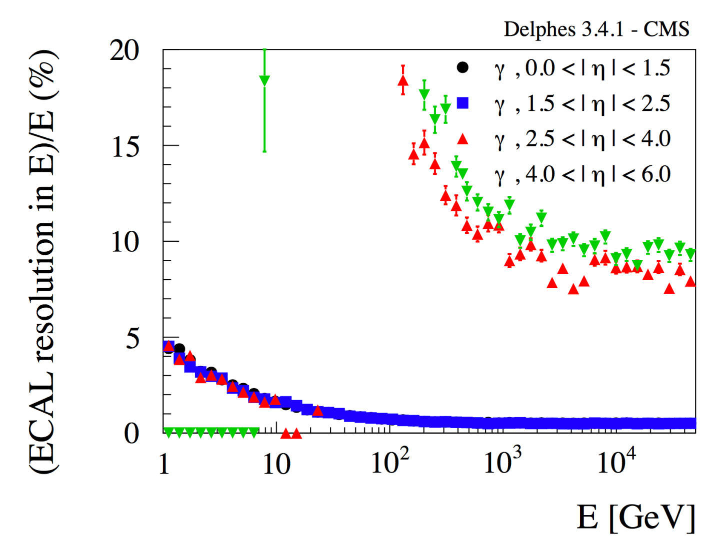
	σ(η,φ)	σ(E)/E
0 < |η| < 2.5	0.0125	10% / √E + 0.7%
2.5 < |η| < 4.0	0.025	10% / √E + 0.7%
4.0 < |η| < 6.0	0.025	30% / √E + 3.5%

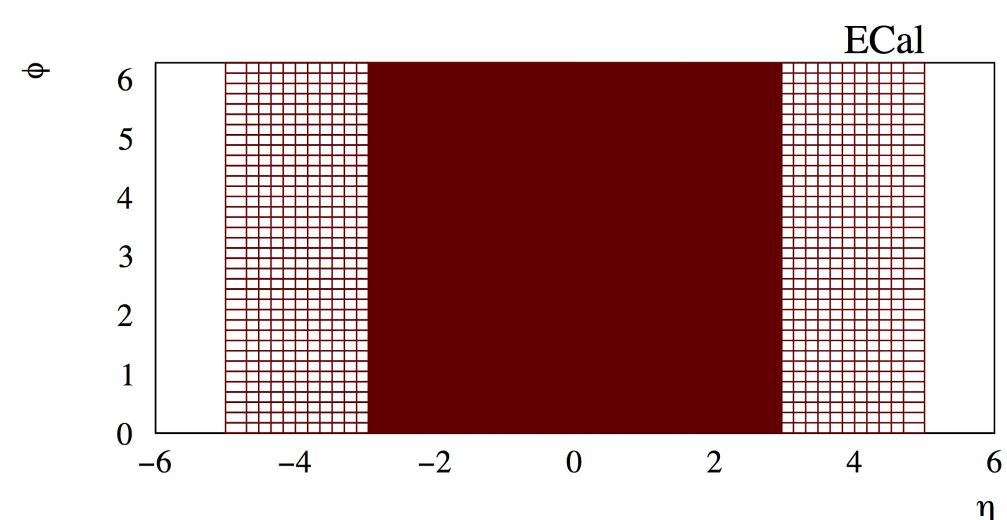




CMS Delphes

	σ(η,φ)	σ(E)/E
0 < |η| < 3.0	0.02	5% / √E + 0.5%
3.0 < |η| < 5.0	0.175 - 0.35	200% / √E + 10 %

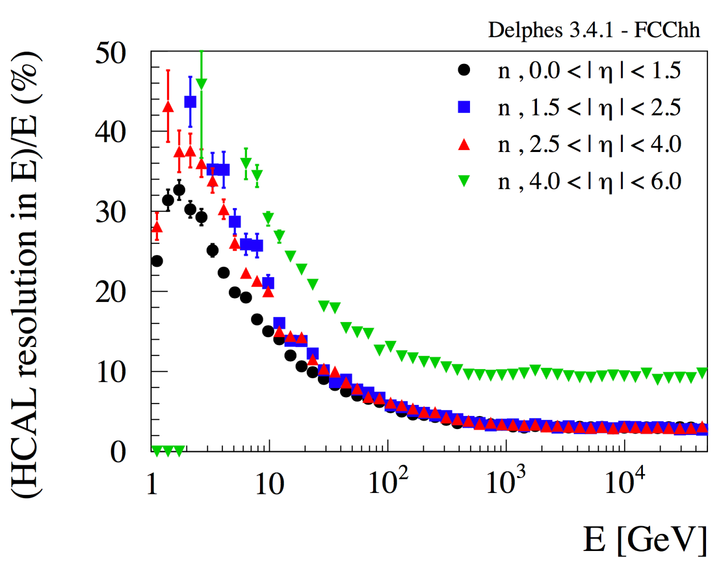


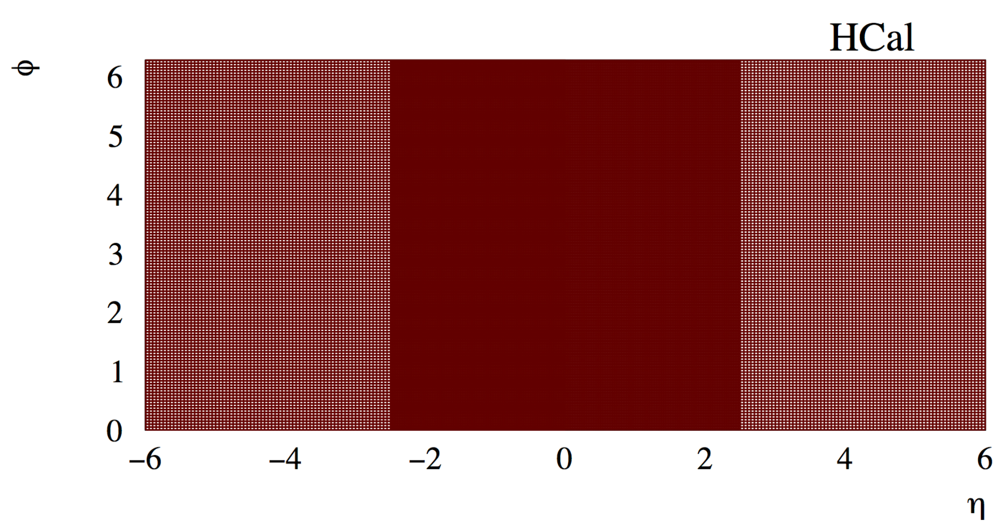


Performance
HCAL

FCChh Delphes

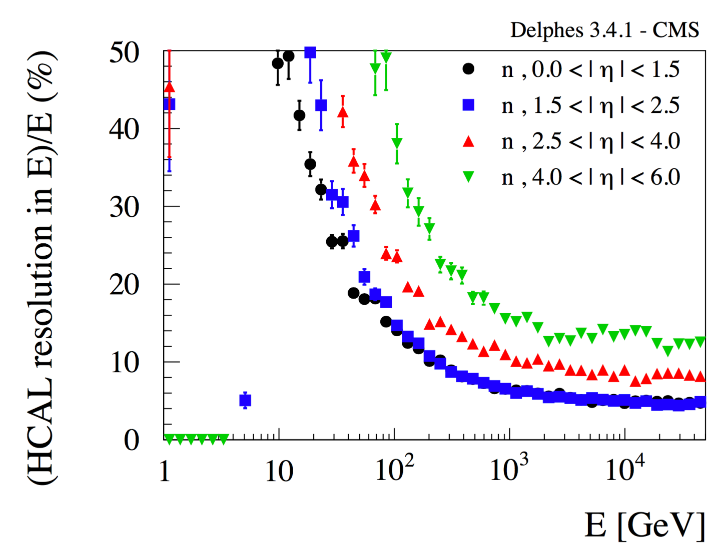
	σ(η,φ)	σ(E)/E
0 < |η| < 2.5	0.025	50% / √E + 3%
2.5 < |η| < 4.0	0.05	50% / √E + 3%
4.0 < |η| < 6.0	0.05	100% / √E + 10%

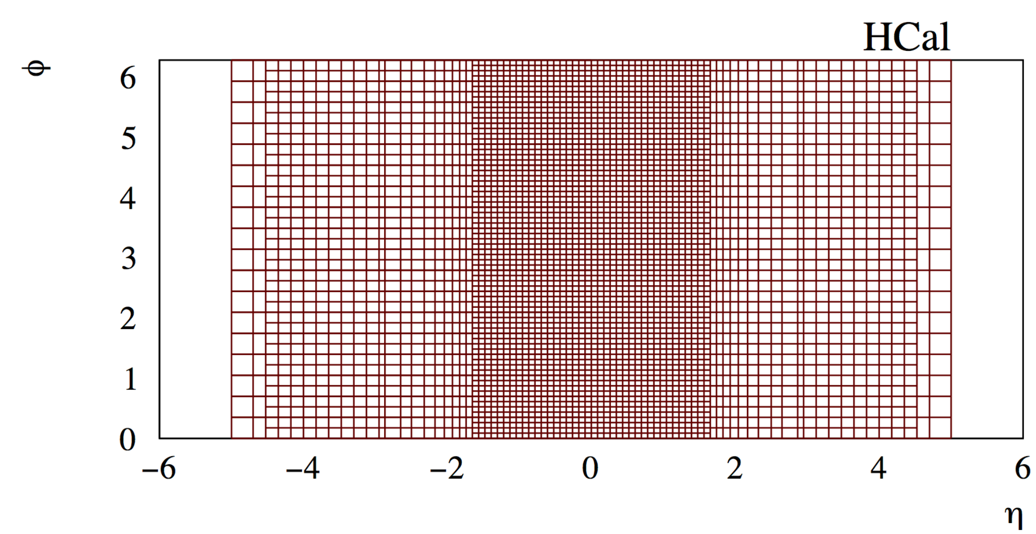




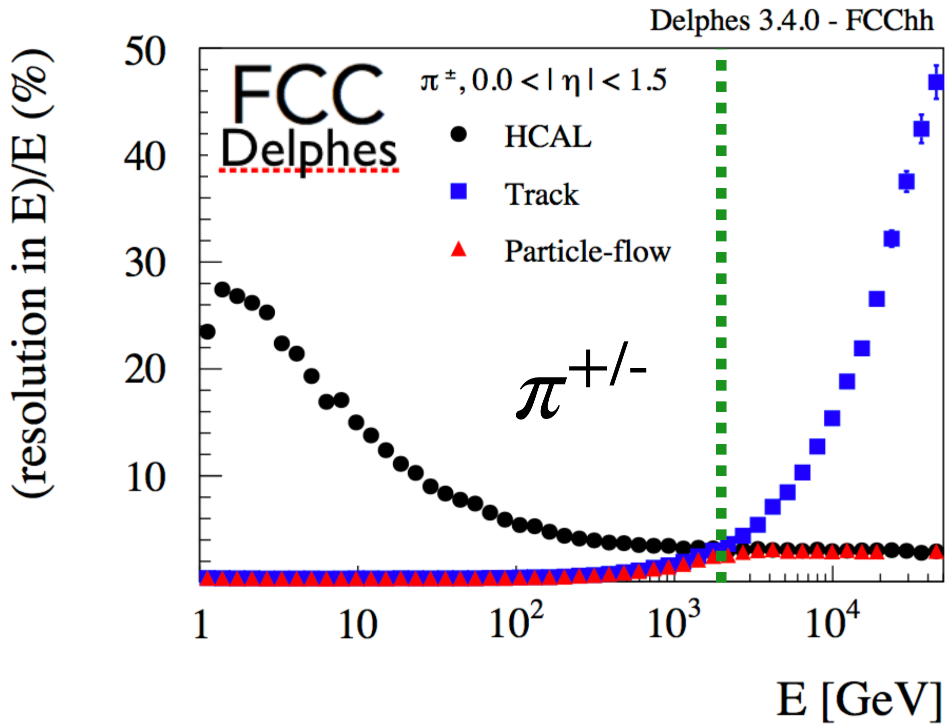
CMS Delphes

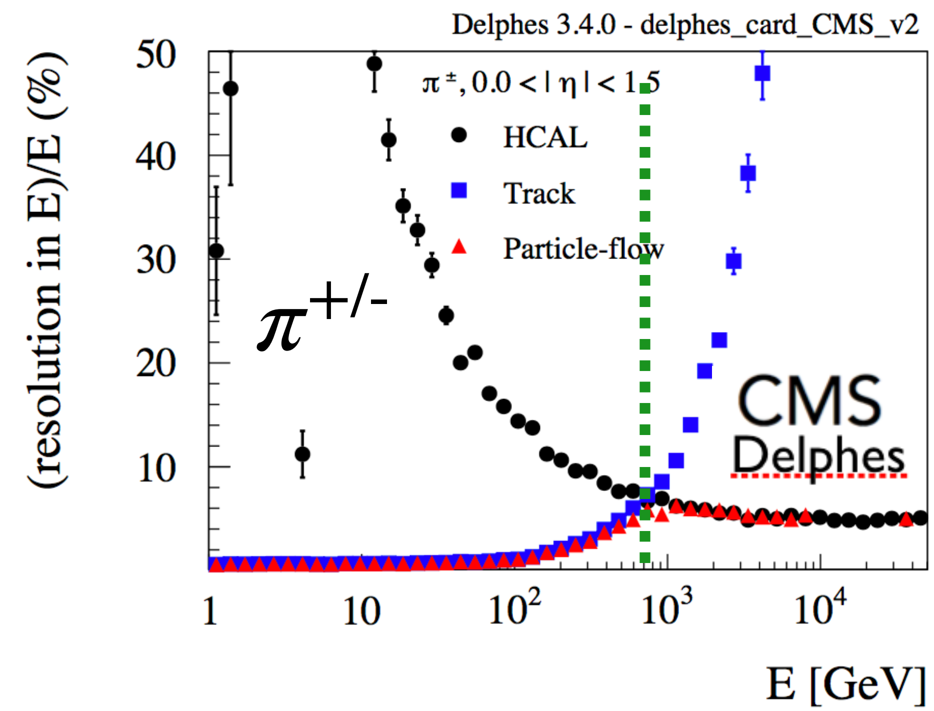
	σ(η,φ)	σ(E)/E
0 < |η| < 1.7	0.08	150 % / √E + 5%
1.7 < |η| < 3.0	0.175	150 % / √E + 5%
3.0 < |η| < 5.0	0.175 - 0.35	250% / √E + 13 %

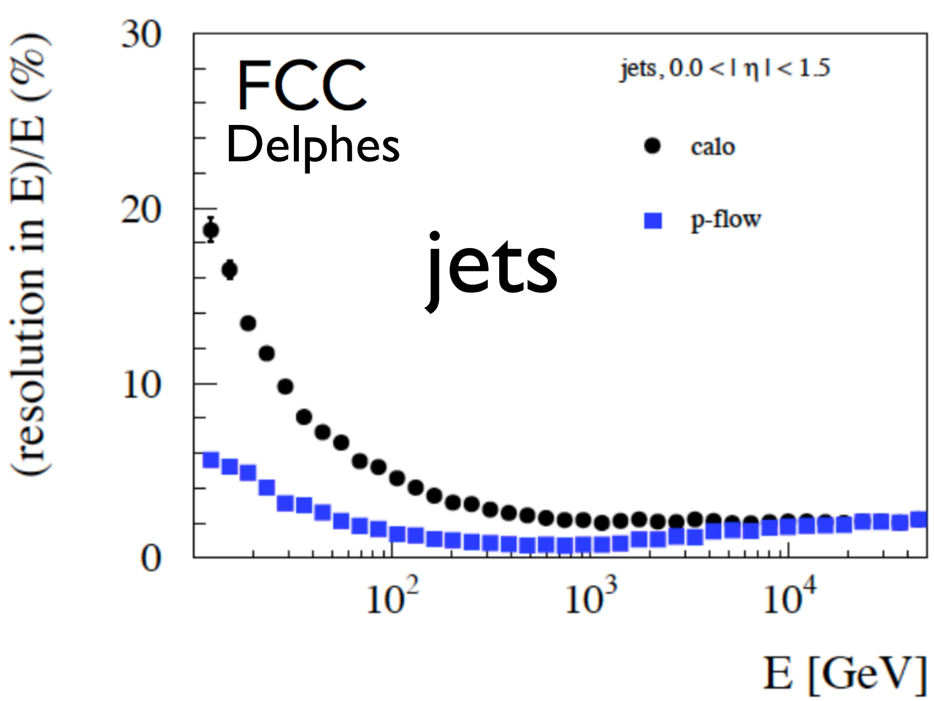


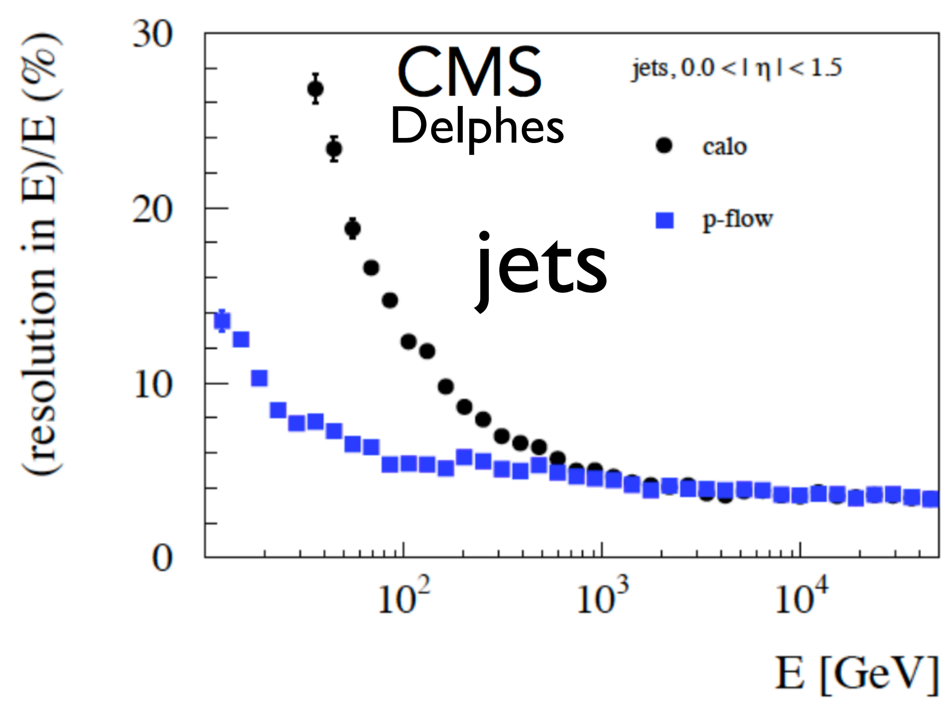


Performance
Particle-flow



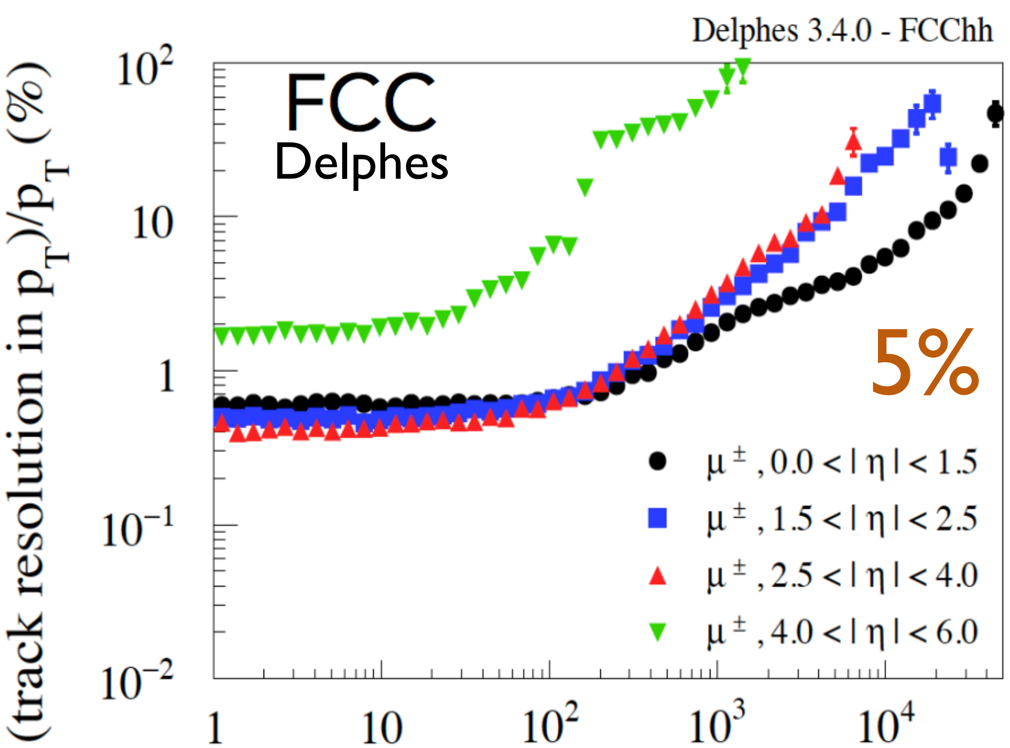




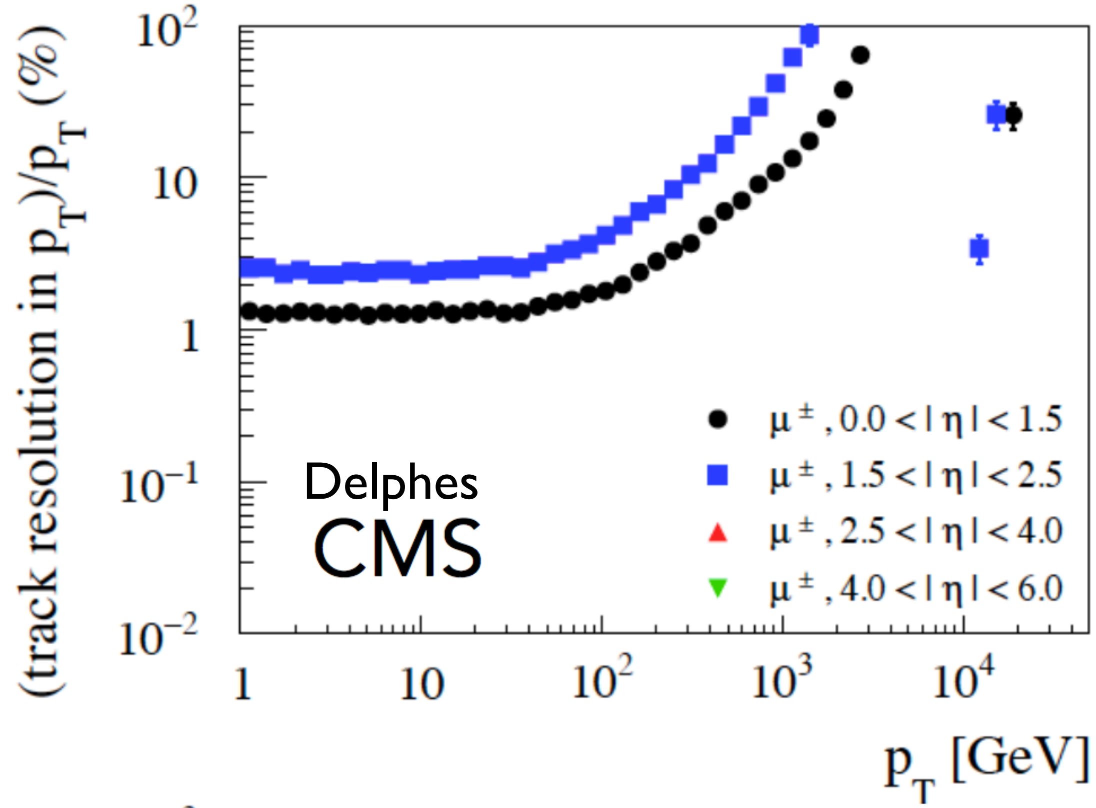


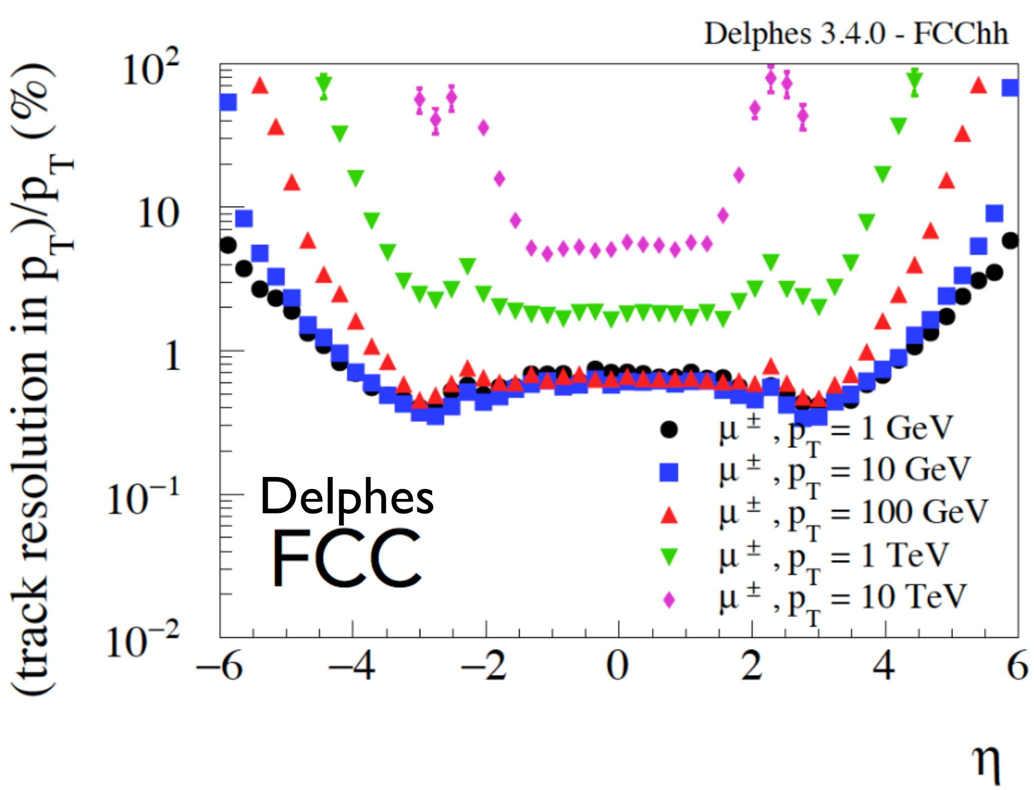
Performance

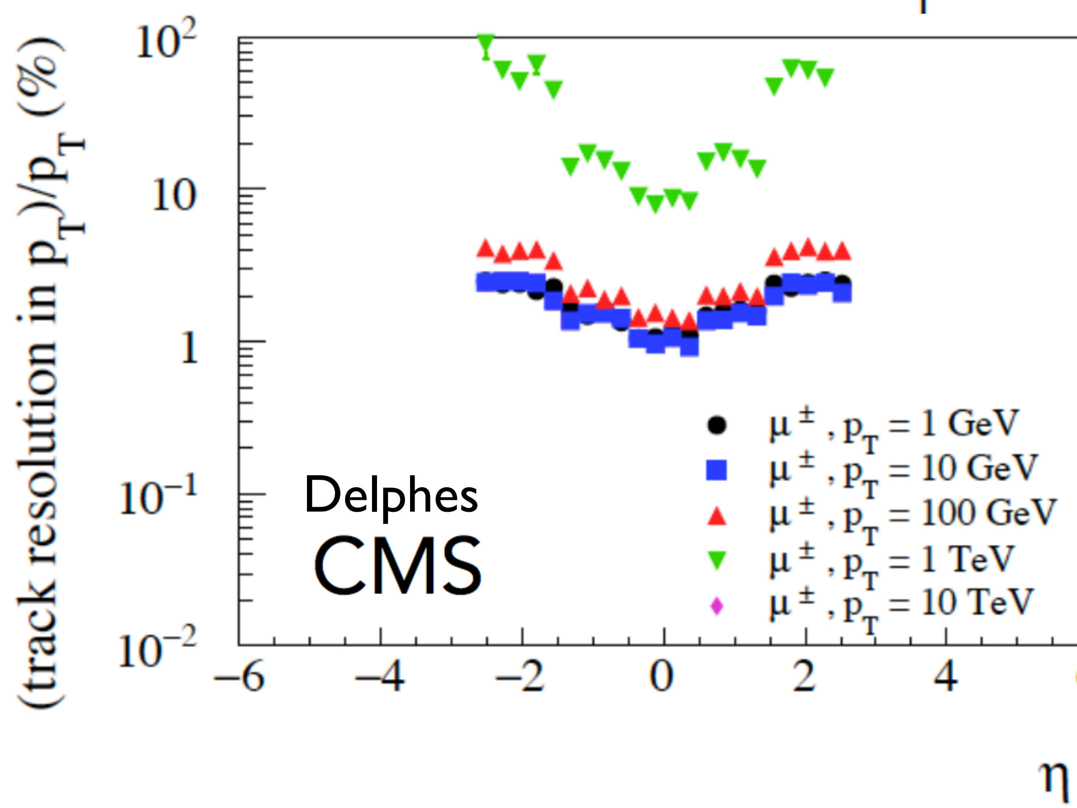
muons



5% @10TeV



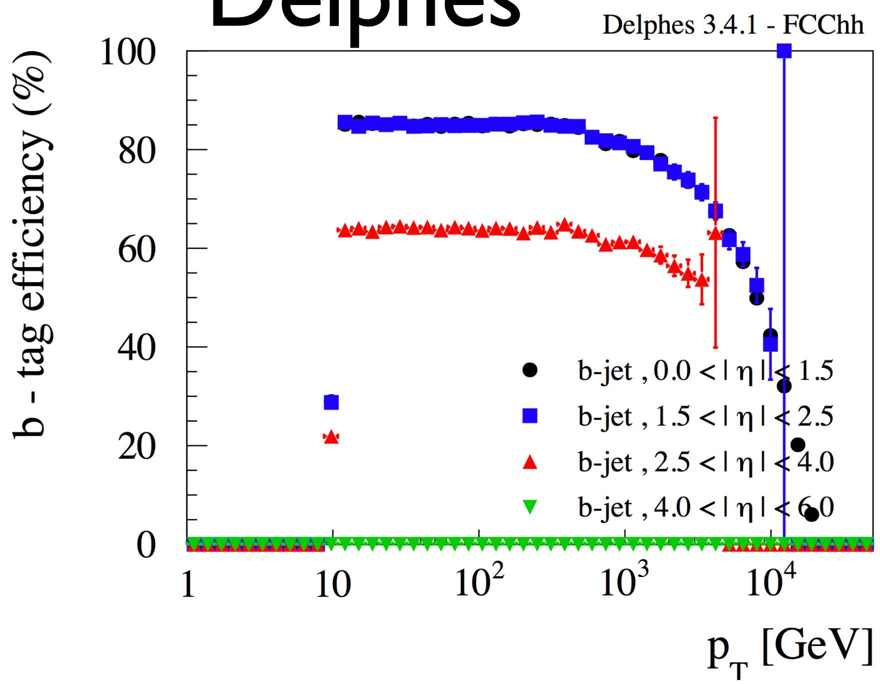


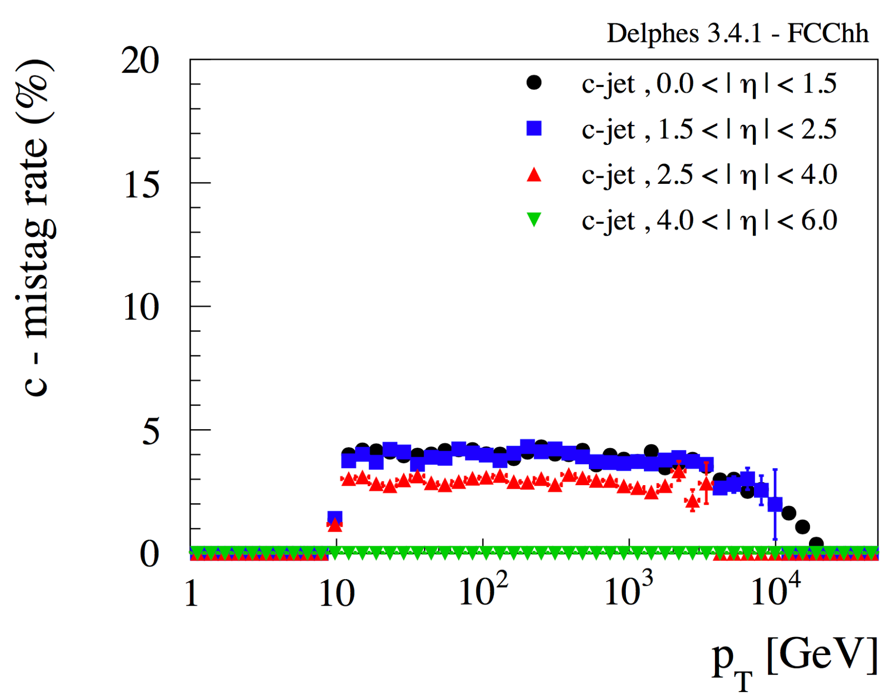


Performance

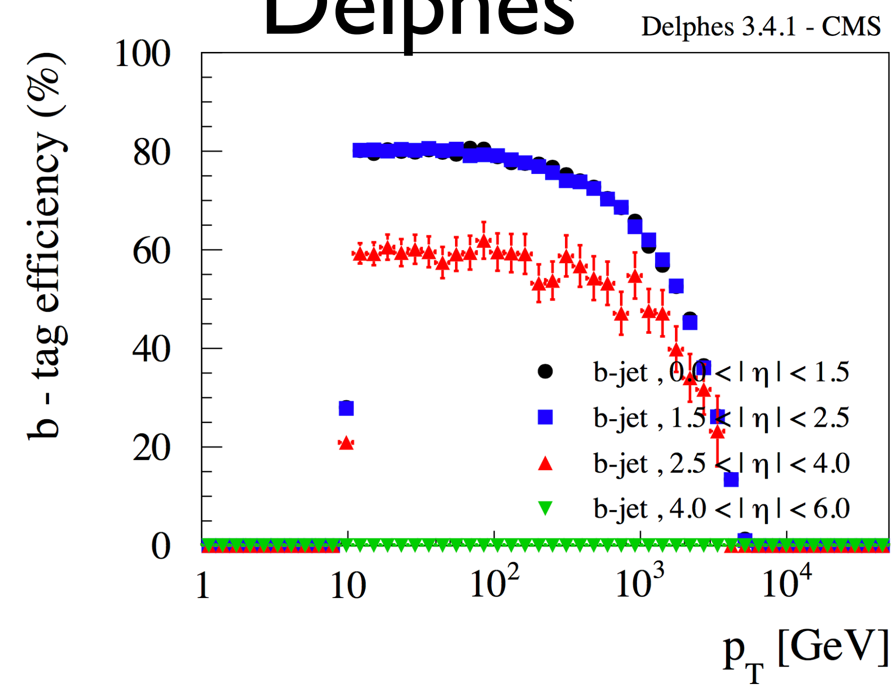
b-tagging

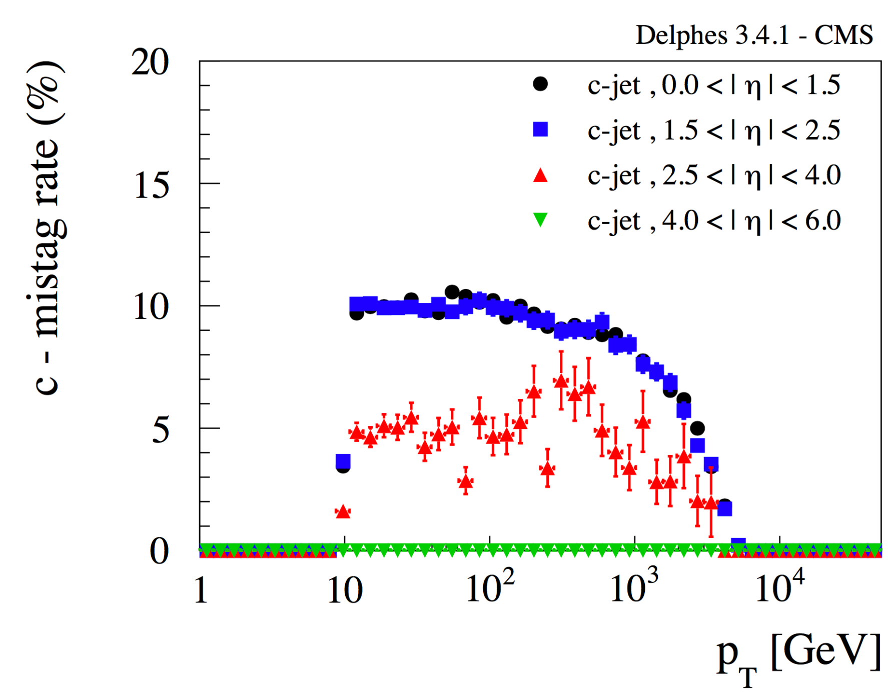
FCChh Delphes





CMS Delphes

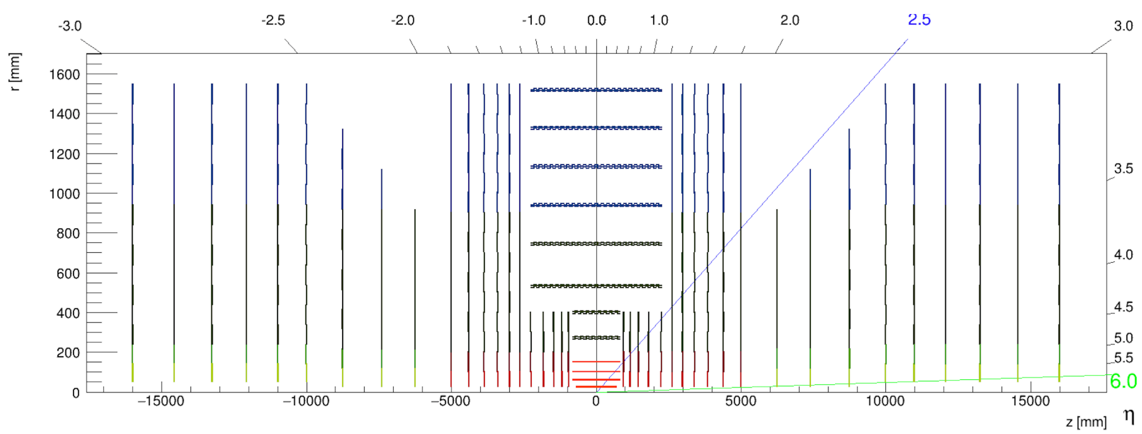




Detector Baseline

Detector Baseline

see later for dedicated presentations on sub-detectors

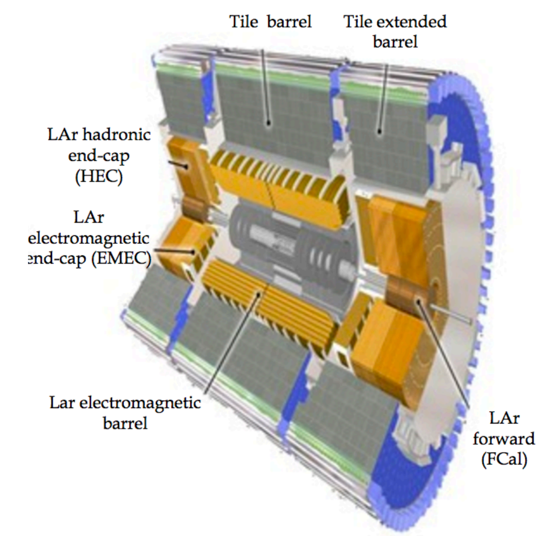


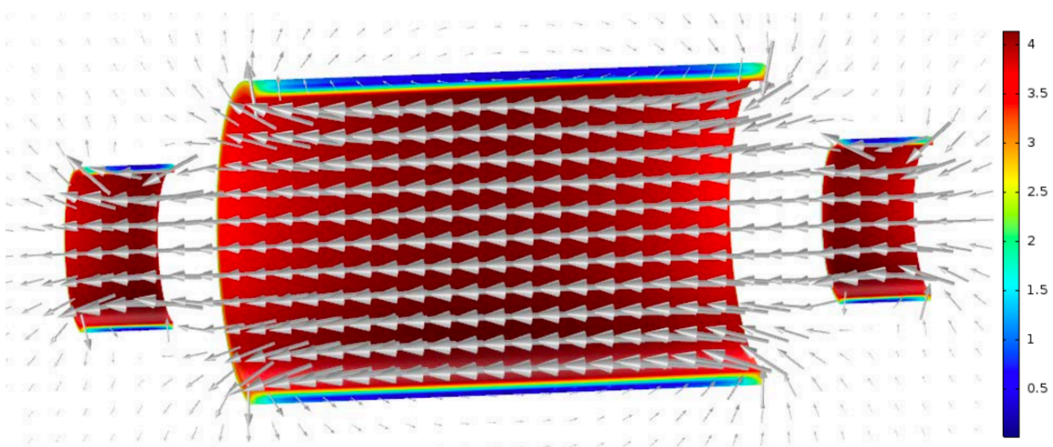
Tracker

- $-6 < \eta < 6$ coverage
- pixel : $\sigma_{r\phi}$ ~10μm, σ_Z ~15-30μm, X/X_0(layer) ~ 0.5-1.5%
- outer : $\sigma_{r\phi}$ ~10μm, σ_Z ~30-100μm, X/X_0(layer) ~ 1.5-3%

Calorimeters

- ECAL: LArg , $30X_0$, 1.6 λ, r = 1.7-2.7 m (barrel)
- HCAL: Fe/Sci , 9.2 λ, r = 2.8 - 4.8 m (barrel)
- endcaps and fwd to be defined
- investigating Digital ECAL



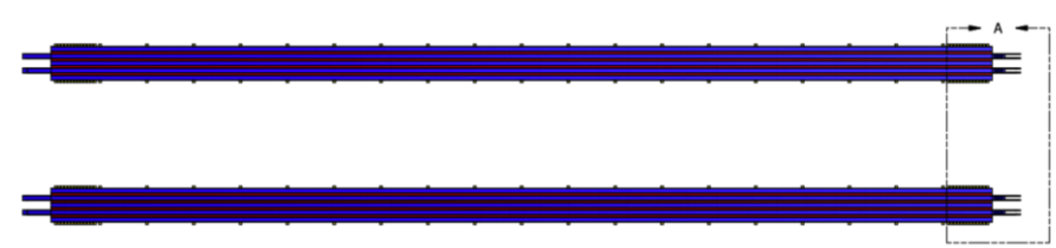


Magnet

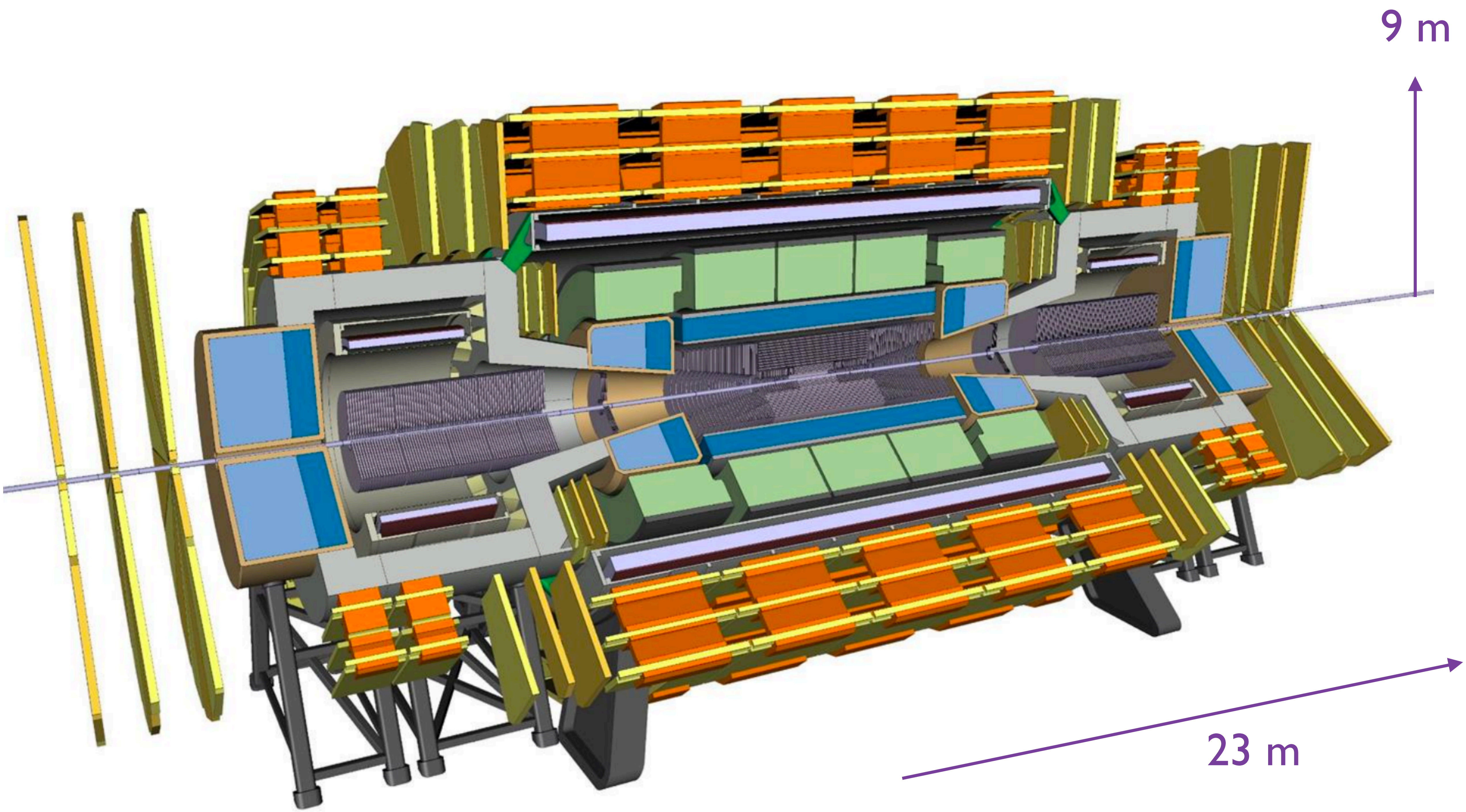
- central R = 5, L = 10 m, B = 4T
- forward R = 3m , L = 3m , B = 4T

Muon spectrometer

- Two stations separated by 1-2 m
- 50 μm pos., 70μrad angular



FCC-hh reference detector



Conclusions

- **Benchmarks for physics** studies have been defined.
- A **reference detector** for preliminary studies at p p @ 100 TeV has been defined.
- The detector **performance** has been **parameterised** in Delphes.
- Detector baseline should be used as a **reference point** from which one can **explore deviations** in performance (in better or worse).
- Tools are in place to explore the potential of the FCC-hh detector

In order to follow the FCChh activities, subscribe to the e-group:

fcc-experiments-hadron

Backup