Input to jet reconstruction: towers, clusters and topo-towers

Contribution to the Lisbon Hadronic Calibration Workshop

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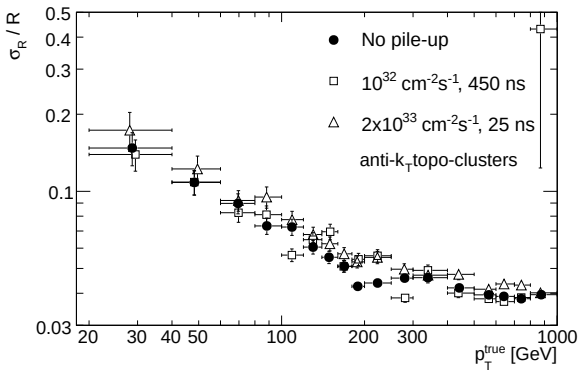
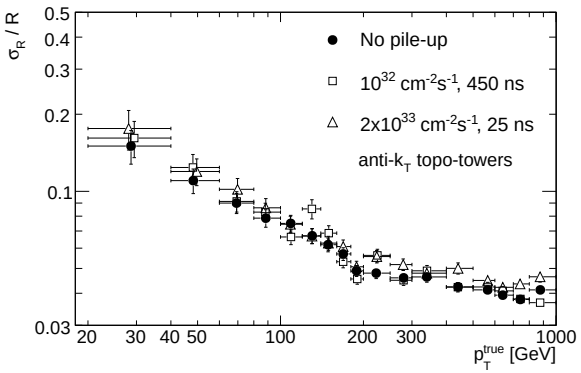
Fractional resolution for jets with different inputs

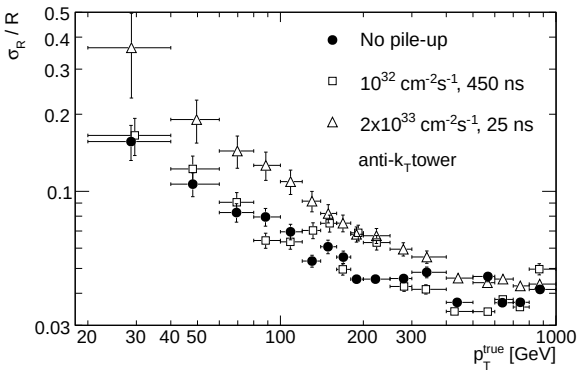
Compare different inputs at various luminosities



Topo-cluster



Topo-tower

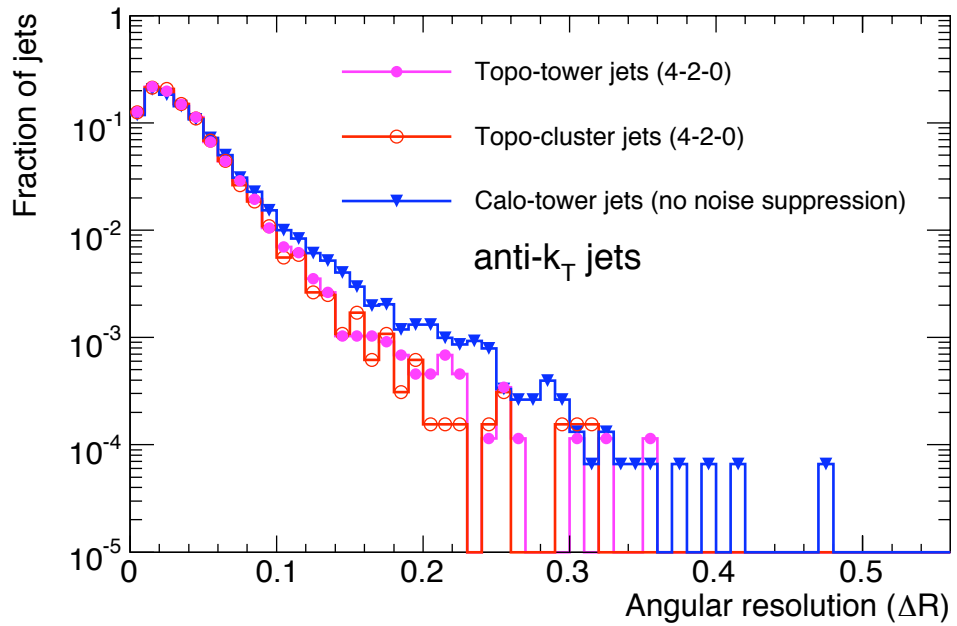


Tower

- Jets built from topo-clusters and topo-towers show very similar stability with respect to luminosity
  - This coincides with what I showed several months ago in only a single p_T bin without numerical inversion
- Tower jets continue to show the sensitivity to higher luminosity environment that we expect without noise suppression

Angular resolution in events with pile-up

Di-jet spectrum with $2 \times 10^{33} cm^{-2} s^{-1}$, 25ns bunch spacing

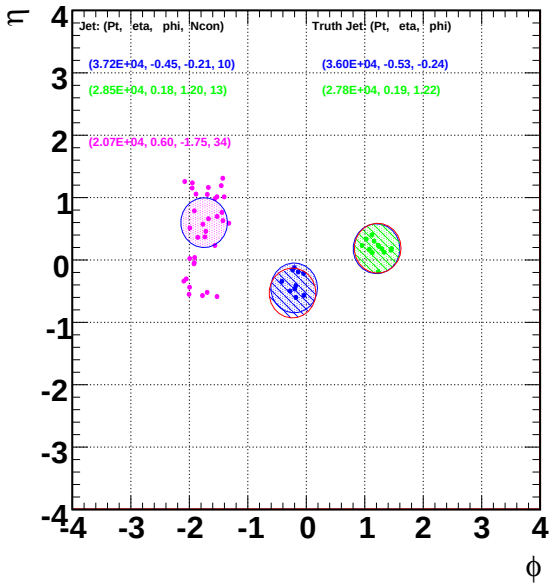


- Angular resolution is identical between topo-cluster and topo-tower jets
- Angular resolution is degraded for standard calo-tower jets
- Both true, even at this "high" luminosity

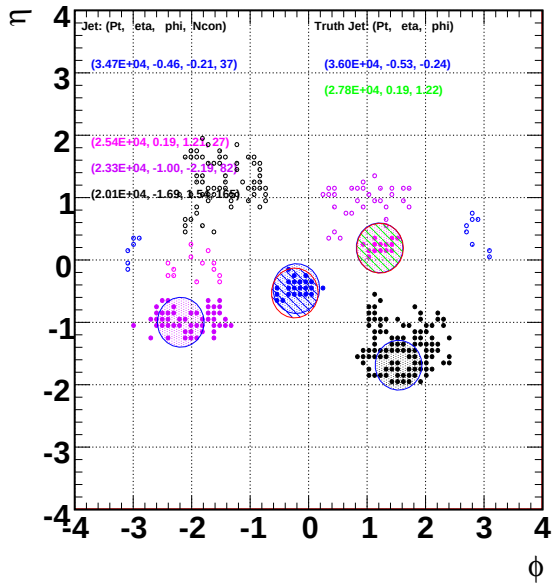
Single J2 event with pile-up at $2 \times 10^{33} cm^{-2} s^{-1}$

Event #179 in `valid1.105011.J2_pythia_jetjet.recon.ESD.e344_s479_d140_r576`

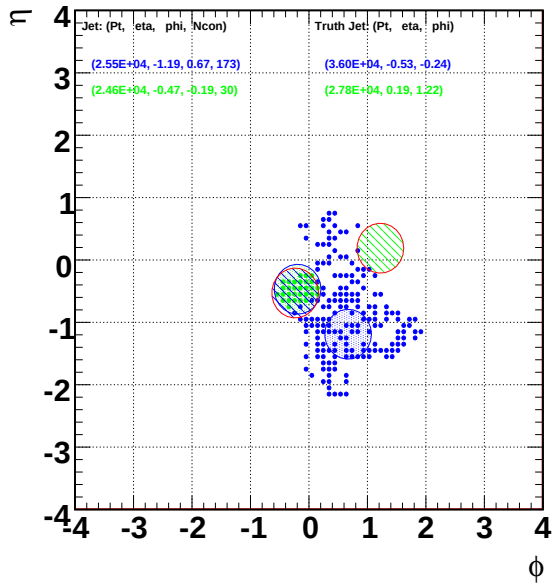
SISCone4H1Topo

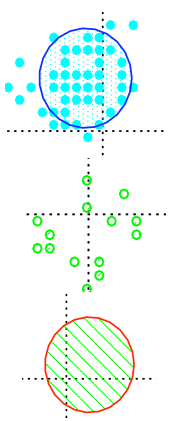


SISCone4H1Tower



SISCone4TopoTower





Reconstructed jet with its constituents

Negative energy jet constituents (open circles)

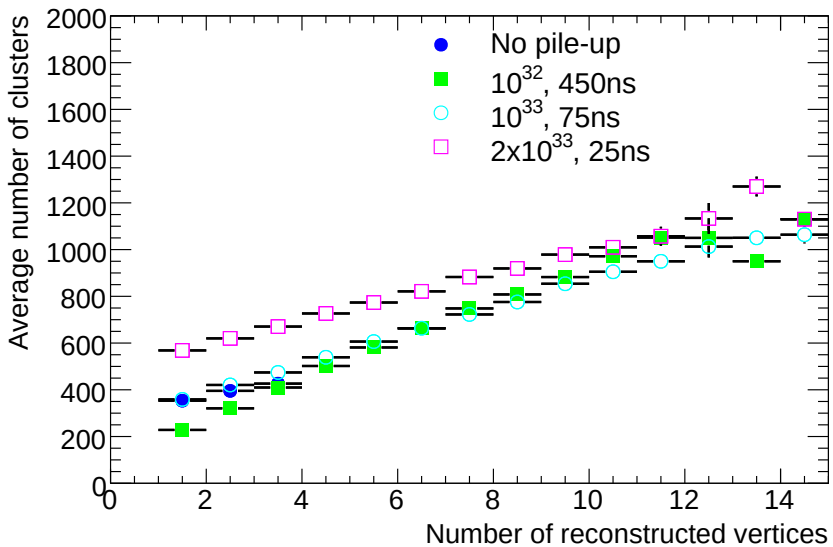
Truth jet

SIS-cone jets

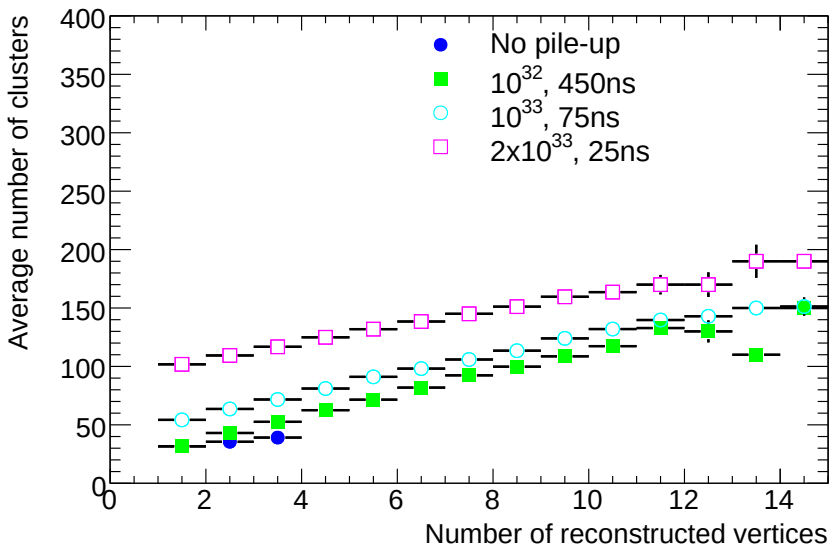
∴ Completely different picture depending on jet input

Cluster properties: multiplicity vs. N_{PV}

Di-jet spectrum at various luminosities and bunch spacing



Full η range

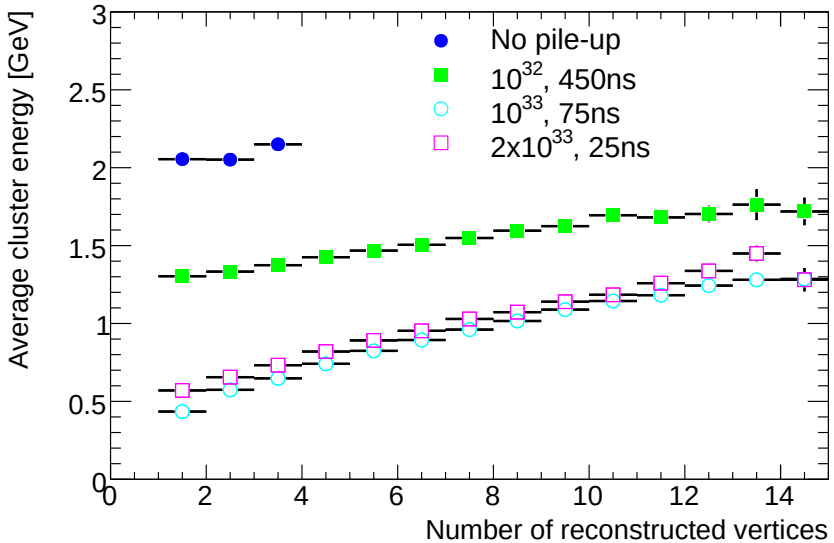


Clusters within $|\eta| \leq 0.5$

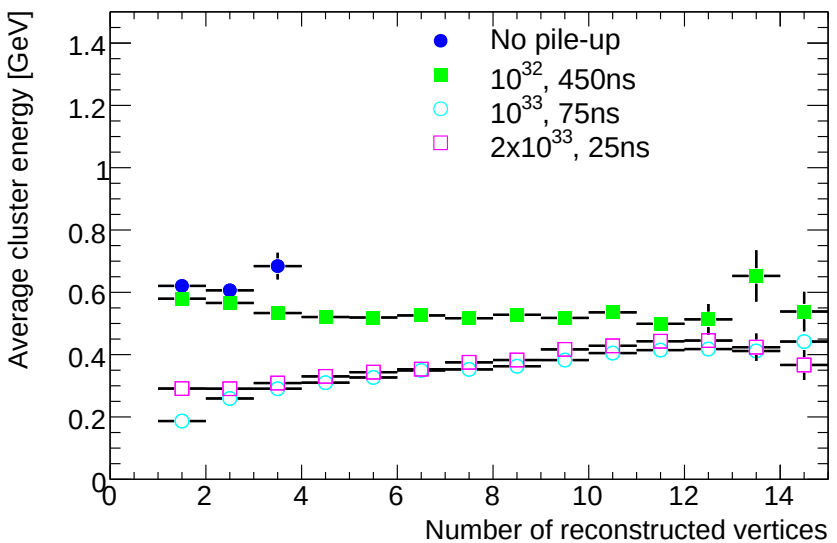
- Many more clusters as the instantaneous luminosity increases, both in central region and forward region
  - Forward region more dramatic
- Large cluster splitting may be difficult to model, especially in this kind of busy environment

Cluster properties: cluster p_T vs. N_{PV}

Di-jet spectrum at various luminosities and bunch spacing



Full η range

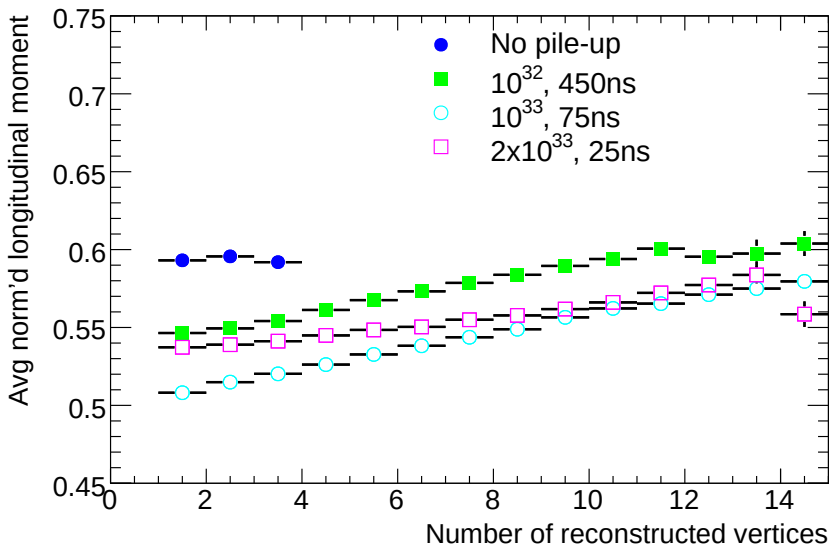


Clusters within $|\eta| \leq 0.5$

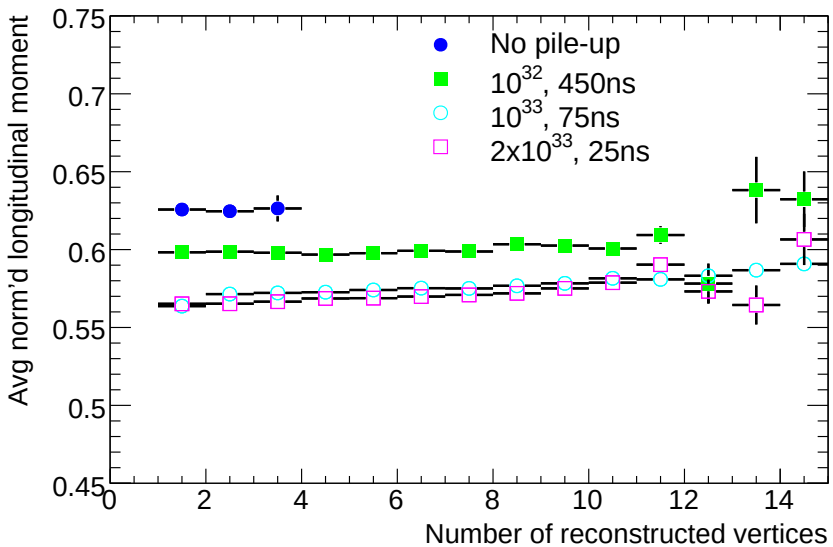
- These clusters are all **very** low p_T
  - Factor 1/3 the p_T of clusters in events without pileup
- Although very small, the average cluster p_T is still growing even in the central region as a function of N_{PV}.
- More particles are contributing to a single cluster

Cluster properties: average longitudinal moment vs. N_{PV}

Di-jet spectrum at various luminosities and bunch spacing



Full η range

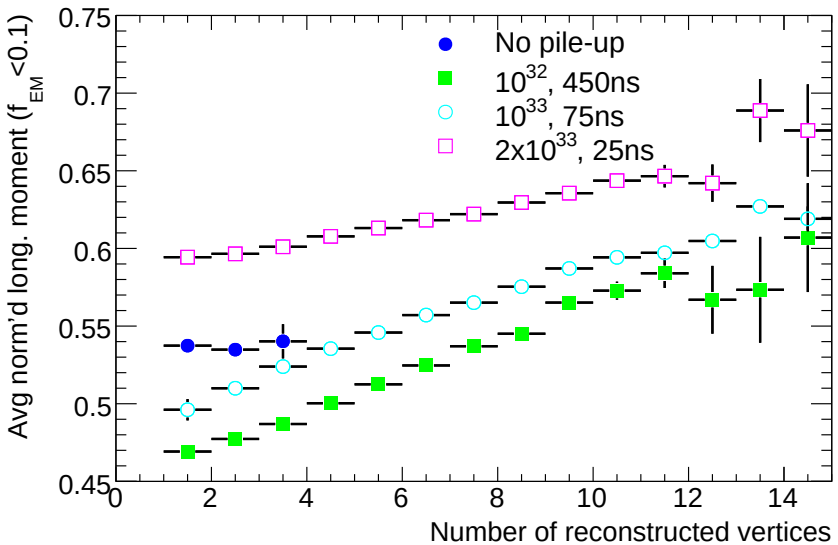


Clusters within $|\eta| \leq 0.5$

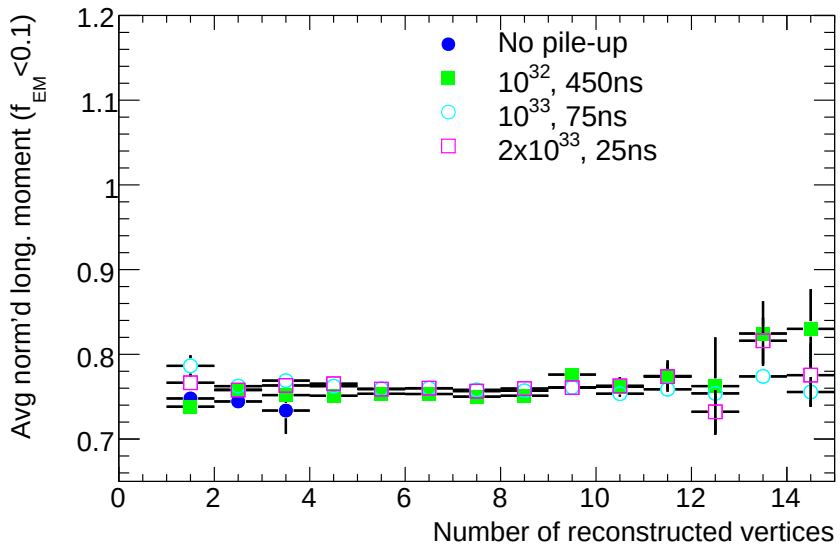
- Smaller clusters, whose size changes as a function of the instantaneous luminosity for all average luminosities
  - Increase of 20% between lowest and highest vertex multiplicity
- The cluster growth is clearly a larger effect in the forward region than central
- Still present, but very subtle, in central region

Cluster properties: average longitudinal moment vs. N_{PV} (hadronic clusters)

Di-jet spectrum at various luminosities and bunch spacing



Full η range

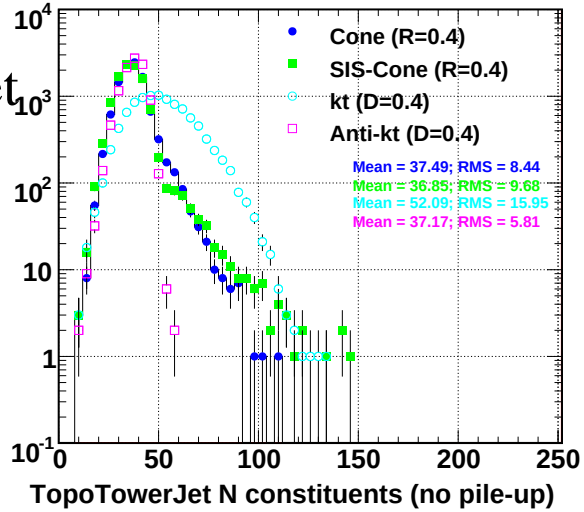


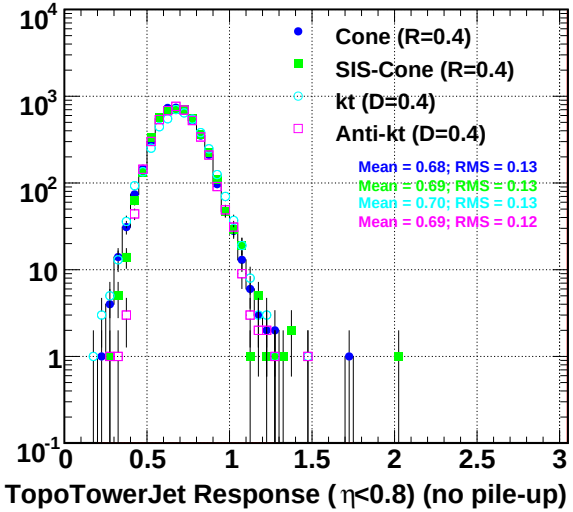
Clusters within $|\eta| \leq 0.5$

- The growth of clusters is more pronounced for hadronic clusters than for all clusters combined
  - Cluster size grows by about 40% between lowest and highest vertex multiplicity
- Again, this effect seems to be confined to the forward region, including the HEC and FCAL

Topo-tower & topo jets in J2 events without pile-up

TopoTower jet constituents

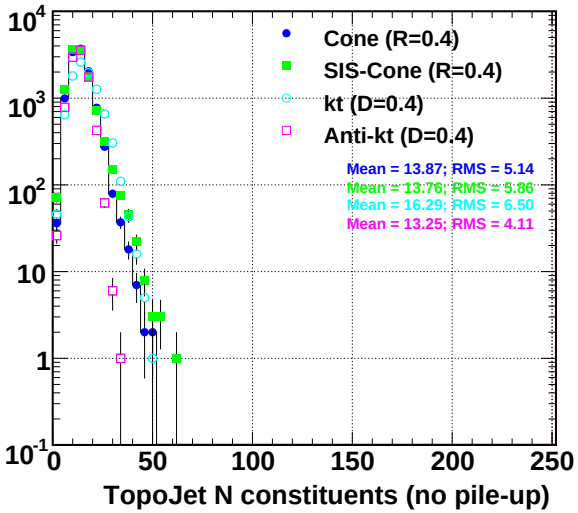


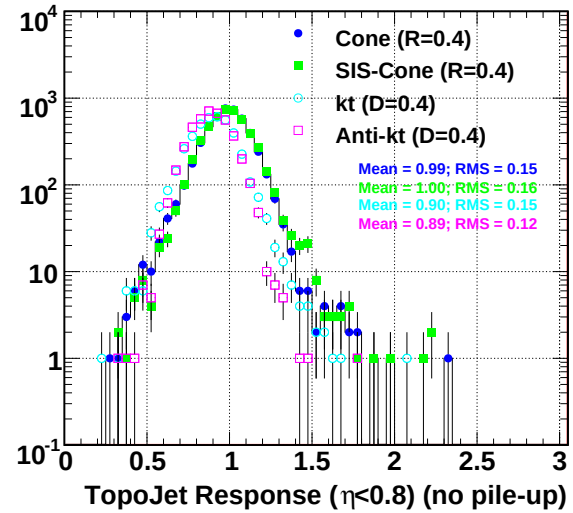


TopoTower jet response (*EM*)

- ATLAS cone
- SIS cone
- k_T
- anti-k_T

Topo jet constituents

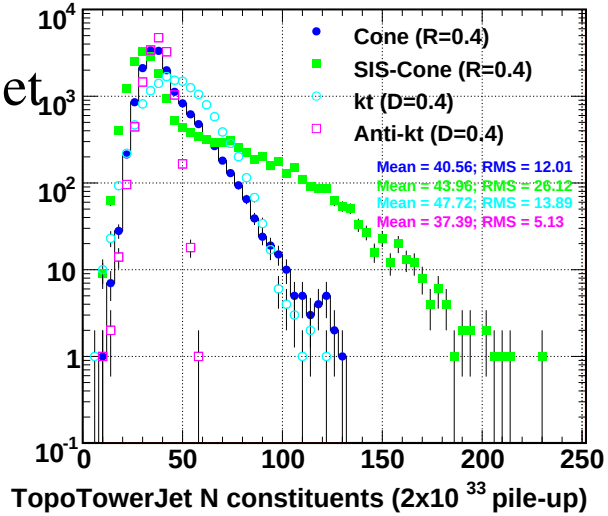


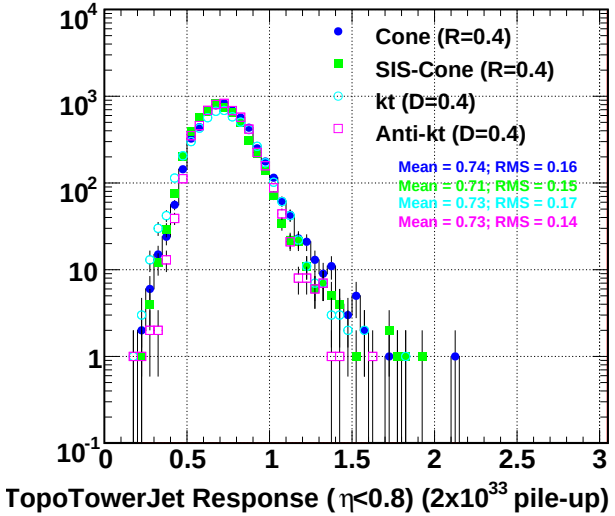


Topo jet response

Topo-tower & topo jets in J2 events at $2 \times 10^{33} cm^{-2} s^{-1}$

TopoTower jet constituents

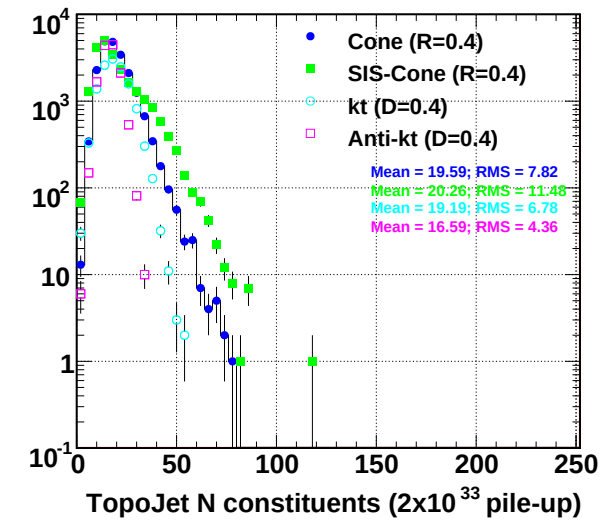


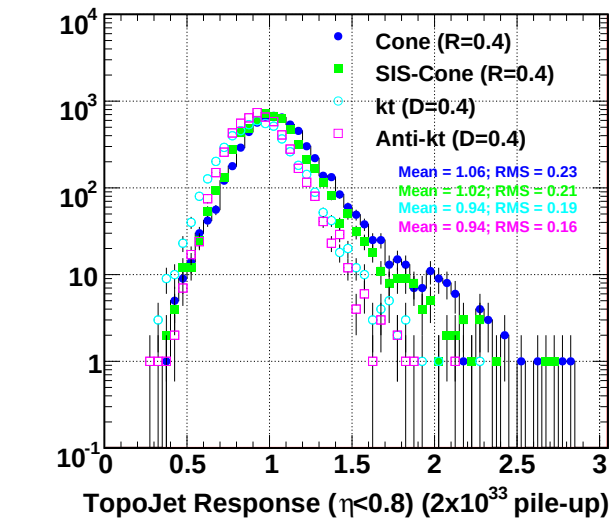


TopoTower jet response (*EM*)

- ATLAS cone
- SIS cone
- k_T
- anti-k_T

Topo jet constituents





Topo jet response

Summary and conclusions

Summary

- Topo-tower and topo-cluster energy and angular resolution are nearly identical, even in high luminosity environments
  - Noise suppression makes a very big difference
- Standard towers (i.e. no noise suppression) clearly show large sensitivities to pile-up and require the use of a non-physics "resummation" tool in order to use as jet input
- Topological cluster properties (size, shape) are affected by the presence of multiple interactions, many small, low p_T clusters appear
- Clusters in the central region are least affected by pile-up

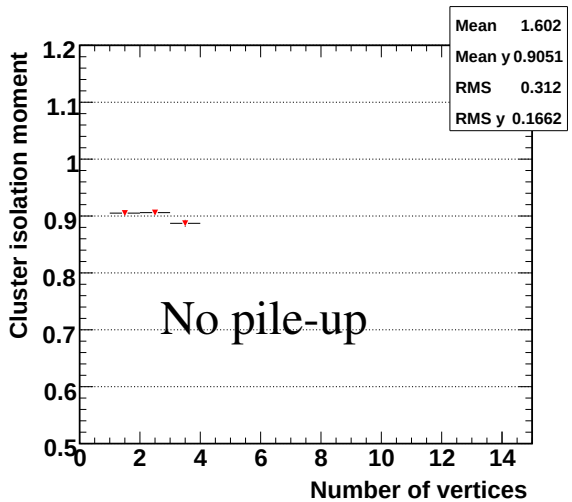
Conclusions

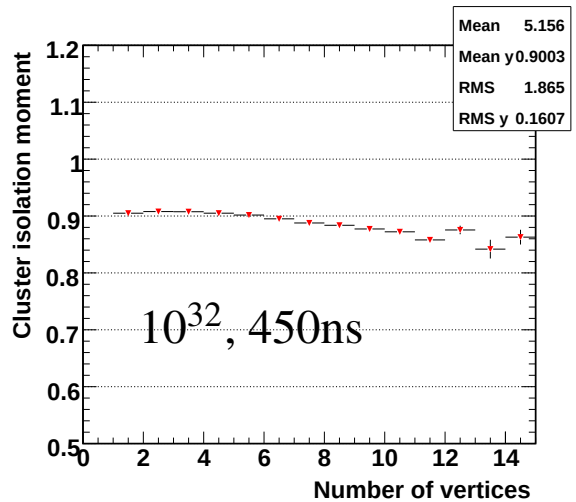
- Noise suppression is essential
- When compared on the same footing, jets built from towers and clusters show similar resolution (energy and angular)
- Size and shape properties of clusters are most affected by pile-up in the forward regions, relatively flat in the central region

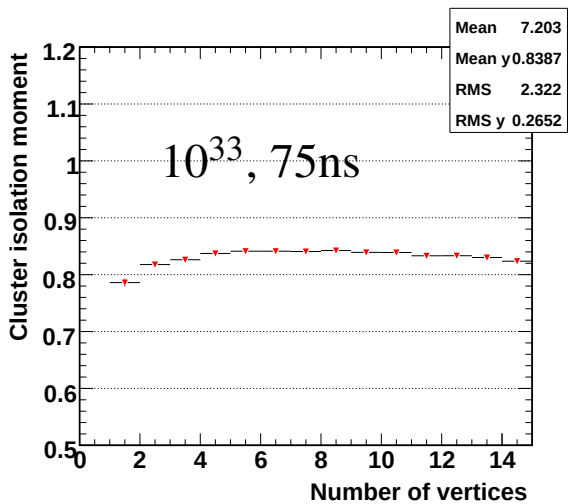
Additional material

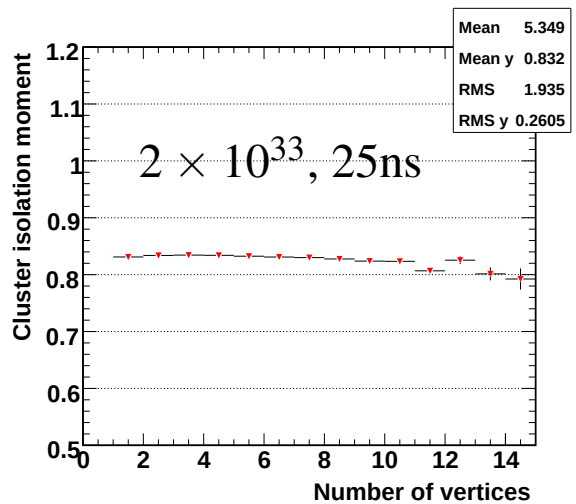
Cluster properties: isolation fraction vs. N_{PV}

Di-jet spectrum at various luminosities and bunch spacing



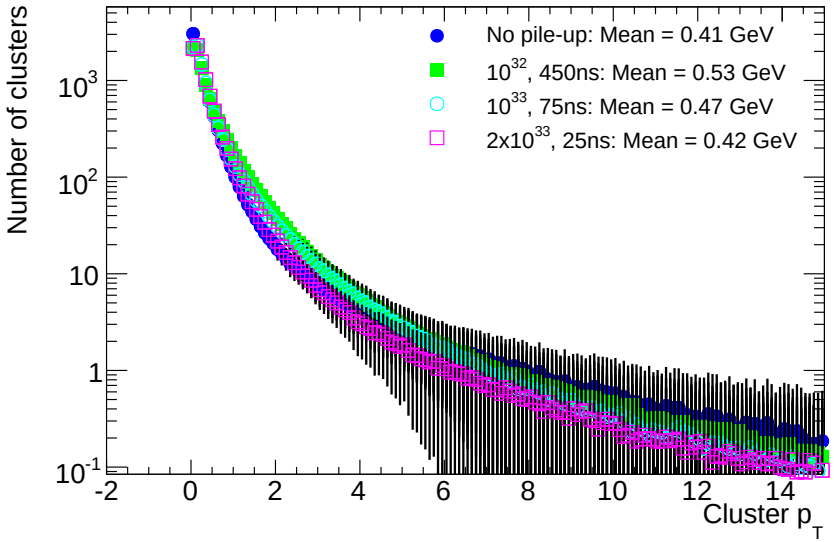




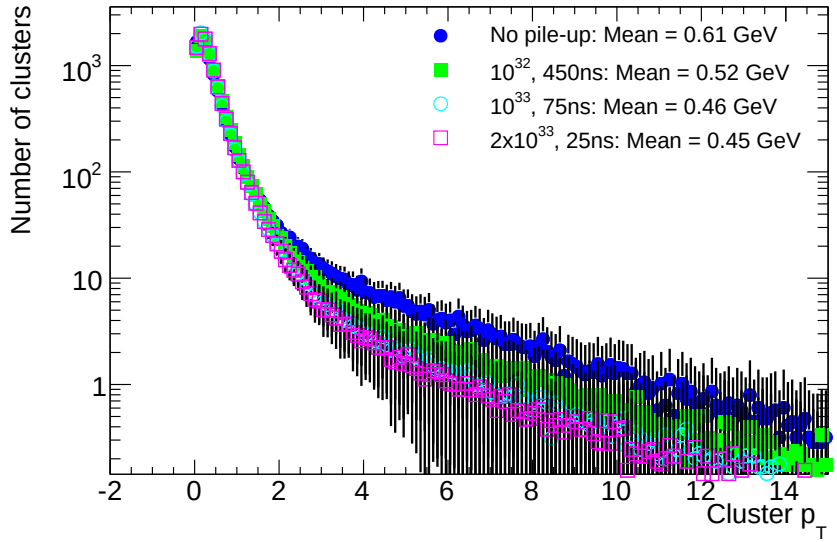


Cluster properties: cluster p_T

Di-jet spectrum at various luminosities and bunch spacing



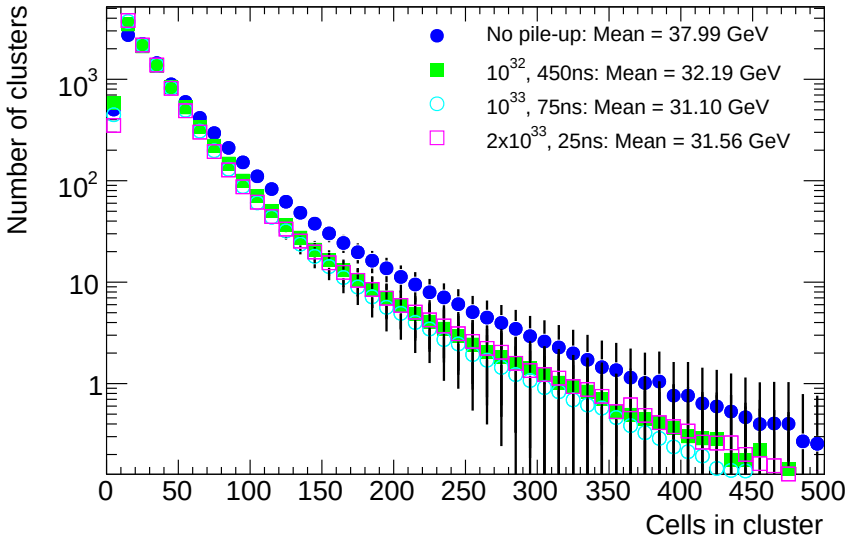
Full η range



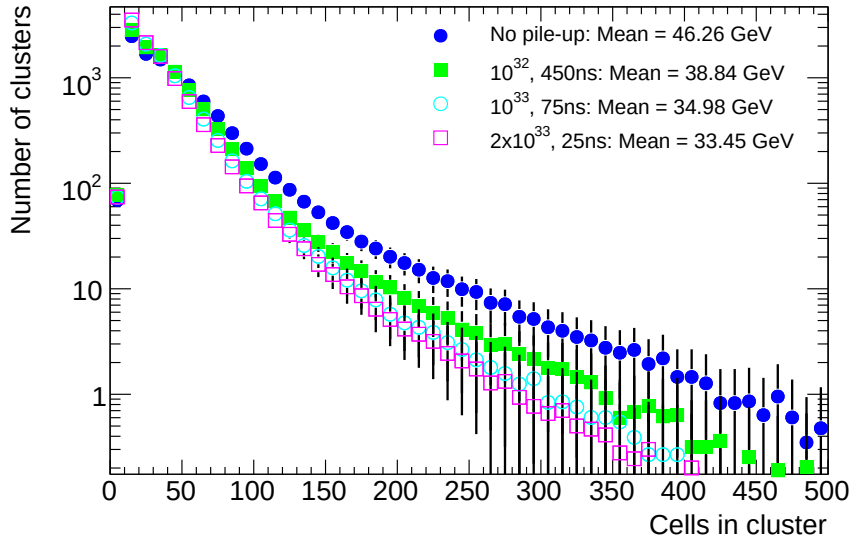
Clusters within $|\eta| \leq 0.5$

Cluster properties: cluster N_{cells}

Di-jet spectrum at various luminosities and bunch spacing



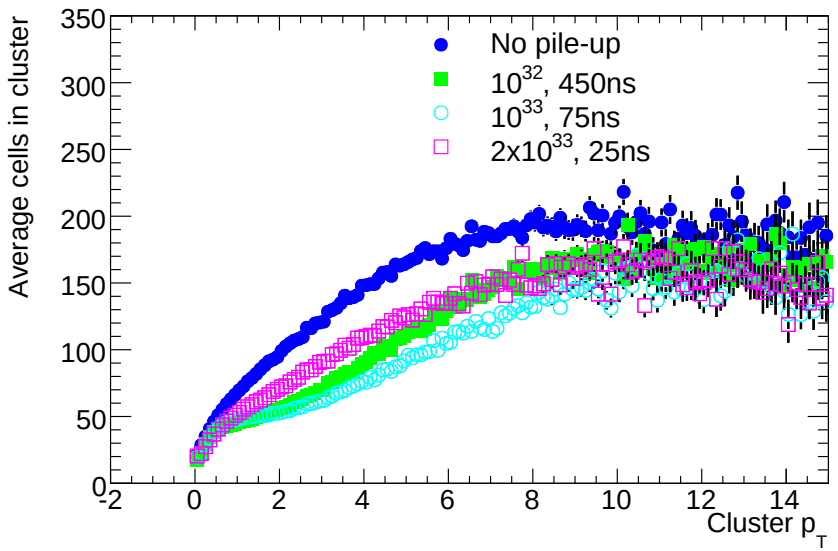
Full η range



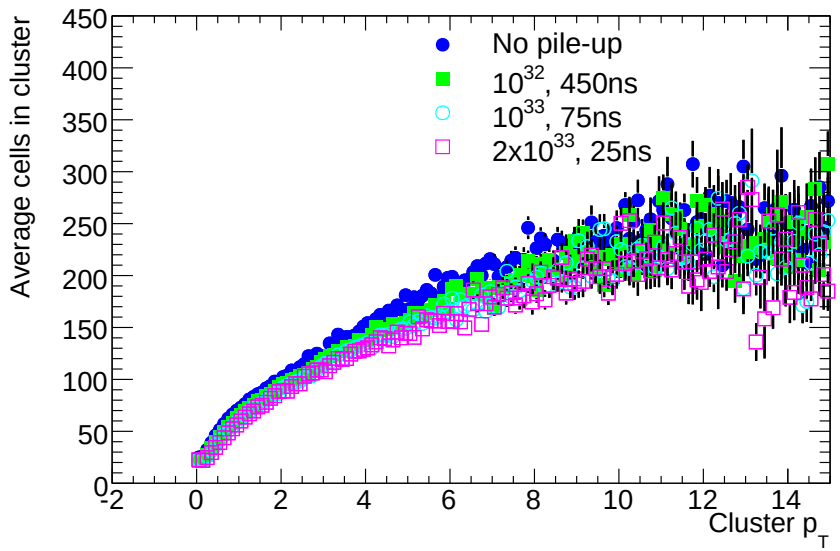
Clusters within $|\eta| \leq 0.5$

Cluster properties: average N_{cells} vs E_T per cluster

Di-jet spectrum at various luminosities and bunch spacing



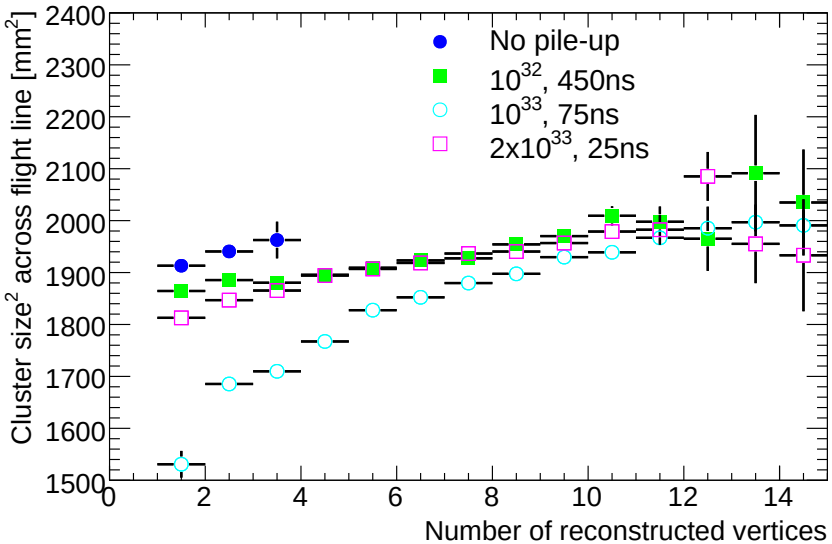
Full η range



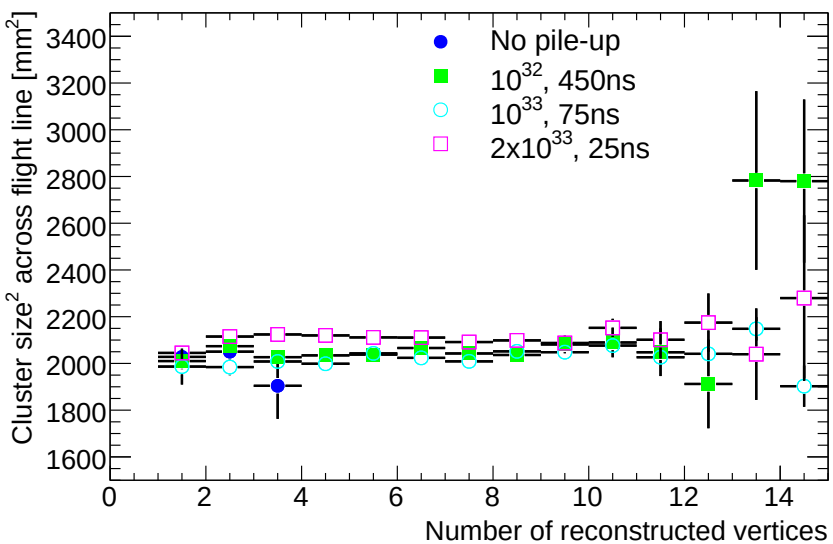
Clusters within $|\eta| \leq 0.5$

Cluster properties: average second long. moment vs. N_{PV}

Di-jet spectrum at various luminosities and bunch spacing



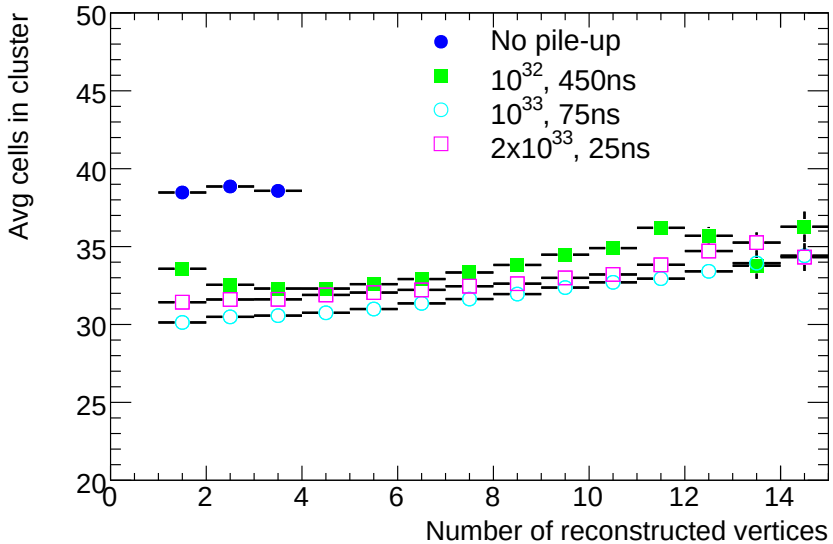
Full η range



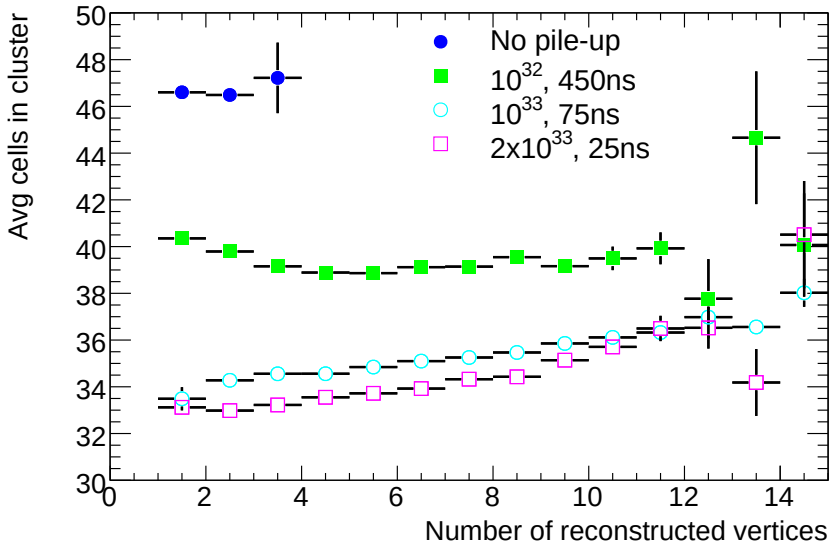
Clusters within $|\eta| \leq 0.5$

Cluster properties: average N_{cells} vs. N_{PV}

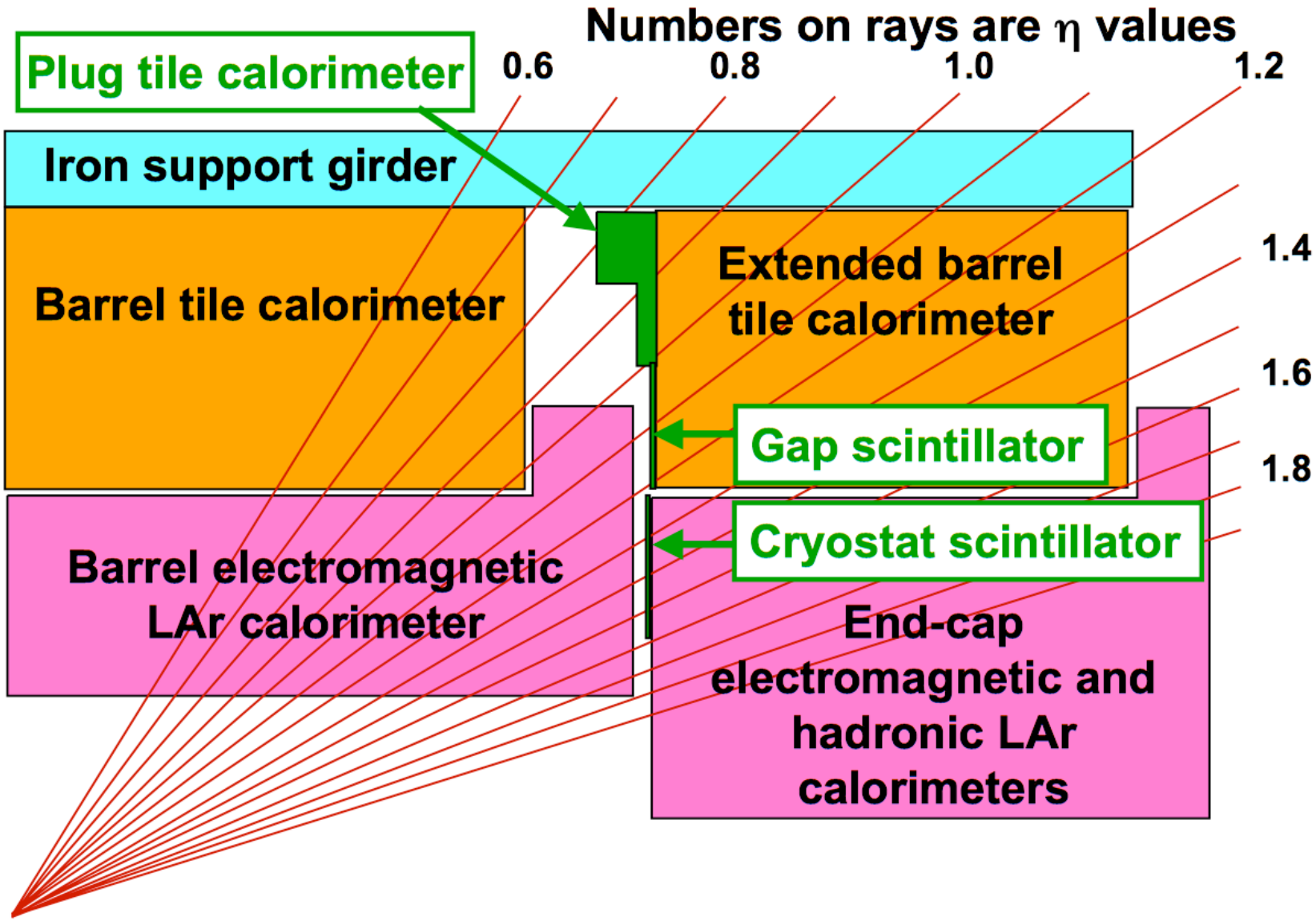
Di-jet spectrum at various luminosities and bunch spacing

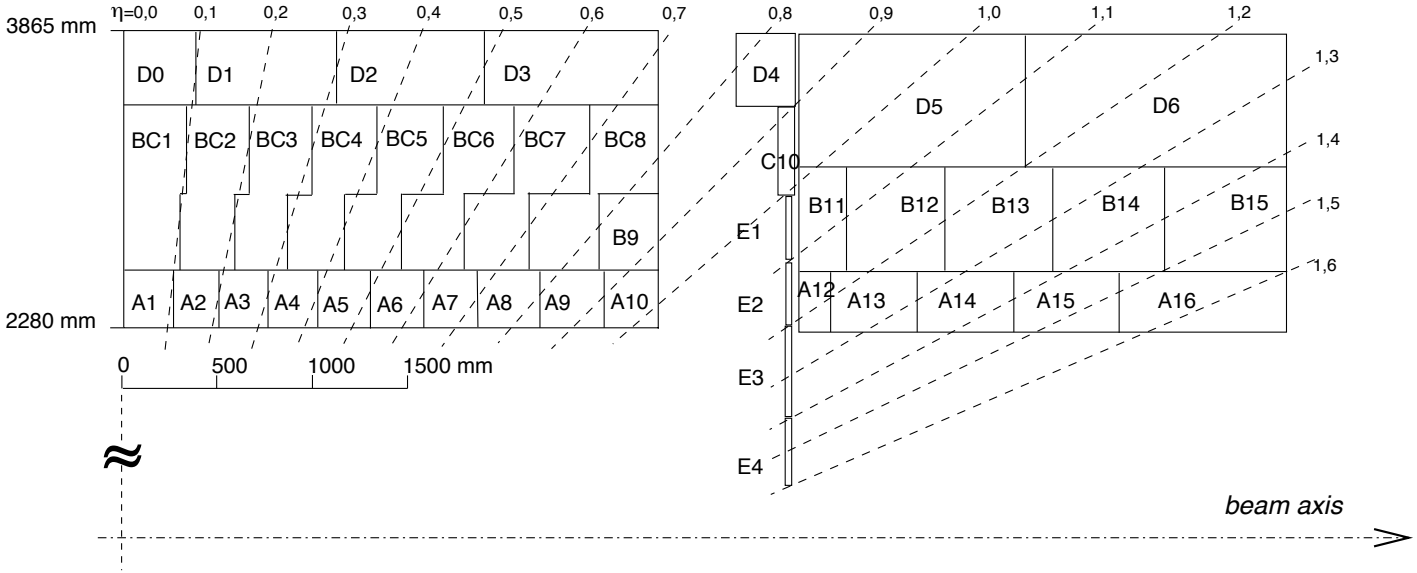


Full η range



Clusters within $|\eta| \leq 0.5$


Numbers on rays are η values
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Plug tile calorimeter
Iron support girder
Barrel tile calorimeter
Extended barrel tile calorimeter
Gap scintillator
Cryostat scintillator
Barrel electromagnetic LAr calorimeter
End-cap electromagnetic and hadronic LAr calorimeters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0,4
0,5
0,6
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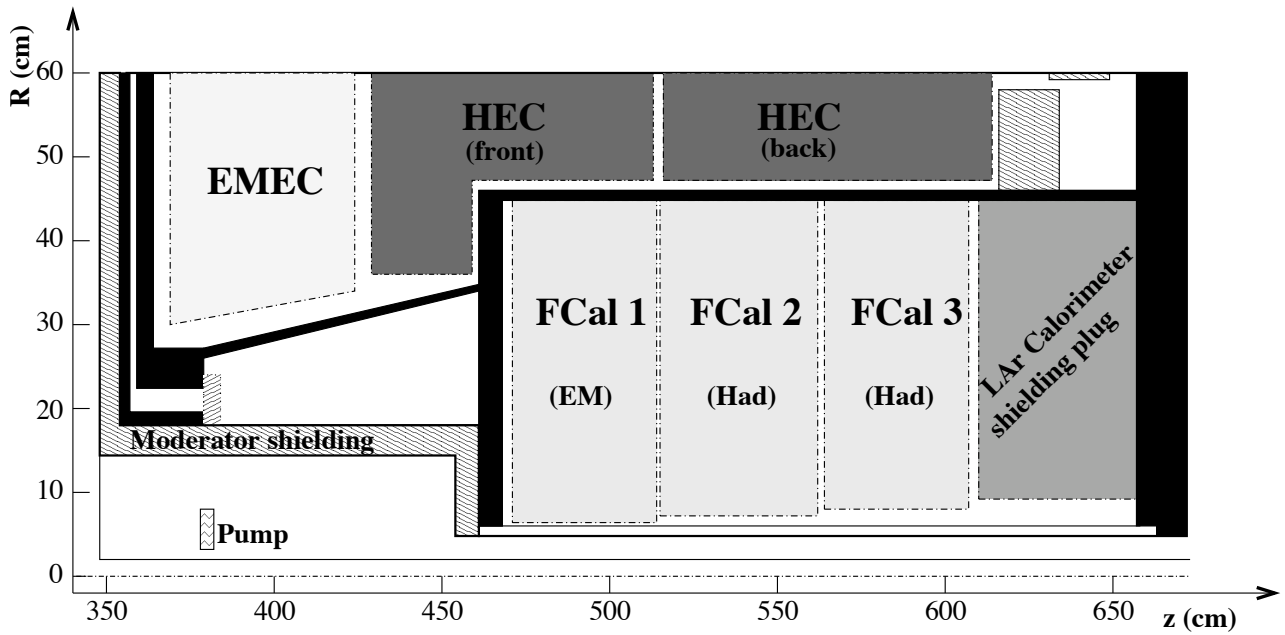
0,9
1,0
1,1
1,2
1,3
1,4
1,5
1,6
3865 mm
2280 mm
D0
D1
D2
D3
D4
D5
D6
BC1
BC2
BC3
BC4
BC5
BC6
BC7
BC8
B9
C10
B11
B12
B13
B14
B15
E1
E2
E3
E4
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A12
A13
A14
A15
A16
0
500
1000
1500 mm
beam axis


R (cm)
60
50
40
30
20
10
0
EMEC
HEC
(front)
HEC
(back)
FCal 1
(EM)
FCal 2
(Had)
FCal 3
(Had)
LAr Calorimeter
shielding plug
Moderator shielding
Pump
350
400
450
500
550
600
650
z (cm)

Information related to LAr design for high luminosity

- Marco Delmastro's thesis:
  `http://cdsweb.cern.ch/record/953119/files/thesis-2003-033.pdf`
- LAr ECAL Team tutorial this summer.
  `http://indico.cern.ch/conferenceDisplay.py?confId=35889`
- *The* reference for LAr
  - "*Signal processing considerations for liquid ionization calorimeters in a high rate environment*"
  - NIM A: Volume 338, Issues 2-3, 15 January 1994, Pages 467-497
- Comparison between the estimated noise from `CaloNoiseTool` and the real noise from the pileup overlay with release 12
  - ATL-LARG-PUB-2007-011
- Wiki for calorimeter digitization:
  `https://twiki.cern.ch/twiki/bin/view/Atlas/CaloDigitization`
- Some related posts to the Pileup Hypernews Forum
  - `https://hypernews.cern.ch/HyperNews/Atlas/get/pileUp/61/3/1/2/1.html`
  - `https://hypernews.cern.ch/HyperNews/Atlas/get/pileUp/47/1/1.html`
  - `https://hypernews.cern.ch/HyperNews/Atlas/get/pileUp/46/1.html`