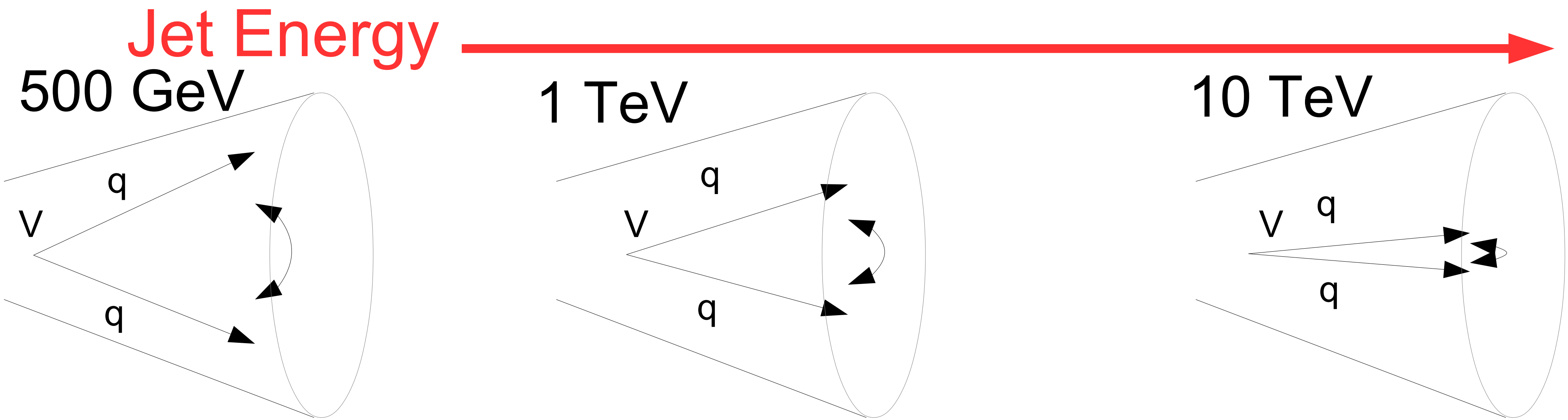
Super Boosted Objects

P.Harris
+ Boost members

What makes it super boosted?

- Boost so large resolving particles becomes tough



Jet Radius

$$R=\frac{2m}{p_T}=0.3\text{-}0.8$$

R=0.1-0.2

$R < 0.05$

Small boost

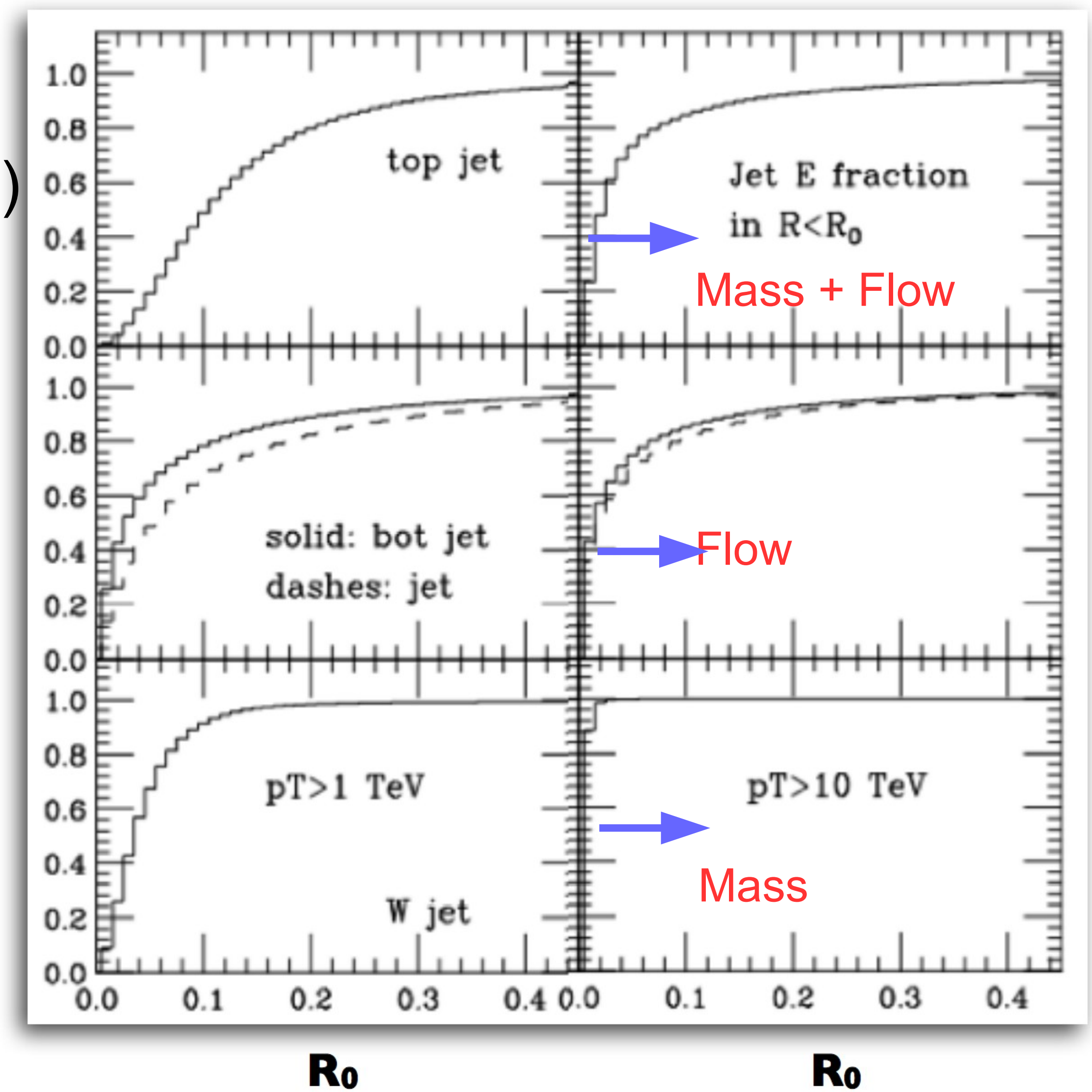
Medium Boost

Super Boost

How boosted is super boosted?

- Boost scale
  - Tau lepton(8 TeV)
    - E/M_τ = 120 (200 GeV)
  - Top jet (100 TeV)
    - E/M_t = 60 (10 TeV)
    - Color flow
  - V jet (100 TeV)
    - E/M_V = 120 (10 TeV)
    - No color flow

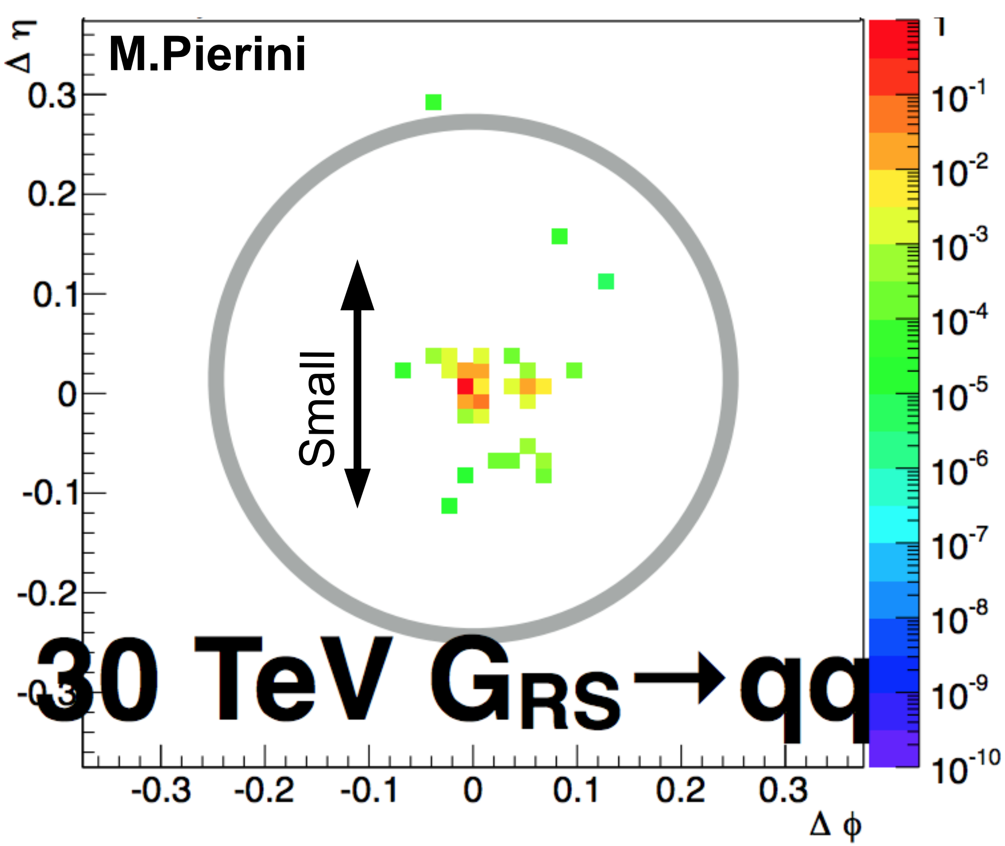
Jet E fraction in R<R0

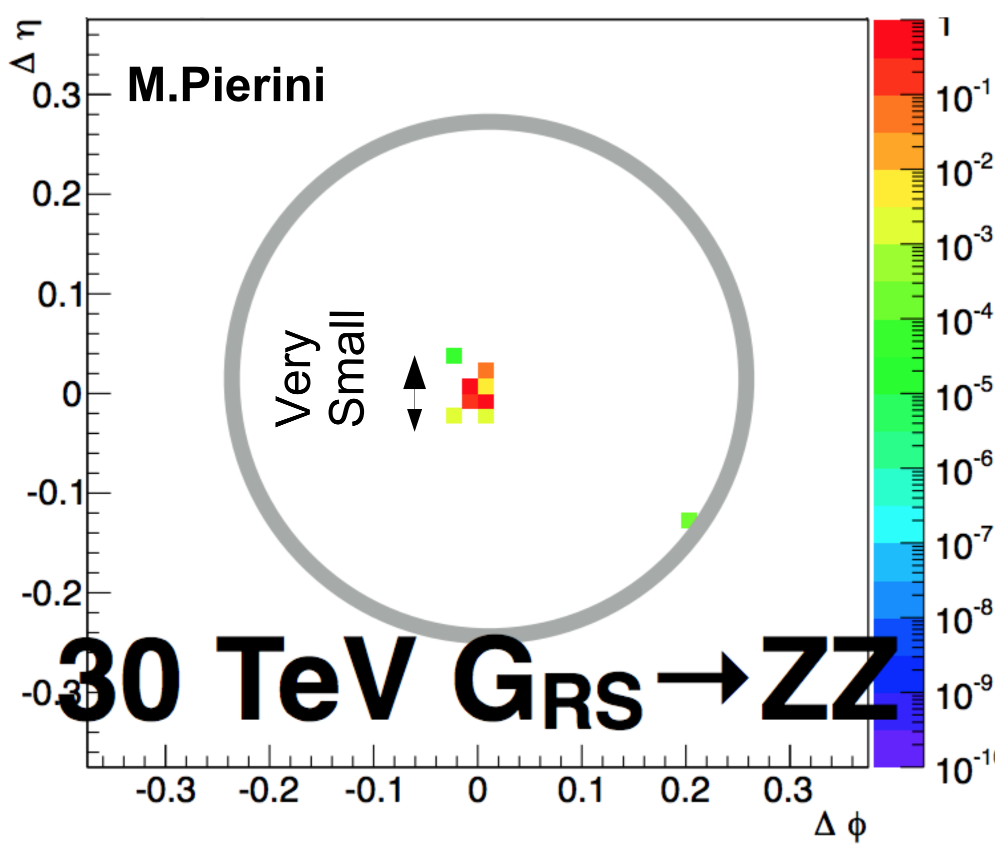


M.Mangano (https://indico.cern.ch/event/382815/session/10/?slotId=3#20150813)

Visualizing the boost?

- Jet scales that we have to deal with are
  - On the order of 0.05x0.05 in φ-η plane
  - Separation of particles needed to resolve mass



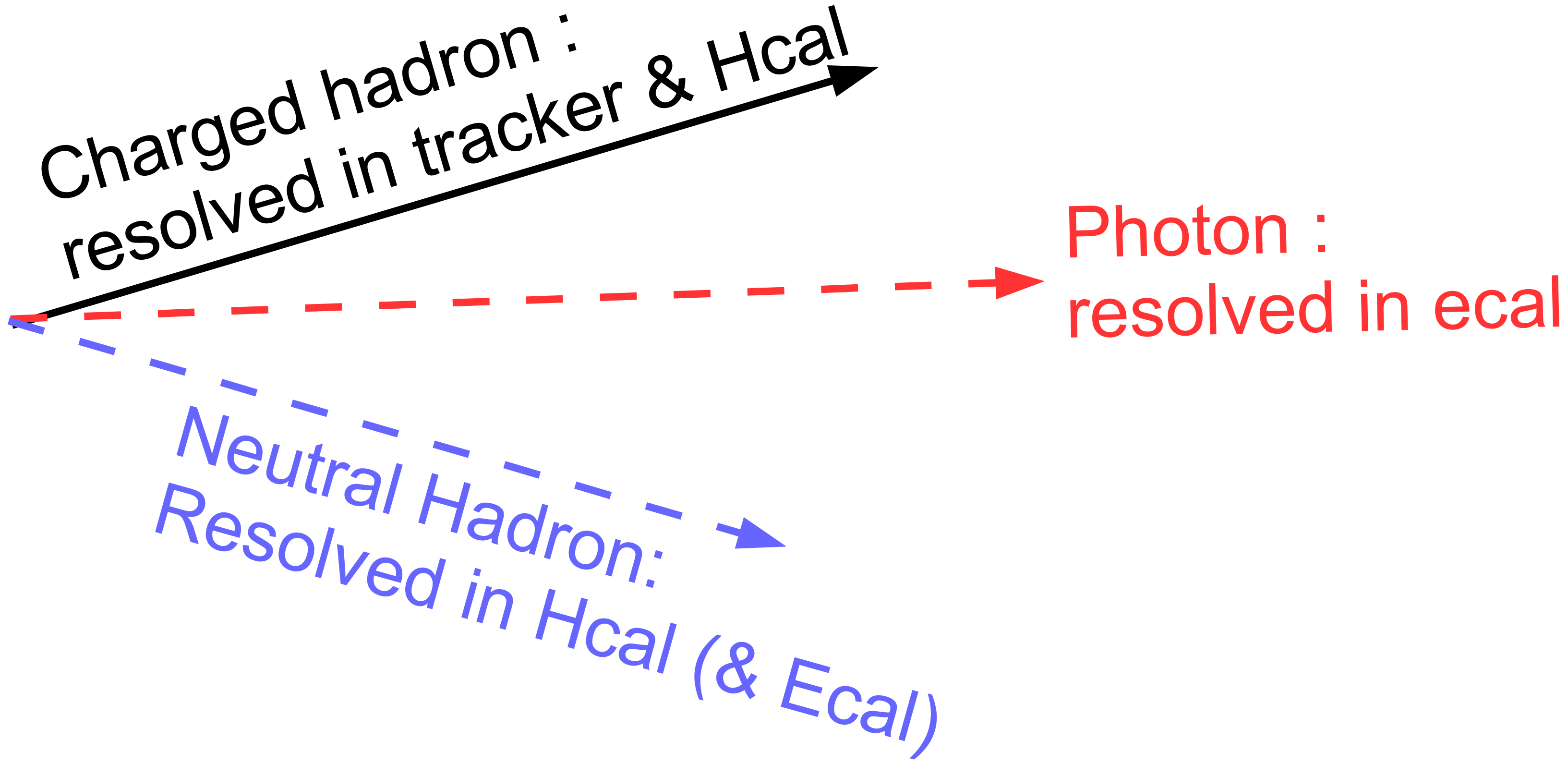


M.Pierini

Objects in Jets

What happens with the super boost?

- Can classify jet by 3 types of particles :



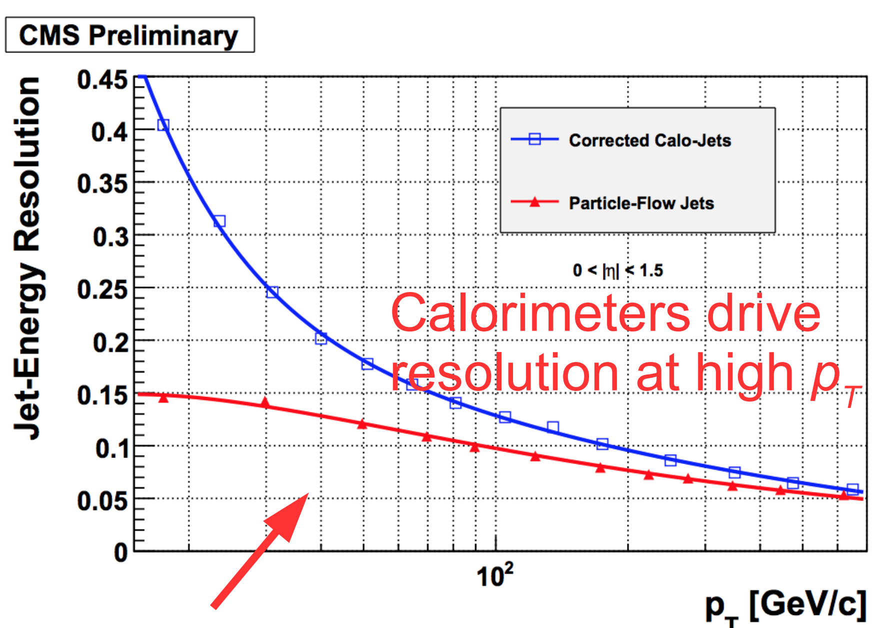
Key Question :
What is the distance scale of each particle in the detector?

Detector resolutions

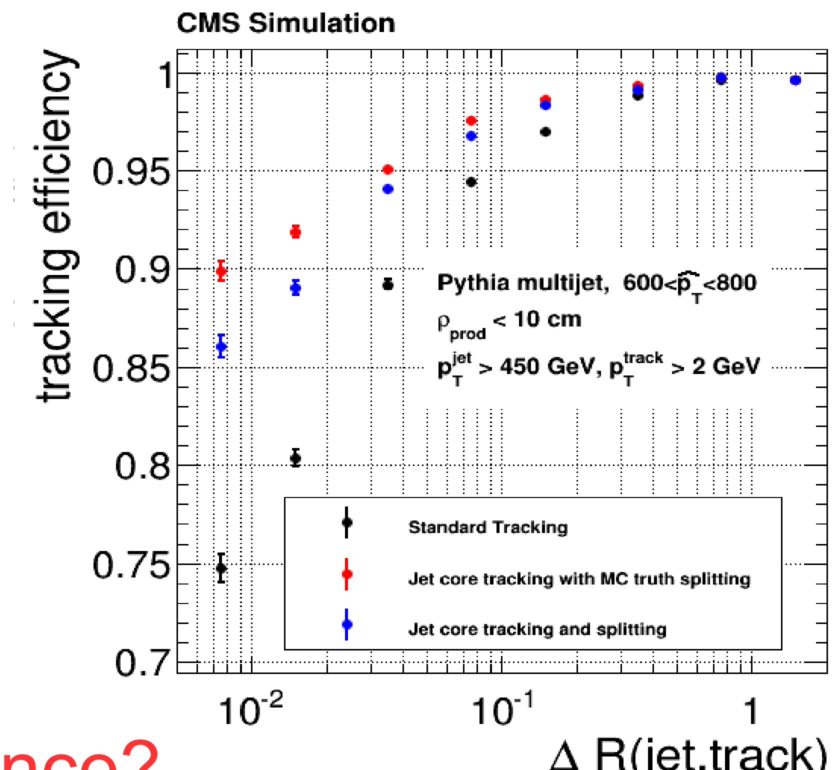
- Can classify jet by 3 types of particles :

Charged hadron :
resolved in tracker & Hcal

Tracking resolution dies out for angular resolution θ = 0.01



Calorimeters drive resolution at high p_T



Does/can Delphes capture balance?

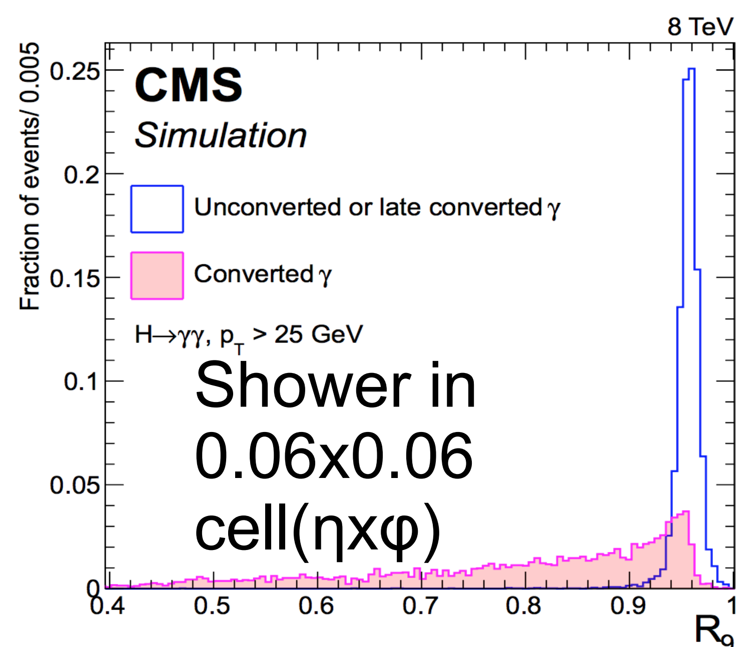
Detector resolutions

- Can classify jet by 3 types of particles :

Charged hadron :
resolved in tracker & Hcal

Photon :
resolved in ecal

Neutral Hadron:
Resolved in Hcal (& Ecal)

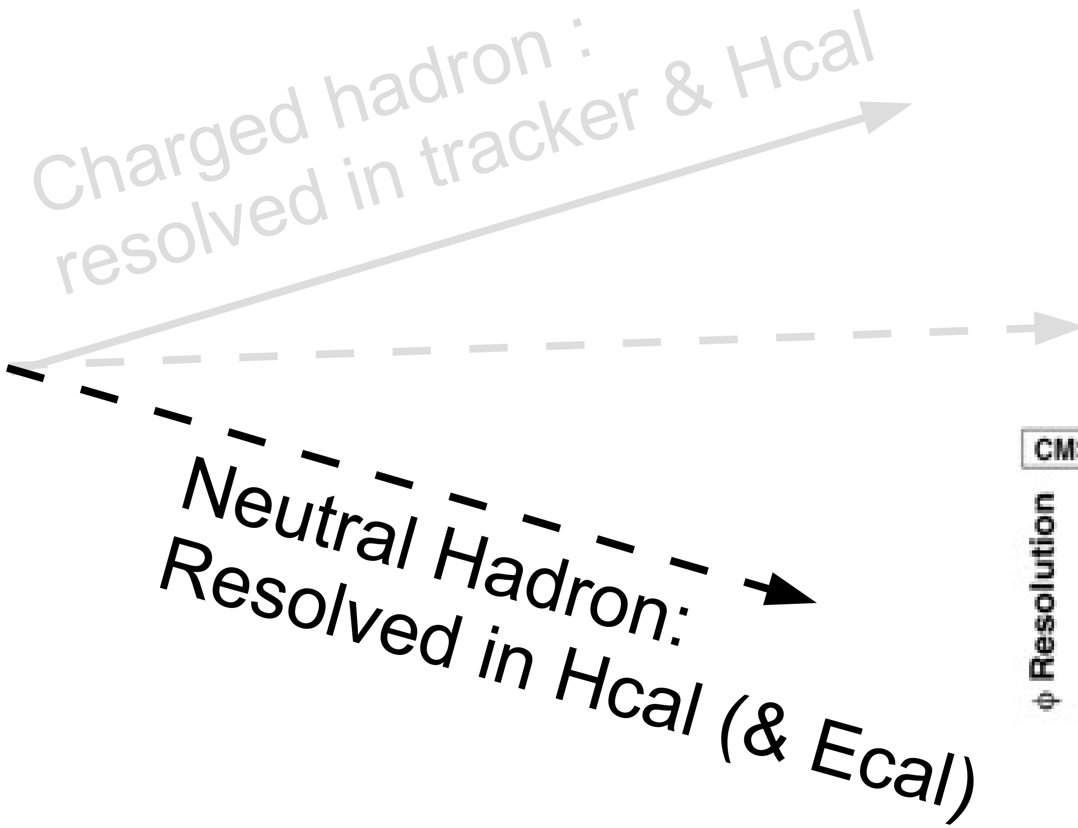


Shower in
0.06x0.06
cell(ηxφ)

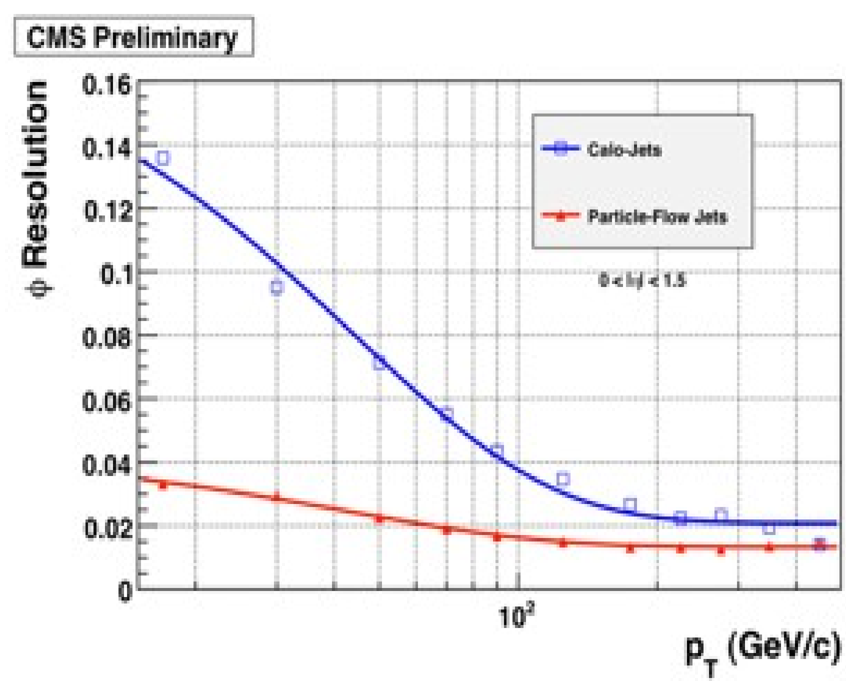
Difficult to resolve
electromagnetic shower
Beyond moliere raidus
$(0.02 \times 0.02) R_0 / R$

Detector resolutions

- Can classify jet by 3 types of particles :

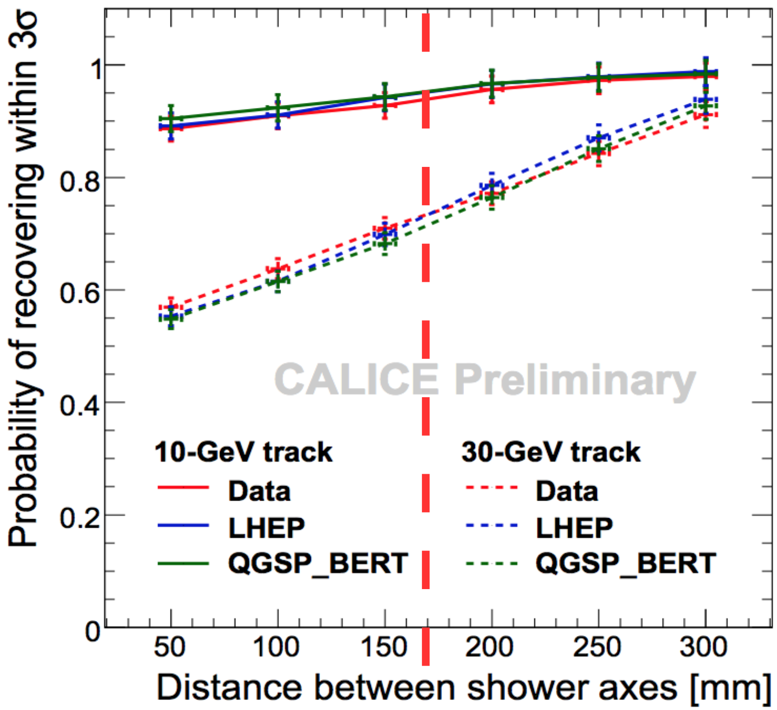


Angular resolution limited by nuclear interaction length?

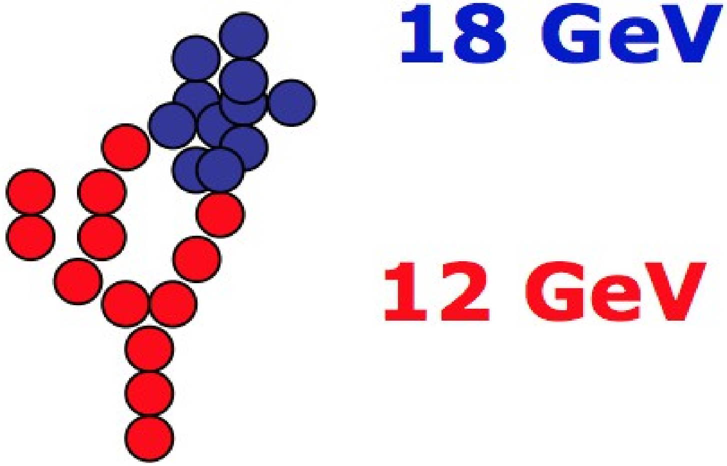


Separating the overlap

- How well can we separate overlapping particles?



Nuclear interaction length



Studies show we can get down to $0.7\lambda_I$

http://iopscience.iop.org/article/10.1088/1742-6596/293/1/012033/pdf

Key question :

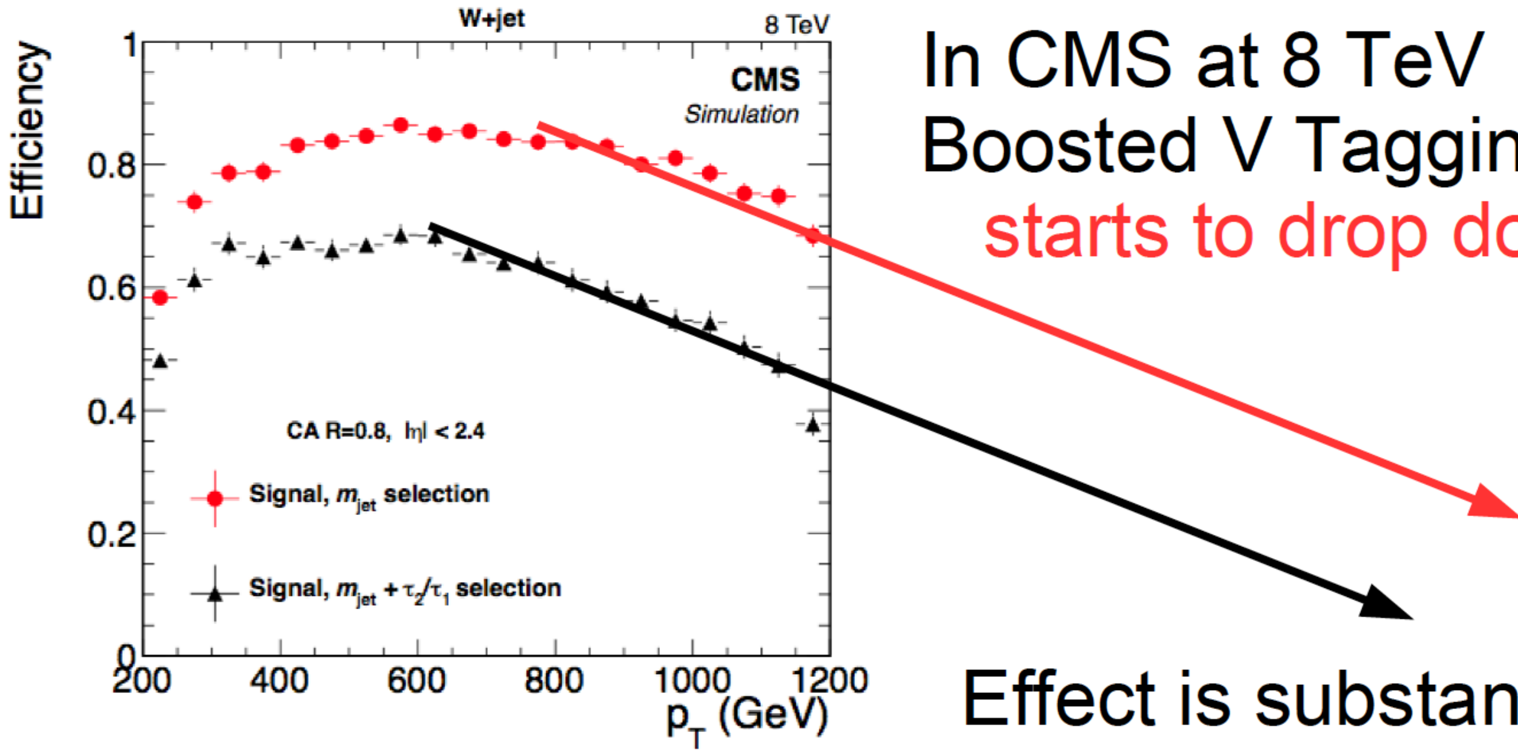
Can we exceed λ_I on the resolution of hadronic showers?

CMS is building a high granulirty calorimeter (this will help)

Super Boosting at LHC

Story from CMS

- Lets recount a story from last year



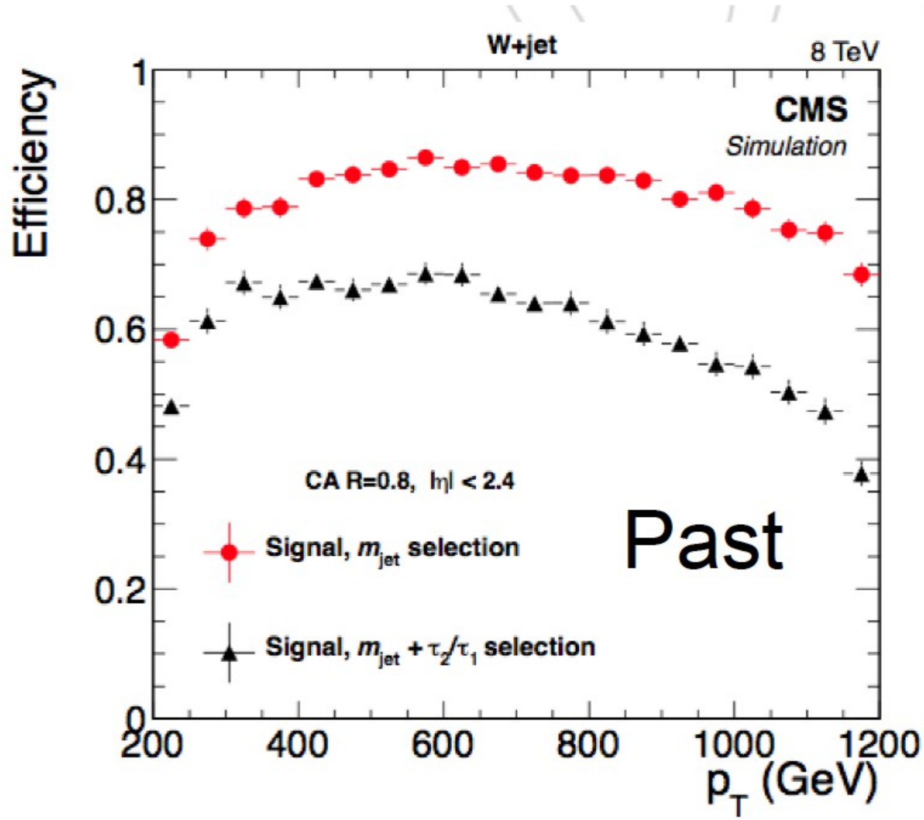
In CMS at 8 TeV
Boosted V Tagging Efficiency
starts to drop down

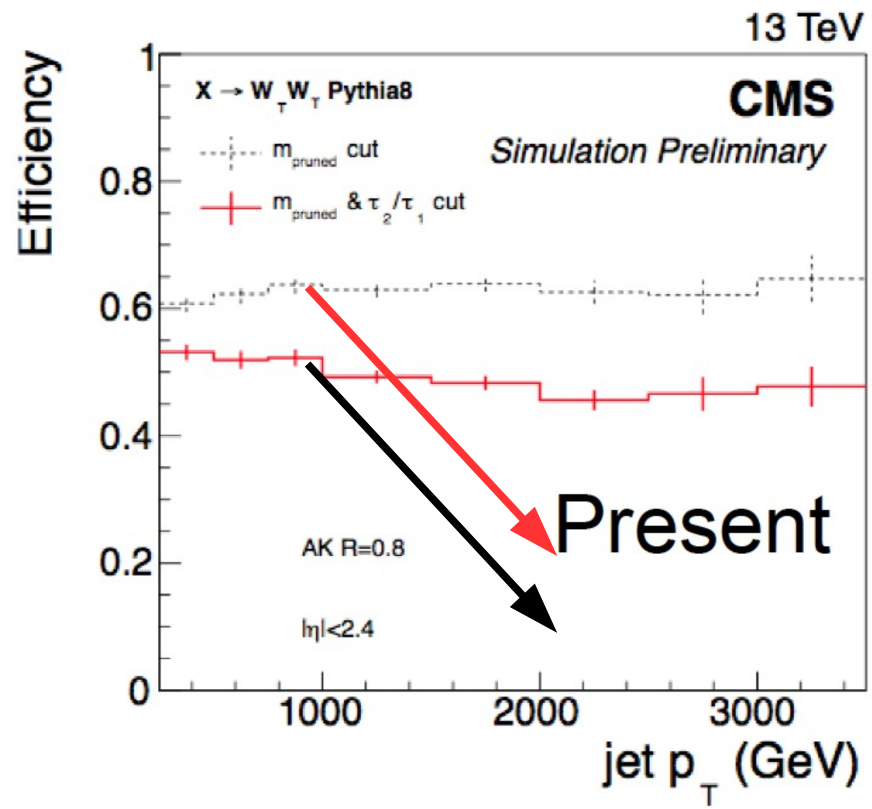
Effect is substantial at high p_T

Was a major concern from Run II jet reconstruction

CMS-JME-14-002

Story from CMS





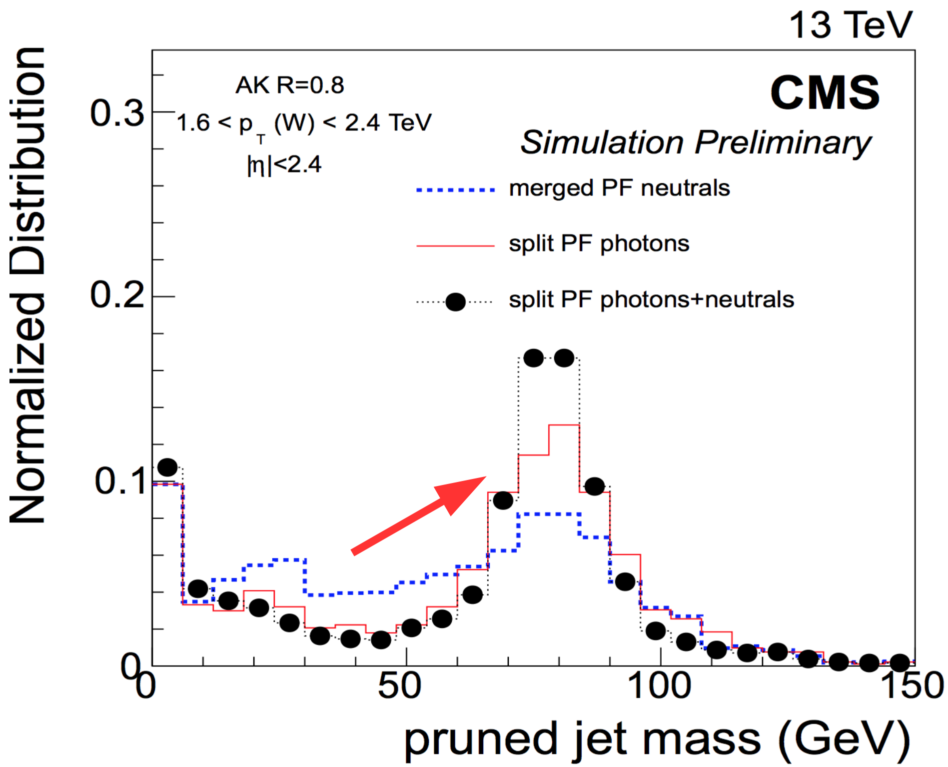
Gain came from splitting Hcal cell with Ecal

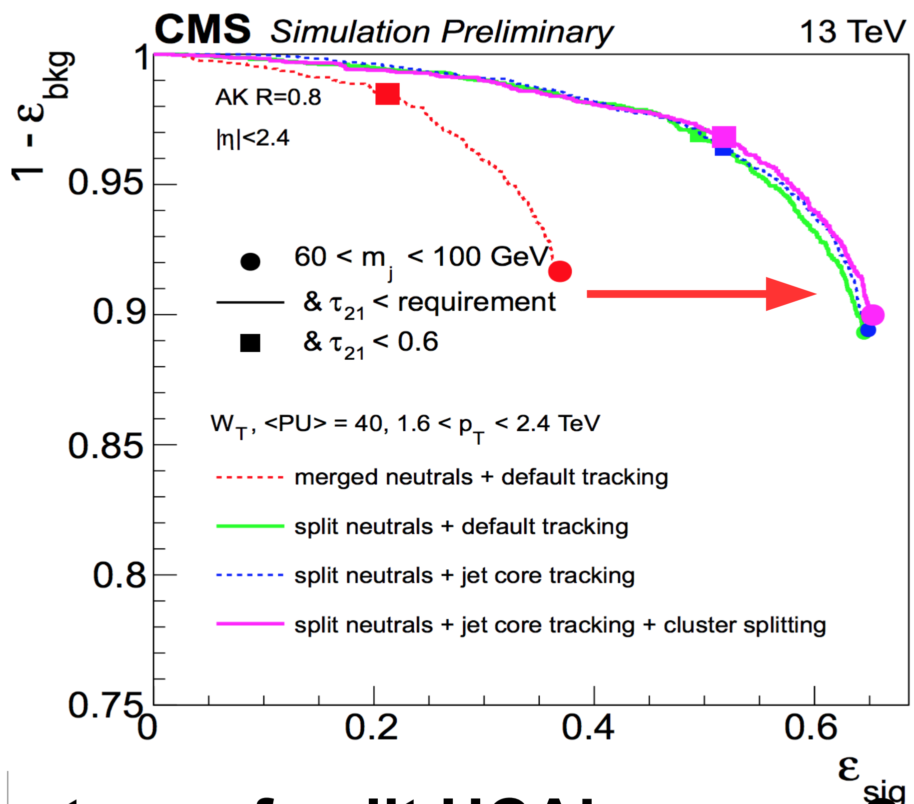
CMS-JME-14-002

Ultimate limit at LHC

- Final granularity in CMS :
  - 0.05x0.05 for Hcal
  - 0.04x0.04 for Ecal
  - 0.01x0.01 for Tracker

Sufficient up to 4 TeV





Question : Are we really taking advantage of split HCAL energy ?

Detector Specs: Generic scenarios

A Detector for Boost

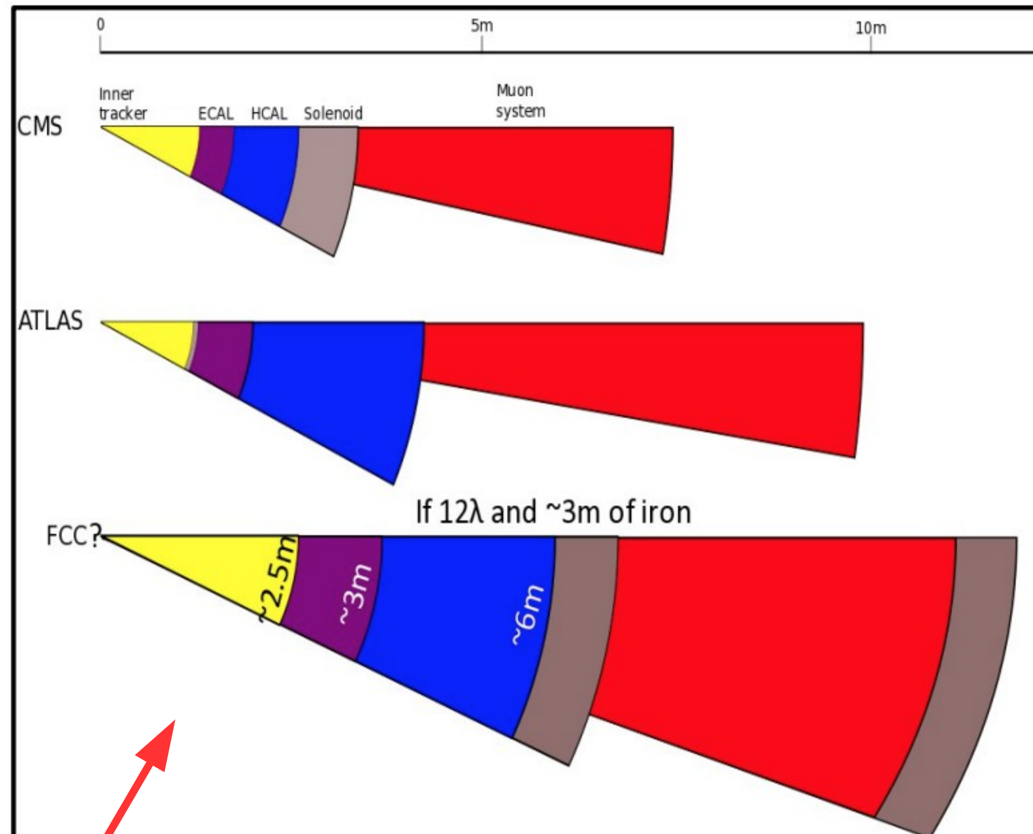
- Granularity has long been a concern

SSC calorimeter (1986)

<u>4π Calorimeter Parameters</u>

Electromagnetic thickness	$25\ X_0$,	$\sim 1\lambda \pm 5X_0$
Precision Hadronic	5λ	
Total Precision EM + Hadr.	6λ	$\pm 1\lambda$
Hadronic tail catcher	6λ	$\pm 1\lambda$
Total	12λ	$\pm 2\lambda$
Transverse Segmentation		
EM $\Delta y \times \Delta\phi$	.03 x .03	$\pm$ .01
Hadronic $\Delta y \times \Delta\phi$	.06 x .06	
Tail Catcher $\Delta y \times \Delta\phi$	.06 x .06	
Longtitudional Segmentation		
EM	3	$\pm$ 1
Hadronic	2	$\pm$ 1
Tail Catcher	2	$\pm$ 1

Detectors for the SSC: Summary report - Williams, H.H. In *Snowmass 1986, Proceedings, Physics of the Superconducting Supercollider* 327-349



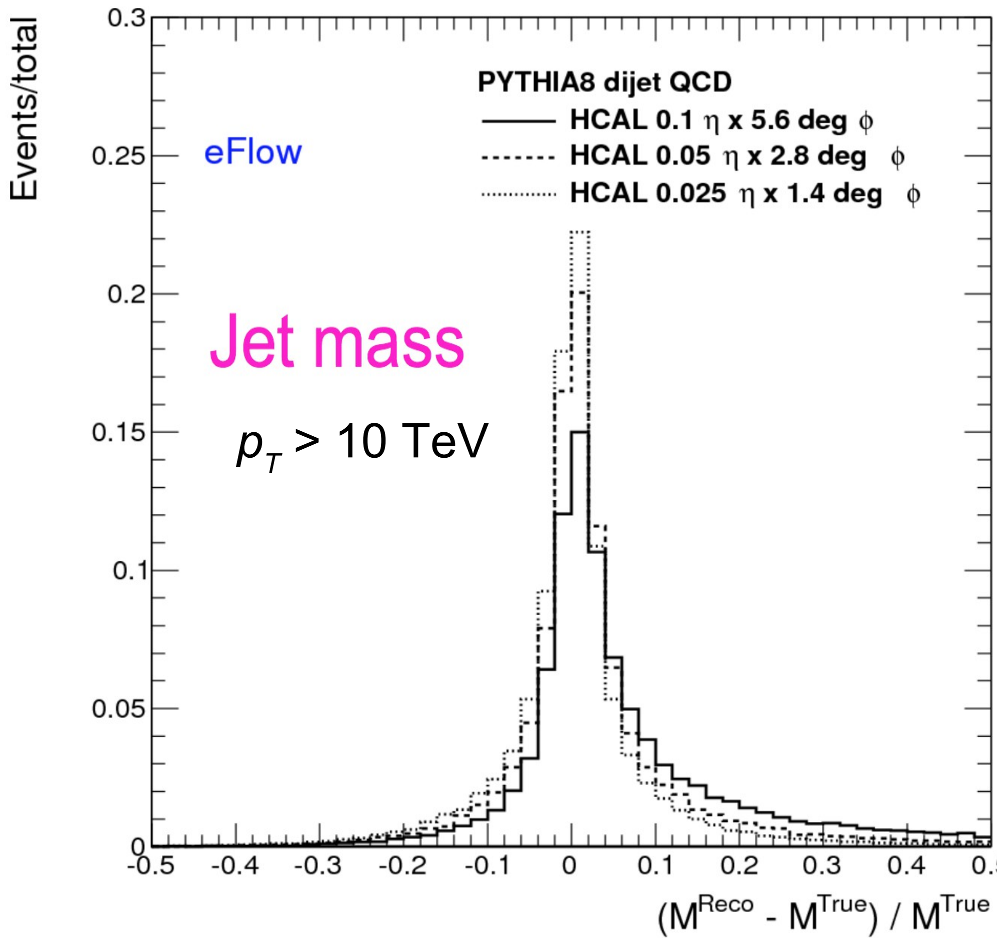
C.Barnet, C.Helsens

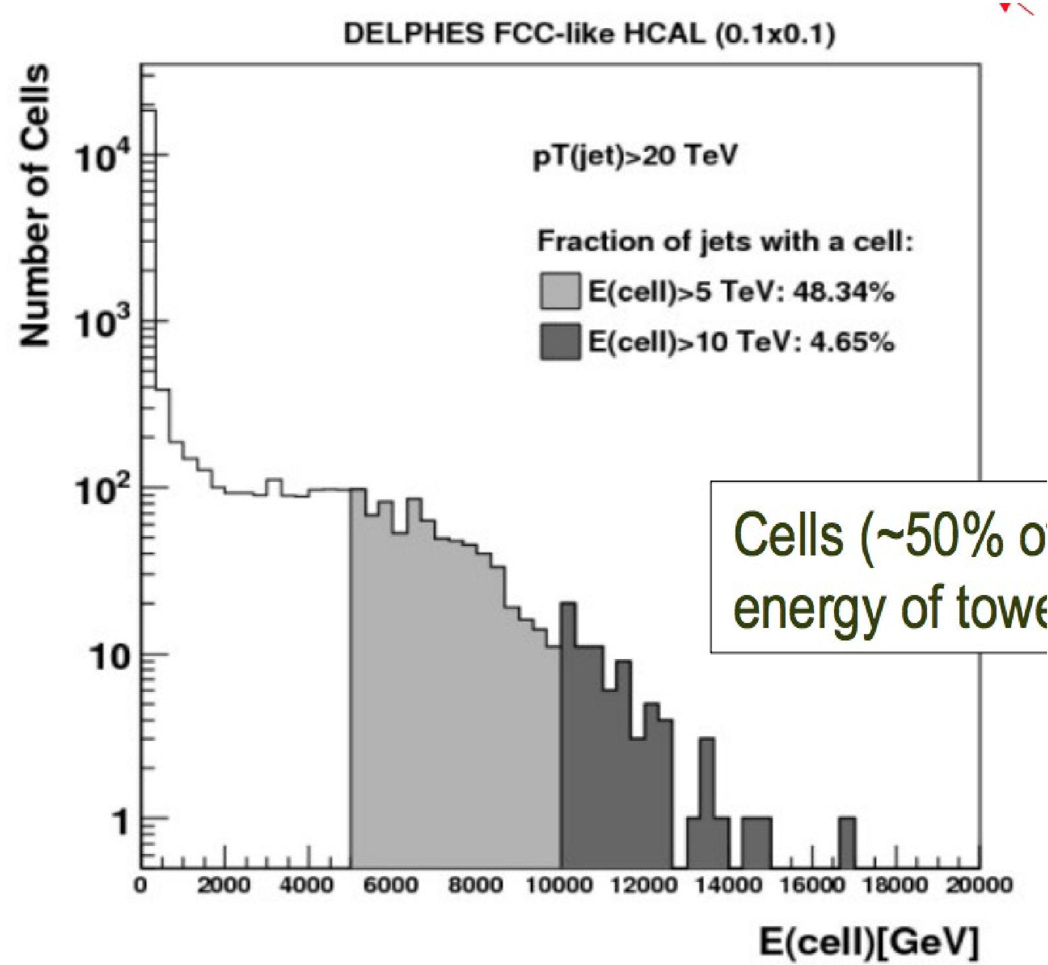
Scaling of the detector will drive our position resolution

S. Chekanov (https://indico.cern.ch/event/382815/session/20/contribution/35)

A Detector for Boost

- Fine granularity mass resolution improved by 30%



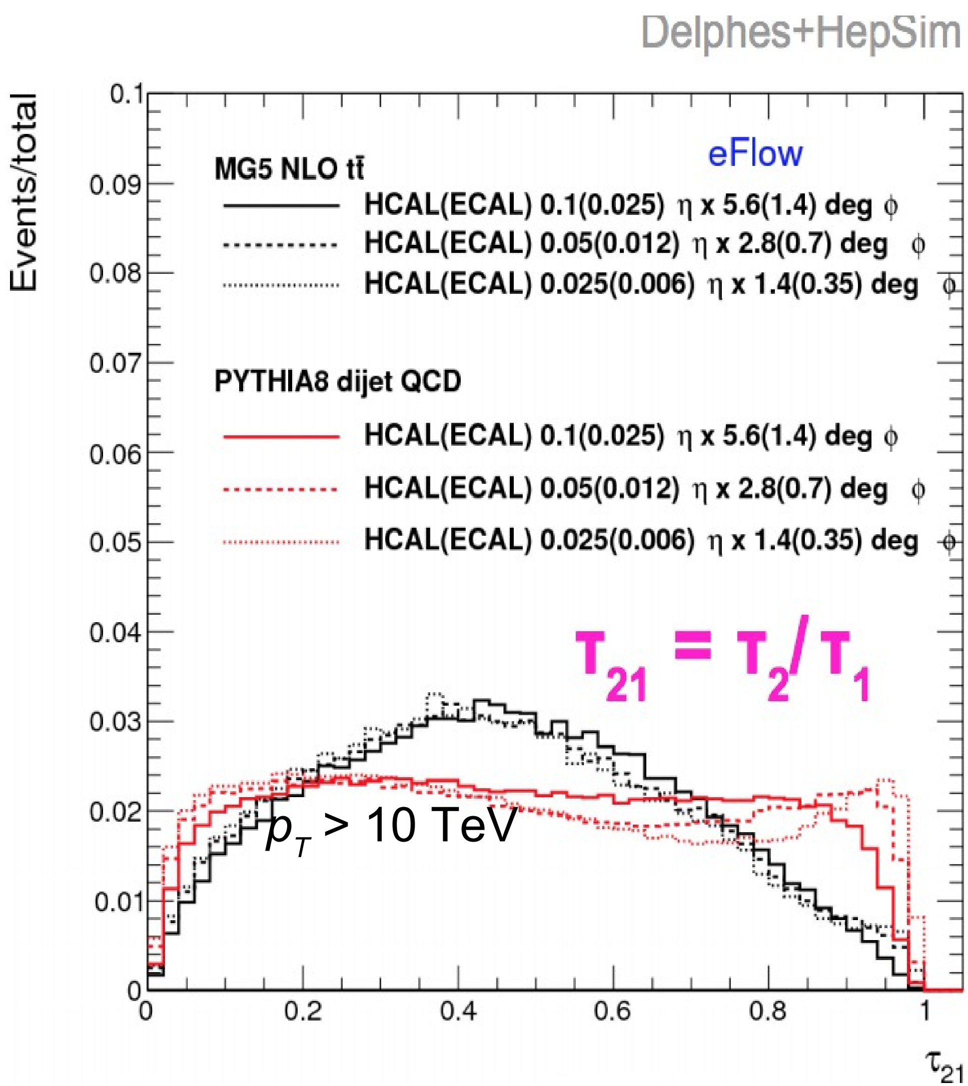


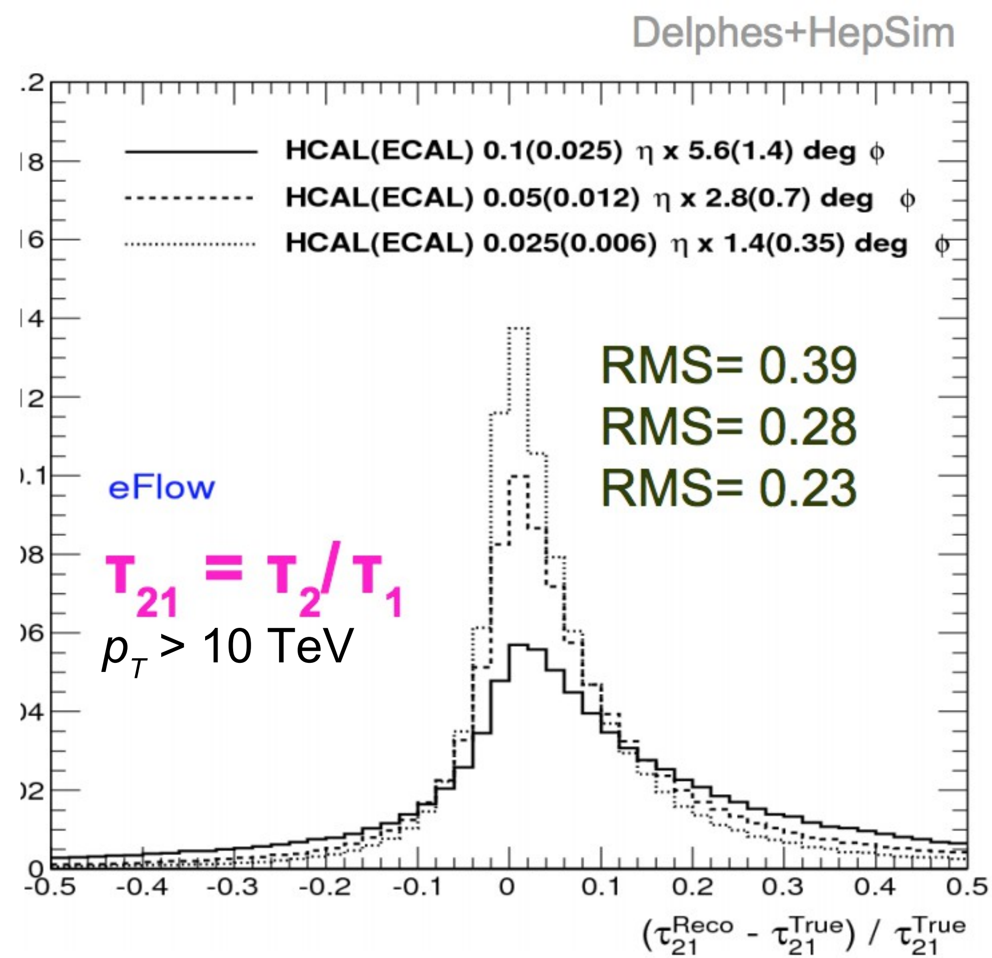
Full dynamic range of detector from 1 GeV to 15 TeV

S. Chekanov (https://indico.cern.ch/event/382815/session/20/contribution/35)

A Detector for Boost

- Gains more substantial on substructure observables





S. Chekanov **(https://indico.cern.ch/event/382815/session/20/contribution/35)**

Detector Specs: Worst case scenario

How do we build an Algorithm?

- Reconstruction improved with a dynamic-R cone
  - Reduces the impact of additional radiation
  - Choose cone to recover the boosted jet mass

    $R=4m_X/p_T$ m_X = resonance mass

- Can we build a boson tagger just out of tracking?
  - Rescale by :

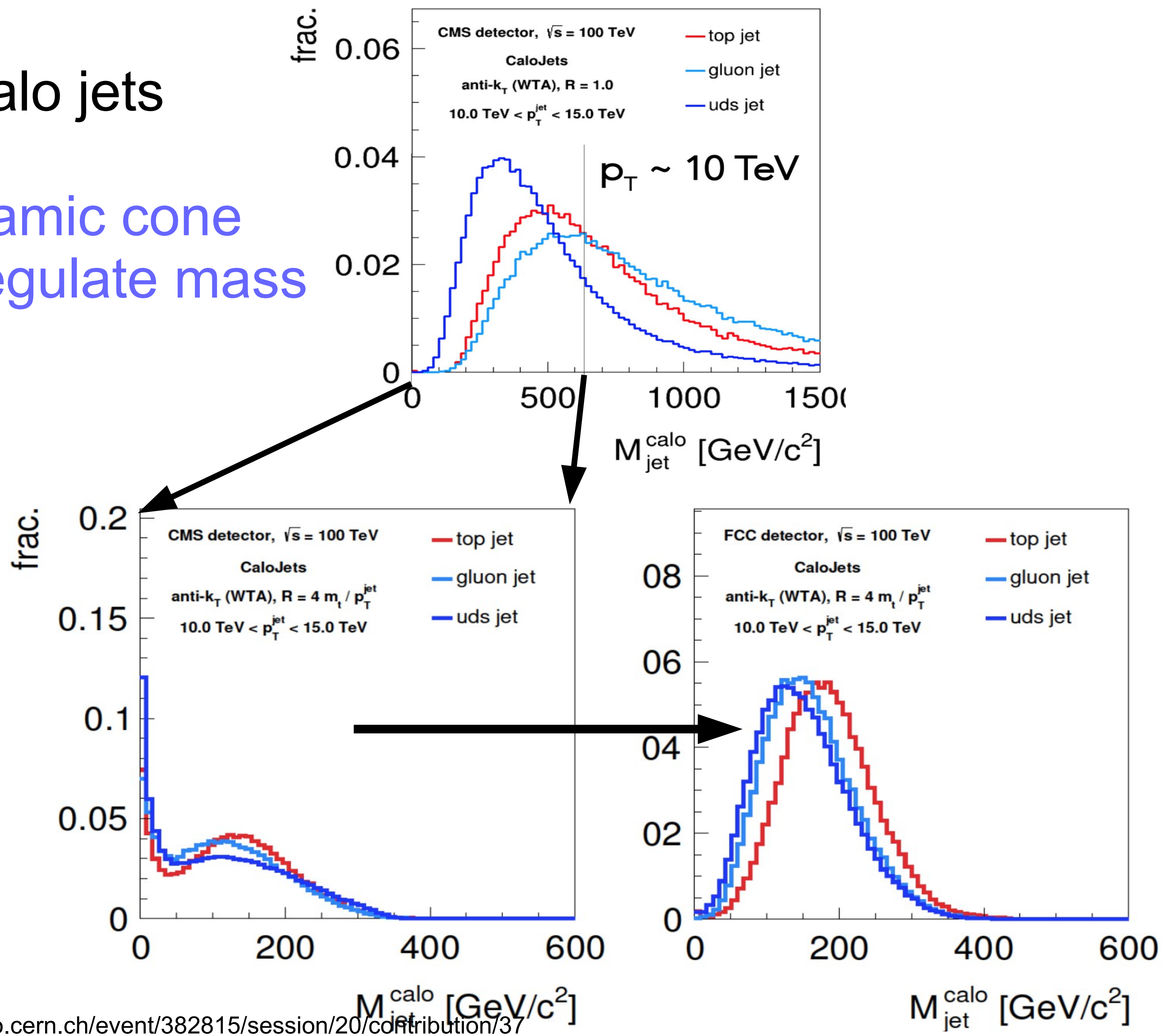
    $p_T^{Total}/p_T^{charged}$

  - This will ensure robustness in a future detector
  - Very pessimistic
    - Assumes calorimeters cannot resolve anything

Dynamic cone and Reconstruction

Consider calo jets

Use of dynamic cone
Helps to regulate mass

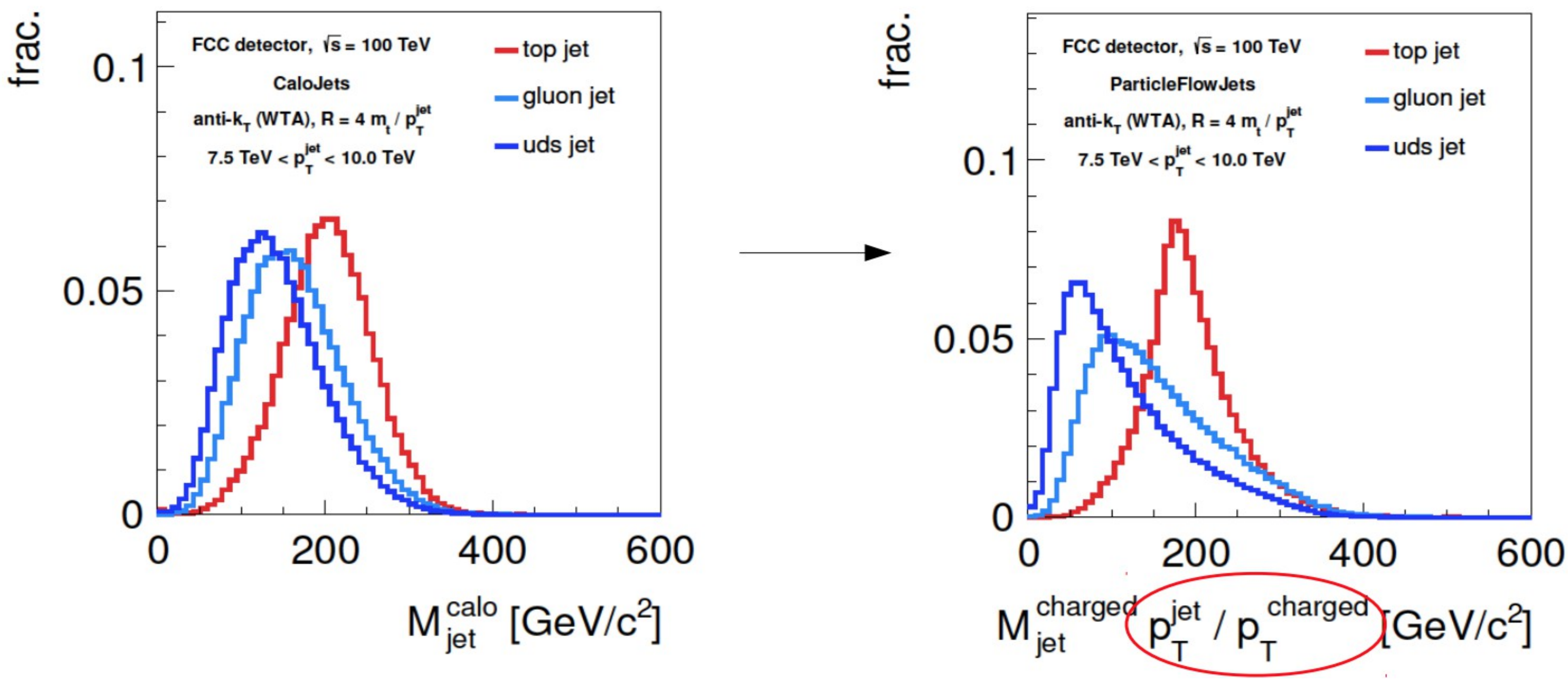


What if don't use calo granularity?

- Rely on tracks to get the shape of discriminators

Calorimeter based jet Mass

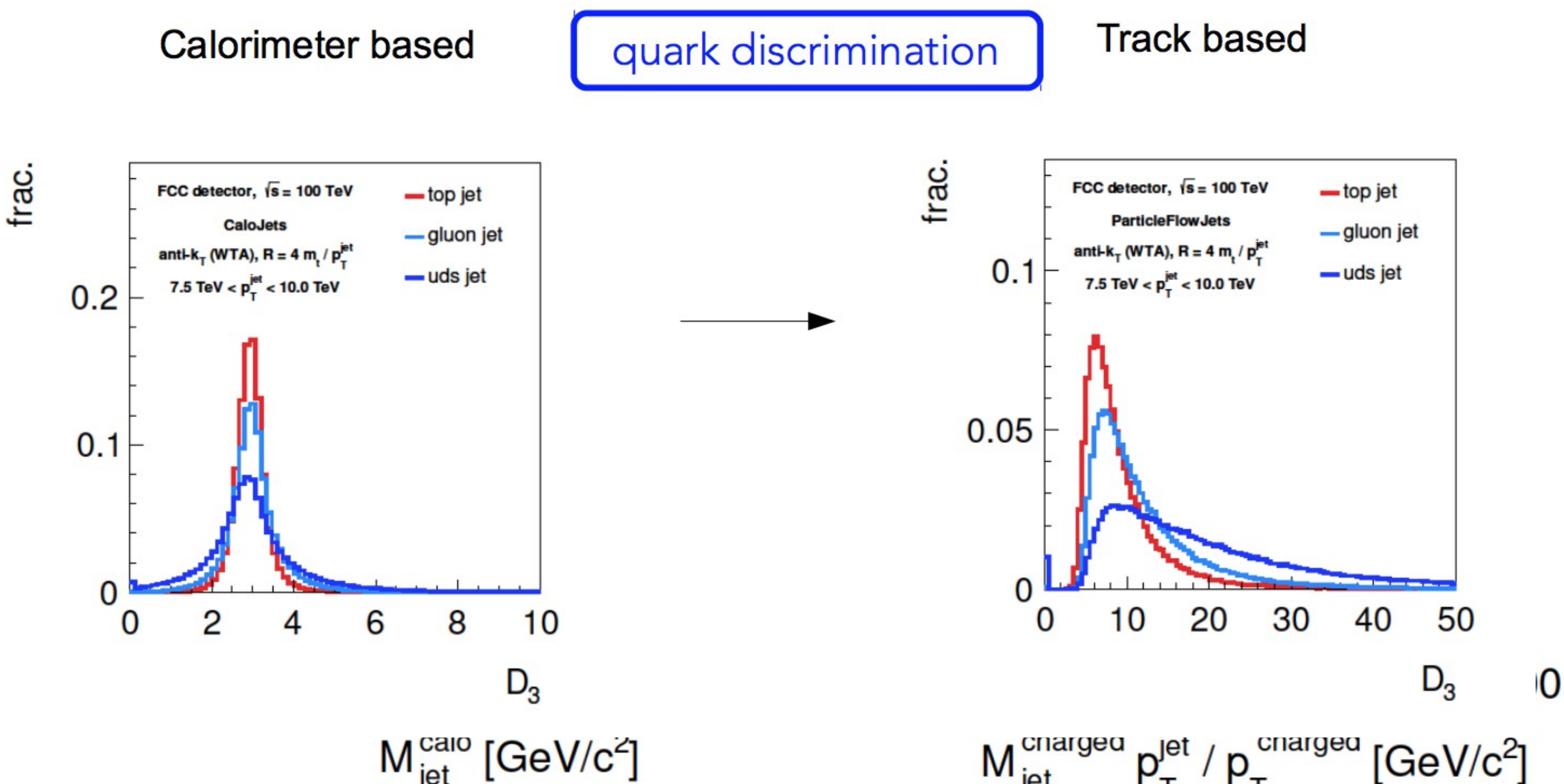
Track- based jet Mass



Mass discrimination gives a noticeable improvement

What if don't use calo grnaularity?

- Rely on tracks to get the shape of discriminators



Track based variables effective for jet shape discrimination

M.Selvaggi https://indico.cern.ch/event/382815/session/20/contribution/37

Detector Specs: In between scenario

Simplifying Concerns

Finite resolution

(typical lengths, in ATLAS , CMS & future cal [CALICE] being 20–30 cm)

- Smaller scales cannot be resolved in the hadronic cal. (HCAL)!

- For any given detector exists minimal angular scale:

$$\theta_{\rm had} \approx \frac{d_{\rm had}}{r_{\rm HCAL}} \approx 0.1 \times \frac{\lambda_{\rm HCAL}}{20\,{\rm cm}} \times \frac{2\,{\rm m}}{r_{\rm HCAL}}$$

θ_{had}=0.05-0.1

(muon-cal+magnets => hard to imagine $r_{\rm HCAL}$ > 1-2 meters)

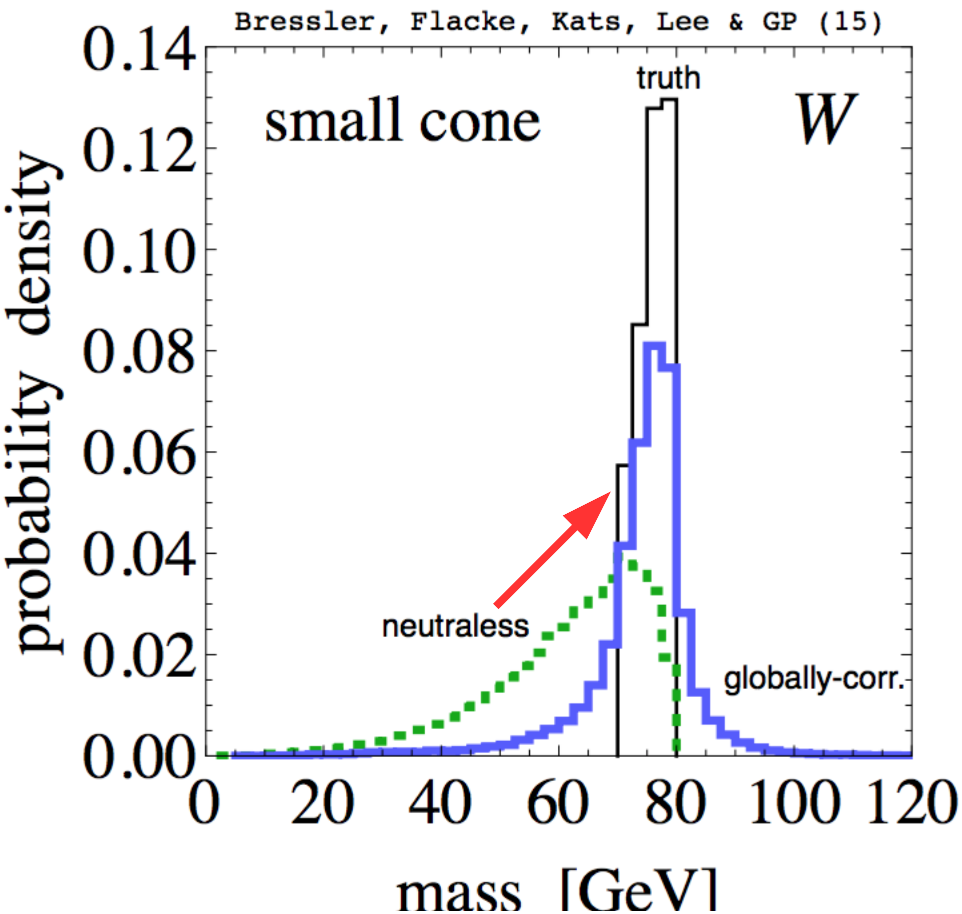
In place of all neutrals consider neglecting the granularity of hadronic neutrals

Without the HCAL: $m^2_{12,\not N} = (1 - f^1_N)(1 - f^2_N)\, m^2_{12}$

Fraction from Hcal

G.Perez (https://indico.cern.ch/event/382815/session/20/contribution/36)

- Global correction: $m_{12,\mathrm{corr}} = \frac{\sum_i E_i}{\sum_i \left(1 - f_N^i\right) E_i} m_{12,\not N}$,



Further gains exploiting
Energy fraction of neutrals (f_N)

Heavy flavor W and top decays have more neutrals

$f_N^{W\to cs} / f_N^{q=ud} = 1.5$

$$\langle f_N^{W\to c\bar{s},\ W\to u\bar{d}/QCD} \rangle = 21, 14, \quad \delta f_N^{W\to c\bar{s},\ W\to u\bar{d}/QCD} = 16, 14$$

G.Perez (https://indico.cern.ch/event/382815/session/20/contribution/36)

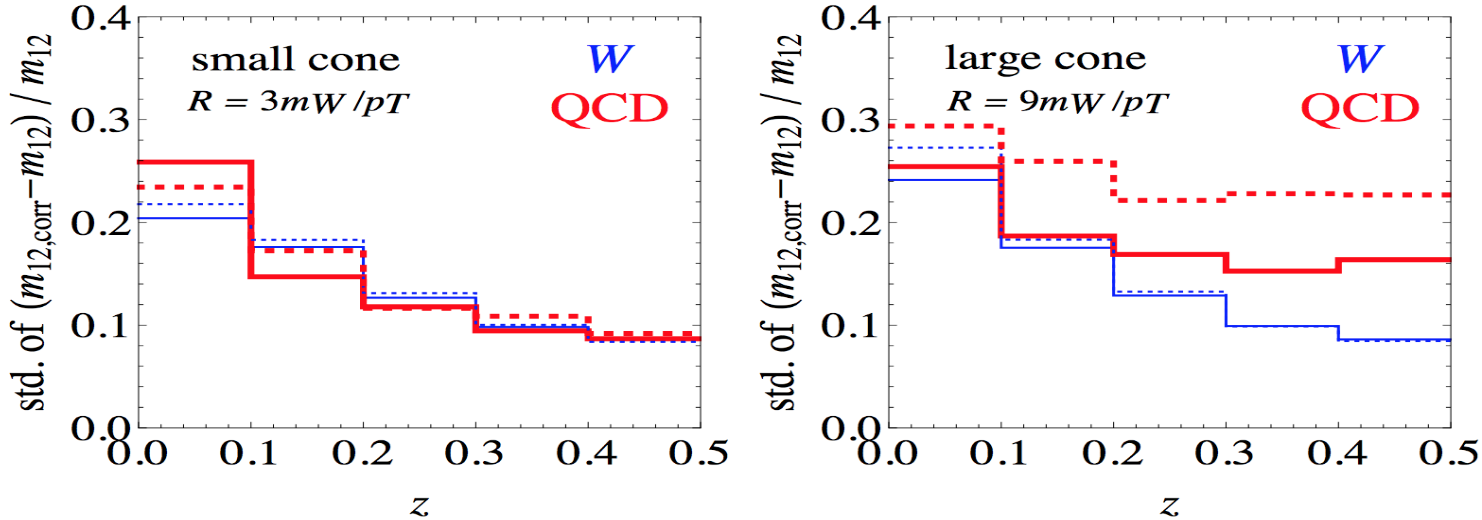
Beyond Boostin': New tools for taggers

J. Love **(https://indico.cern.ch/event/382815/session/20/contribution/38)**
G.Perez **(https://indico.cern.ch/event/382815/session/20/contribution/36)**

Exploiting the size of a jet

- Known that the size/type contains discrimination
- M.Selvaggi *et al* :
  - Use dynamic cone size reconstruction
- G. Perez *et al* :
  - Play large cones of small cones to discriminate QCD

Bressler, Flacke, Kats, Lee & GP (15)



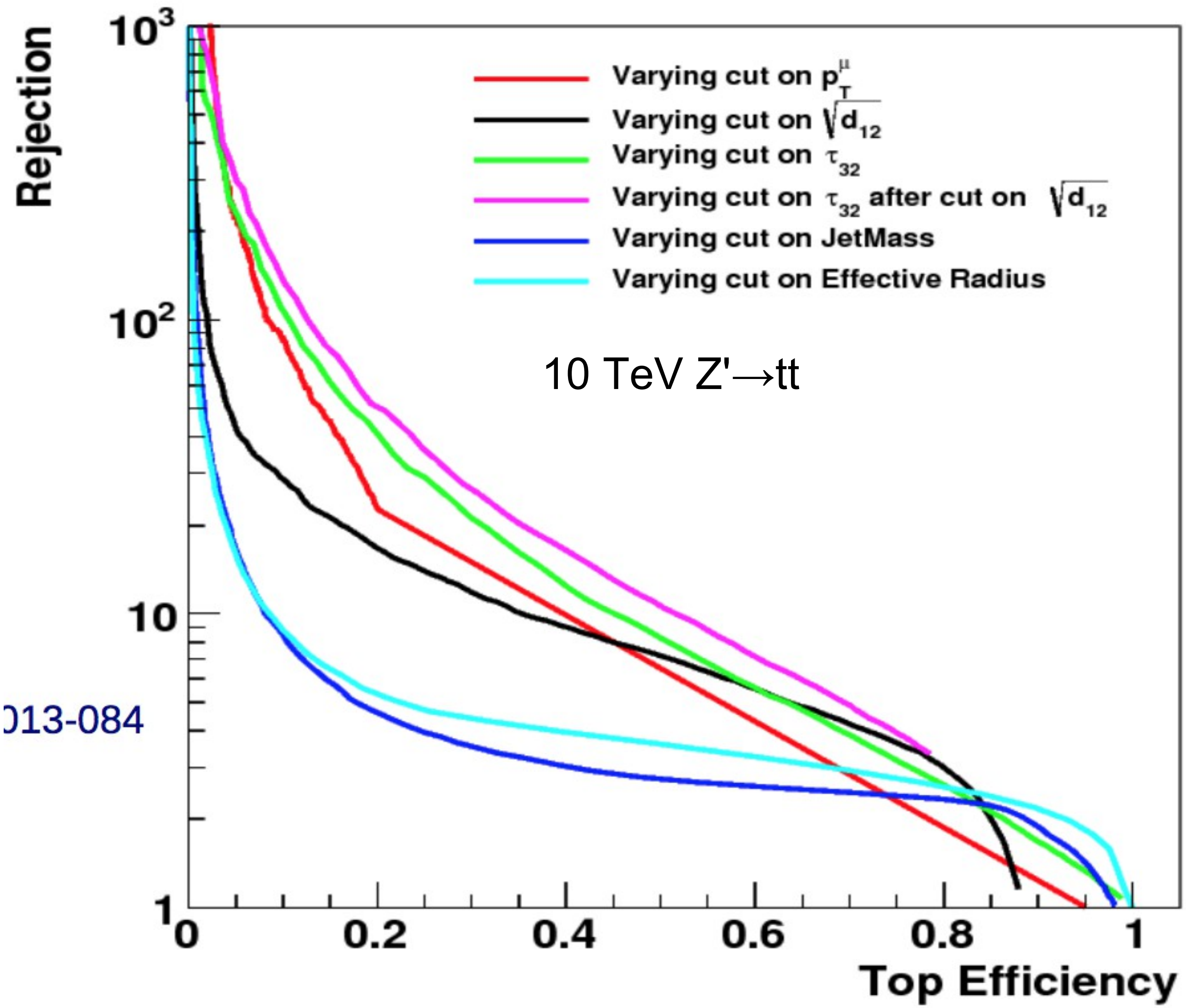
jet mass (truth mass = 75 ± 5 GeV), jet pT = 3 TeV (solid) , 10 TeV (dotted).

- M. Pierini *et al* (not @ boost) :
  - Use (τ) iso-like variables

(http://indico.cern.ch/event/352868/session/5/contribution/21/attachments/698937/959672/XVV_substructure_Mar2015.pdf)

How do Standard variables compare?

- Consider tagging tops w/Standard approaches



ATLAS-like top tagging

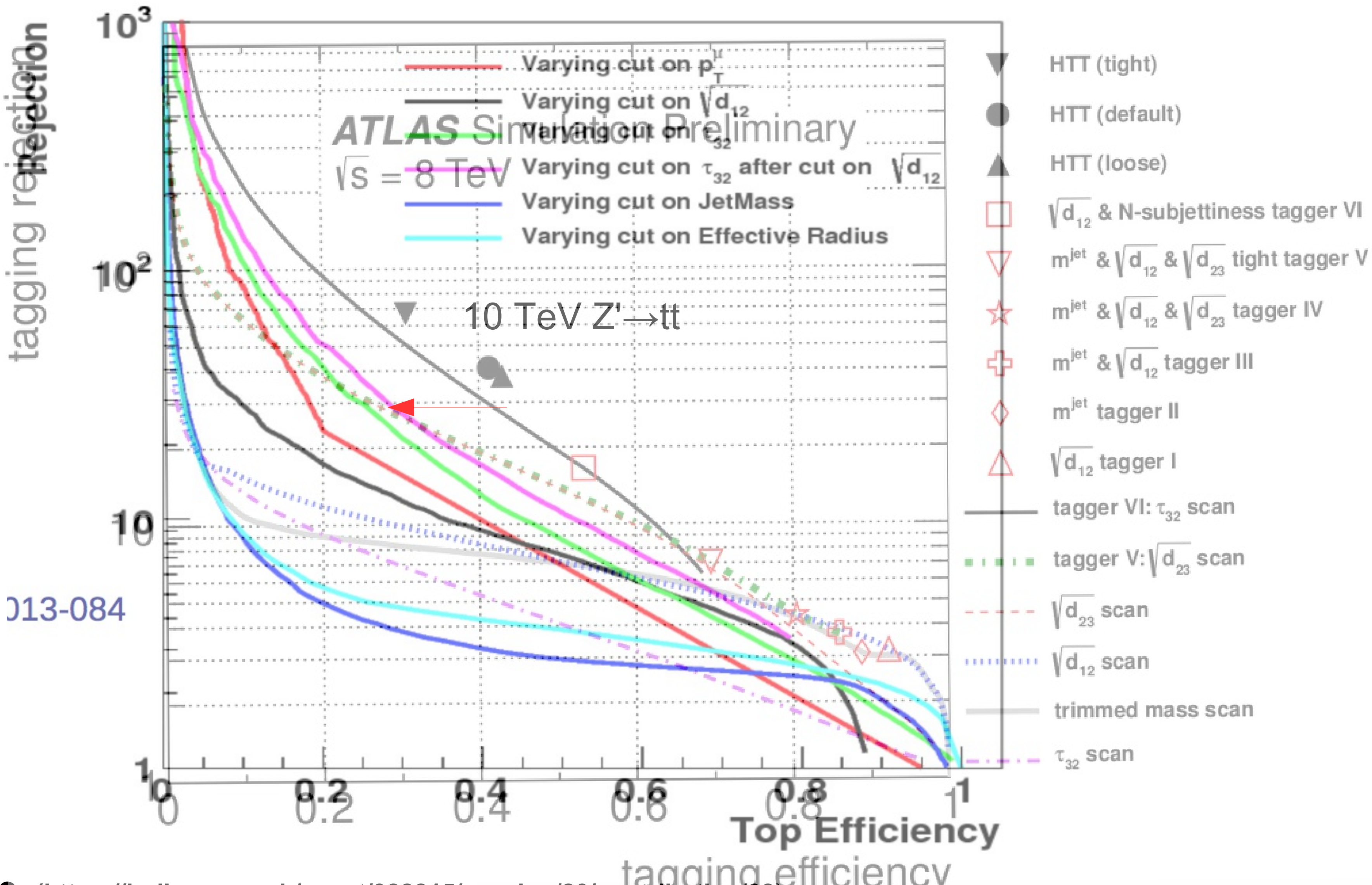
With a pefect detector

For 5 TeV tops

J. Love (https://indico.cern.ch/event/382815/session/20/contribution/38)

How do Standard variables compare?

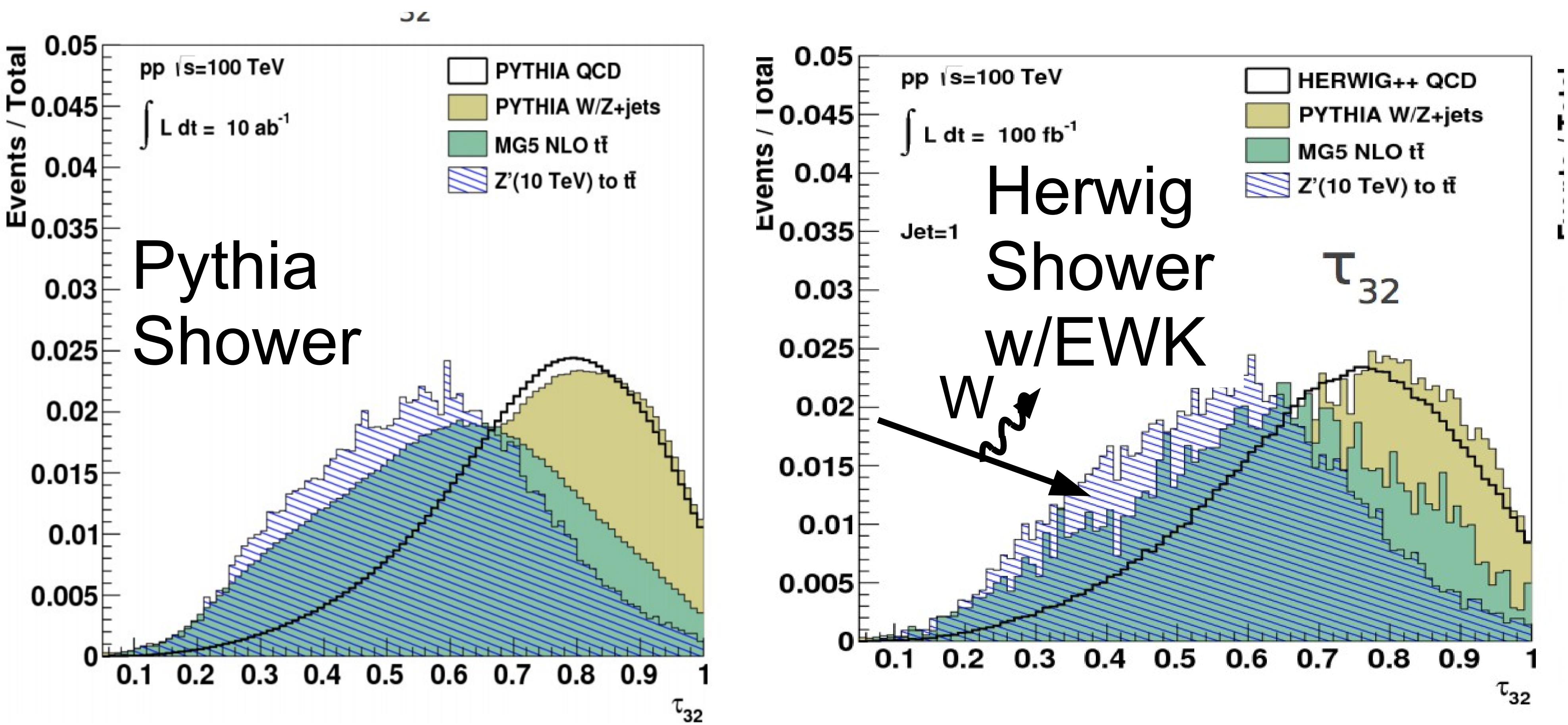
- 10-20% loss of efficiency wrt to ATLAS perf



J. Love (https://indico.cern.ch/event/382815/session/20/contribution/38)

How do different PS models compare?

- No fundamental difference in the showering
  - Herwig or Pythia give a consistent picture to the model
  - EWK shower does not appear to change picture



Discussion Points

- Few key ideas are needed to build understanding:
  - What is the limitation on neutral hadron granularity?
  - Is there an appropriate strategy for cone size?
  - Where can we gain experience from (HL-) LHC?
  - Can we rely on new observables?
  - Do we have an appropriate simulation to study?

Partial Answers

- Few key ideas are needed to build understanding:
  - What is the limitation on neutral hadron granularity?

    Anywhere from 3cm-20cm (θ_{had} from 0.01-0.1)
  - Is there an appropriate strategy for cone size?

    Small cones are good for mass/big for rejecting background
  - Where can we gain experience from (HL-) LHC?

    Limitations on detectors will be test even for high granularity
  - Can we rely on new observables?

    Current observables re-tuned/maybe new ones for big cone
  - Do we have an appropriate simulation to study?

    Delphes? But with a more defined hadronic shower gran

    Dealing with correlation between track and calo resolution

What do we put in the Delphes cards?

- Ganularity down to 0.01 in ΔR is critical
  - E/γ objects should go down to moliere raidus
  - Neutral hadorns : not clear
    - Aggressive number would be 0.5 λ_I (0.01)
- Energy sharing between Hcal and Tracker
  - Calorimeter resolution dominates for high p_T
    - Charged hadron pT (T) = track p_T w/plateau resolution at 5%
    - Remaining calo p_T (C) = C_{tot} – T
      - Leaves small energy neutral hadrons & degrades resolution
- Tracking confusion :
  - Nearby track efficiency needs a good parameterization

Backup

Dealing with Track eff in Delphes