Detector Considerations For EIC Jets

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POETIC Jet Workshop

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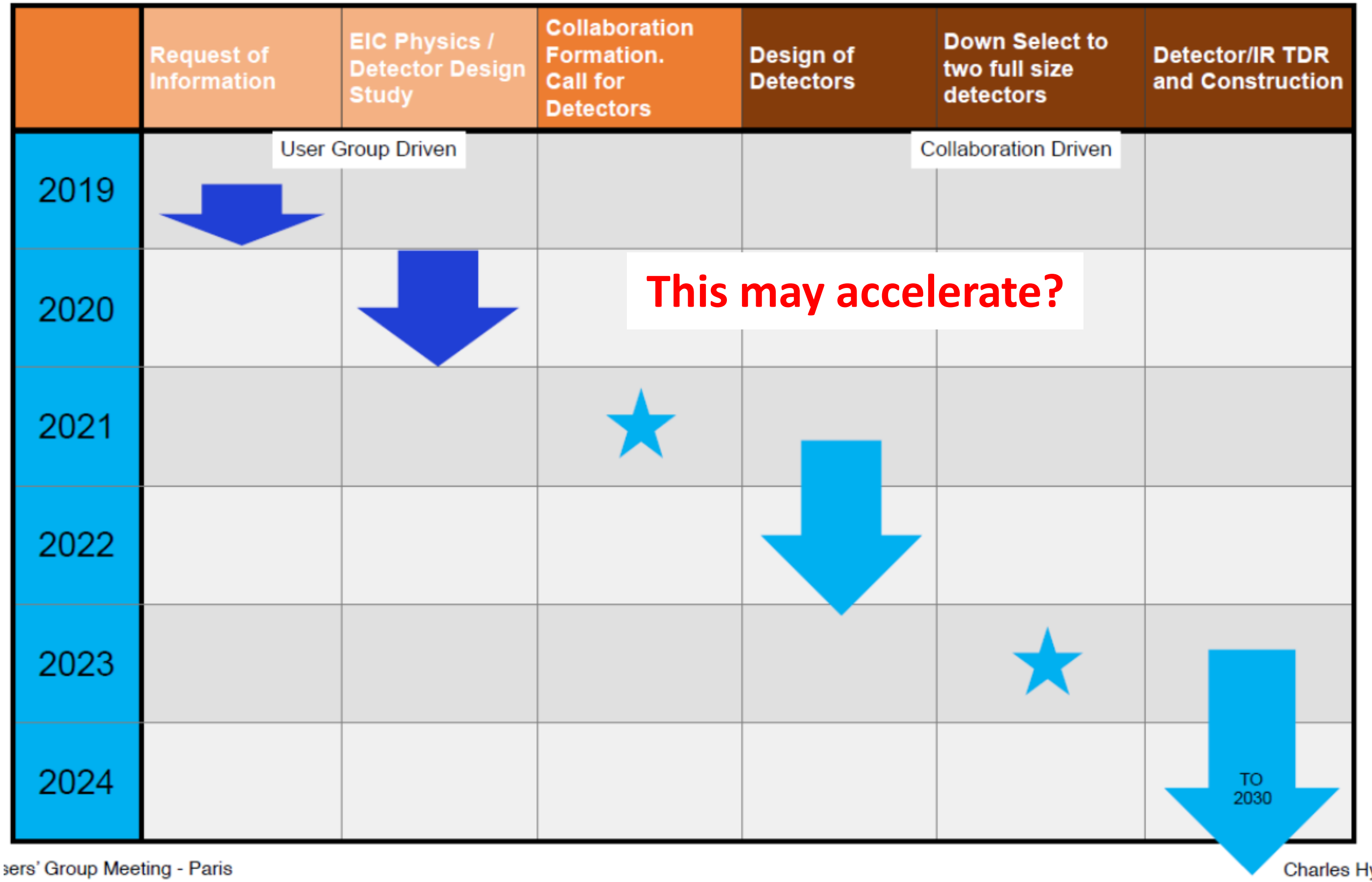
Outline

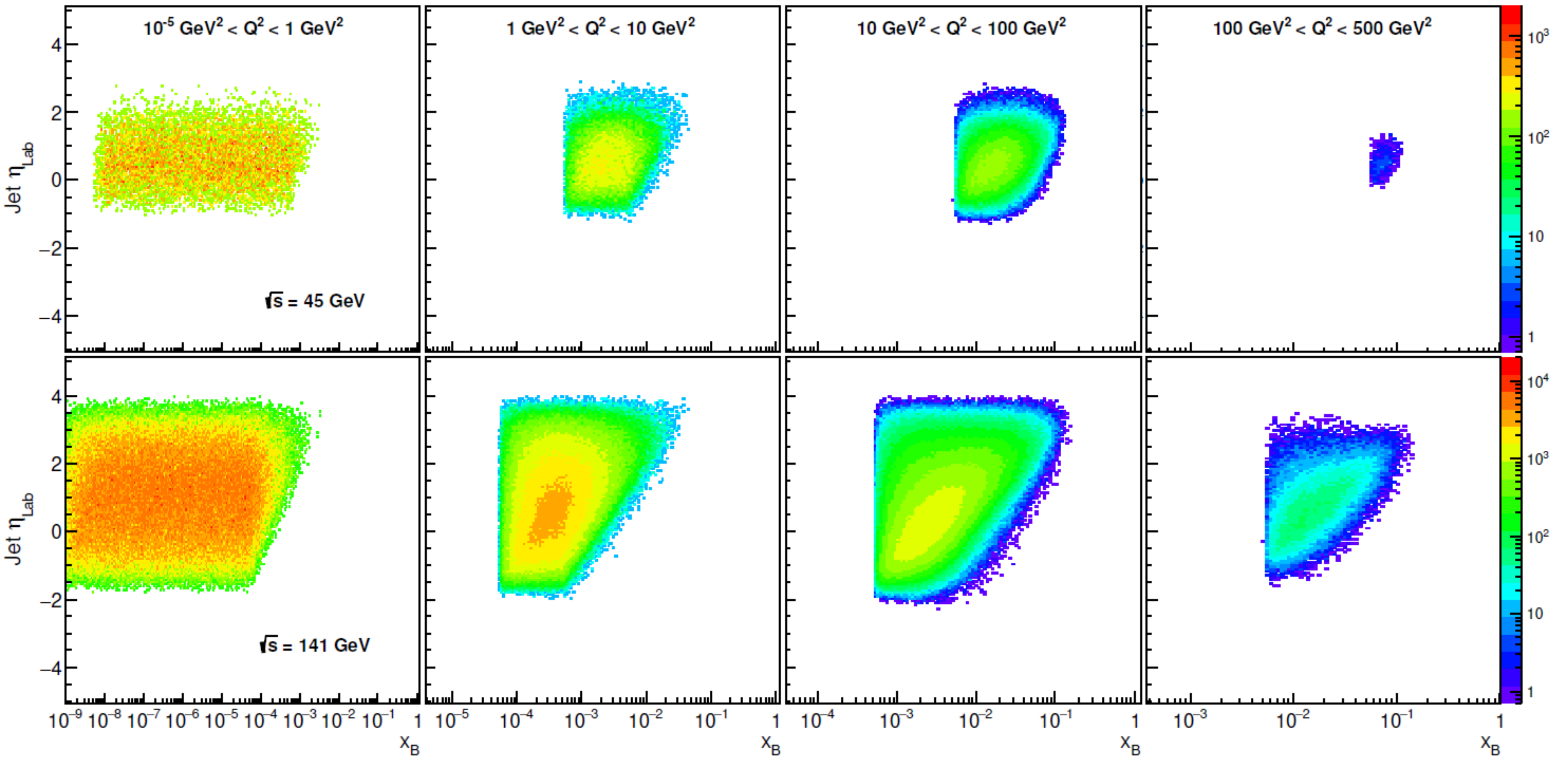
- This talk is not meant to be an overview of existing detector designs / technologies or specific analysis topics
- I want to focus on a couple of aspects of detector design in the context of jet measurements which could benefit from some more thought:
  - Role of Hadron Calorimetry and requirements on energy / position resolutions and segmentation
  - Optimization of magnetic field strength and trade-offs between high and low fields
- Other topics which feed into the above include: event simulation (especially eA), detector simulation, PID, and theory input
- This is meant to generate discussion, please interrupt!

(Potential) Timeline



Speak soon or forever hold your peace!

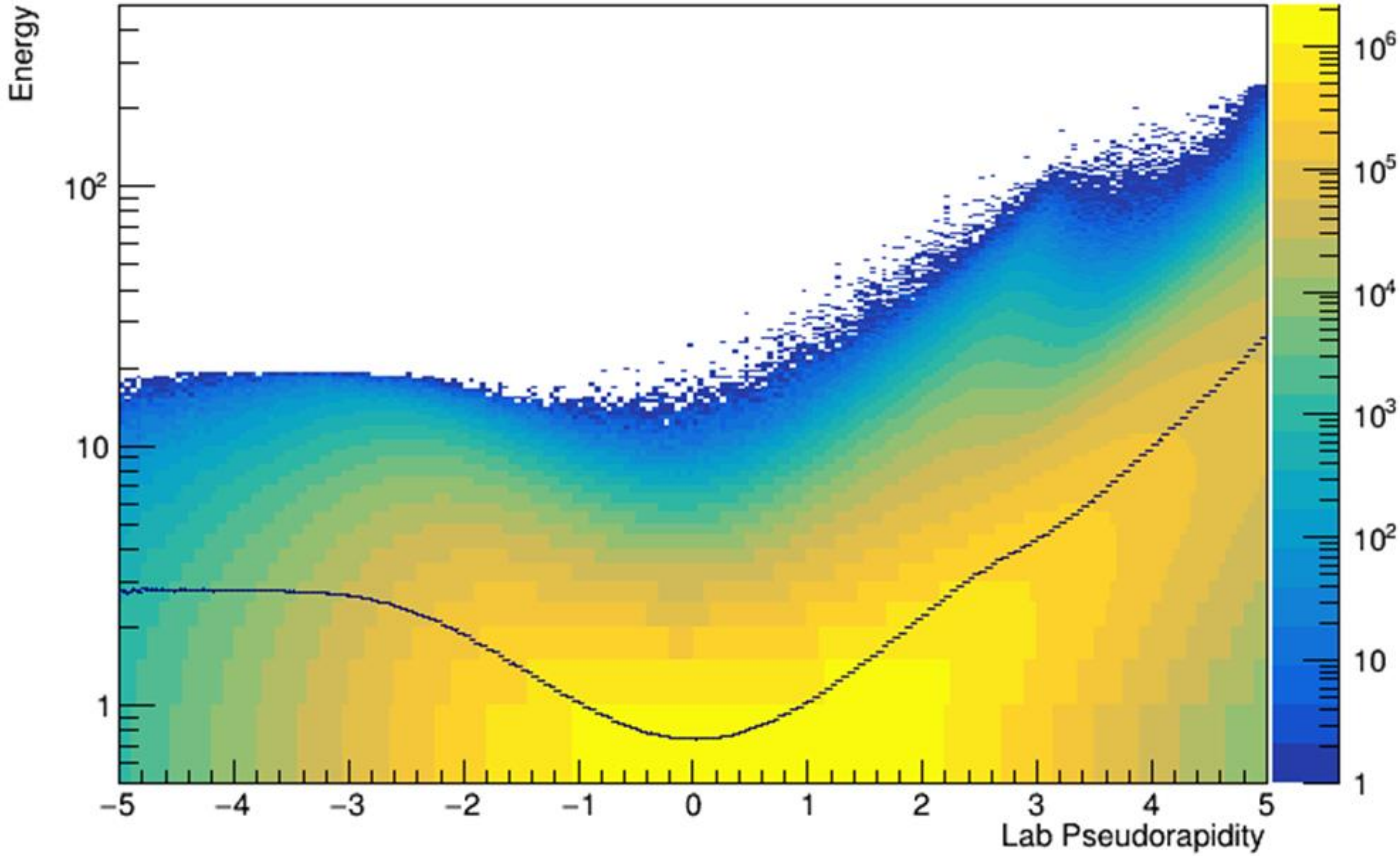
Jet Kinematics



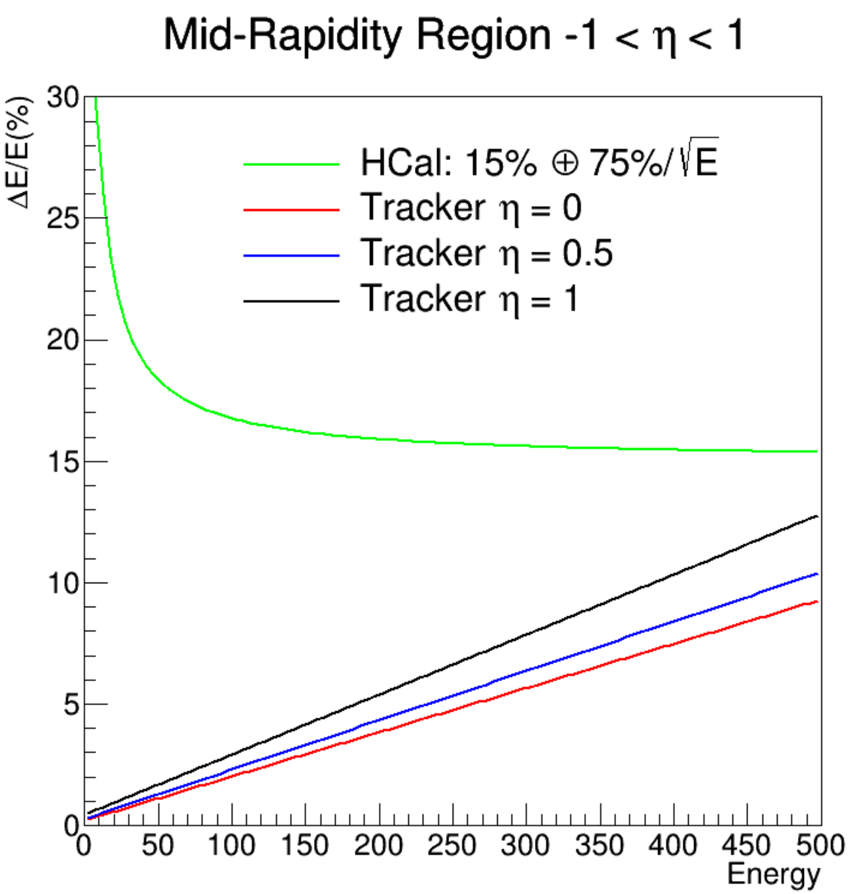
- Jet production extends quite far forward (proton going direction), especially at higher energies – forward tracking and calorimetry will be as important as mid-rapidity

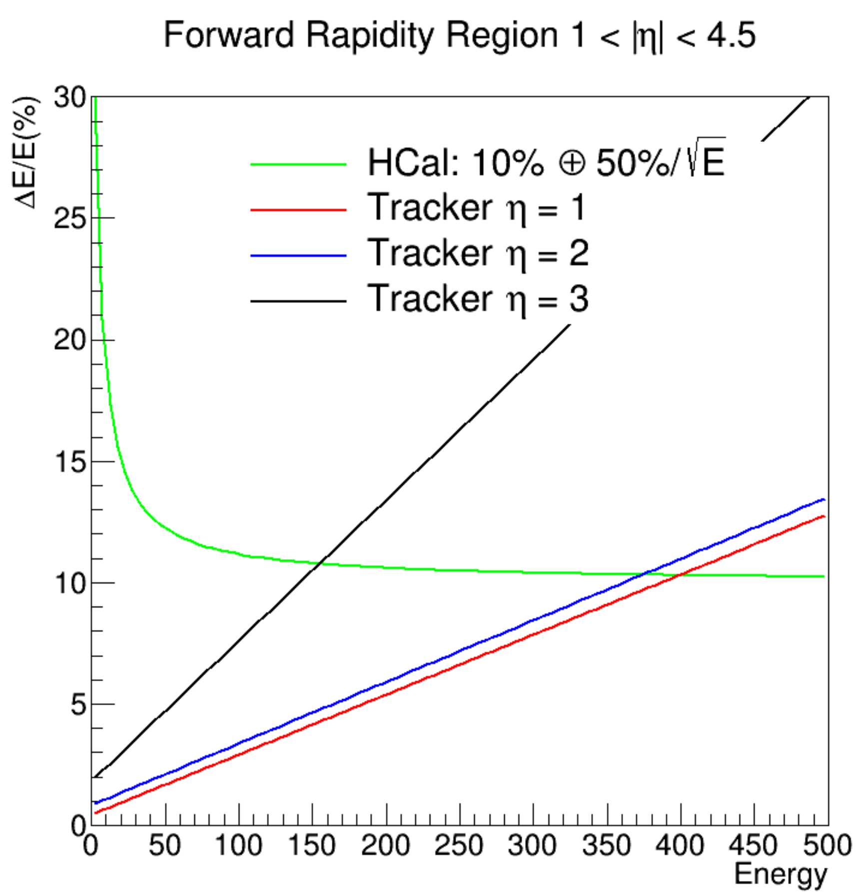
Hadron Calorimetry

Particle Energy Vs η



Tracker Vs HCal Resolution

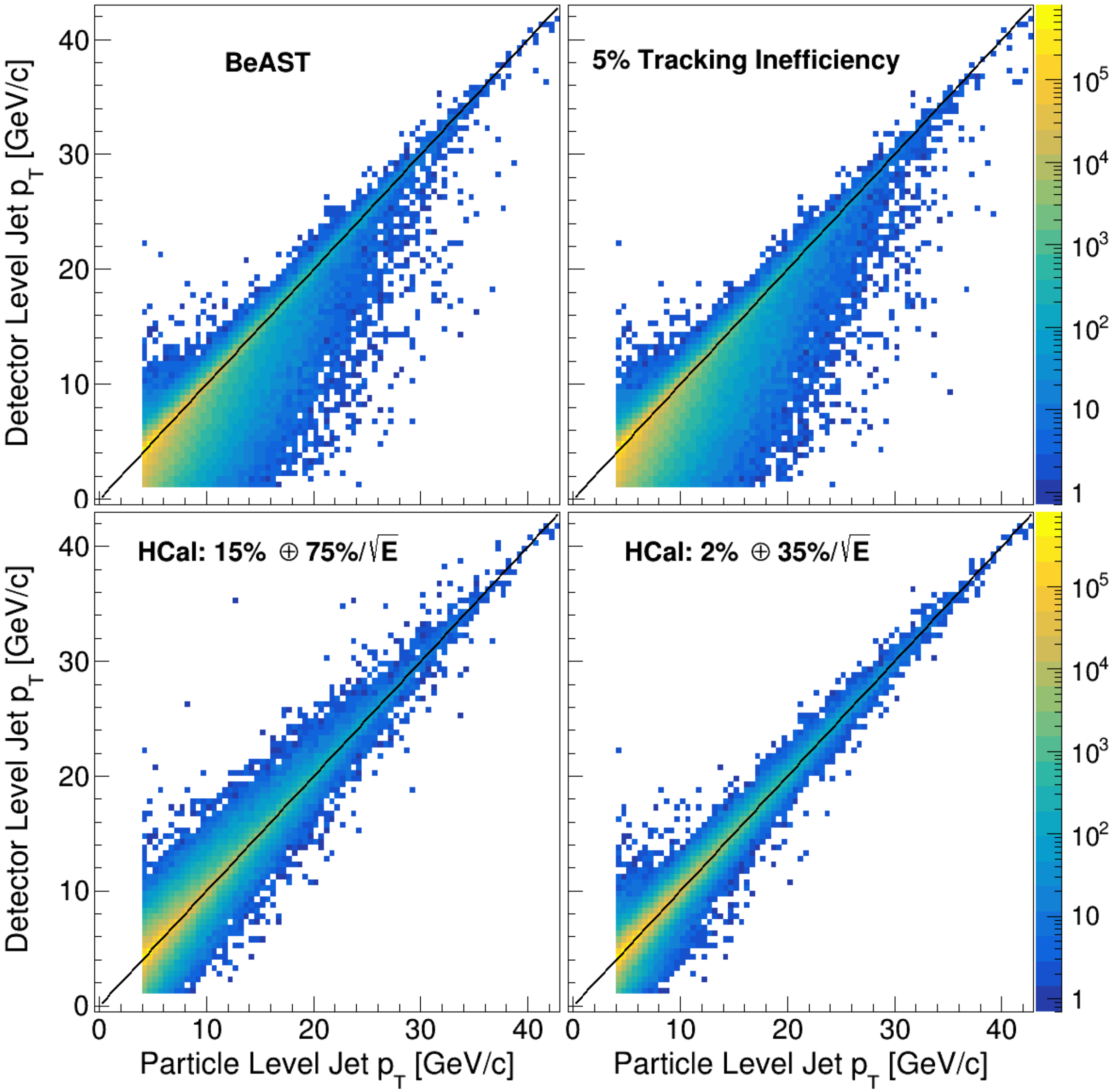




- Tracker provides better resolutions for nearly all energies and pseudorapidities

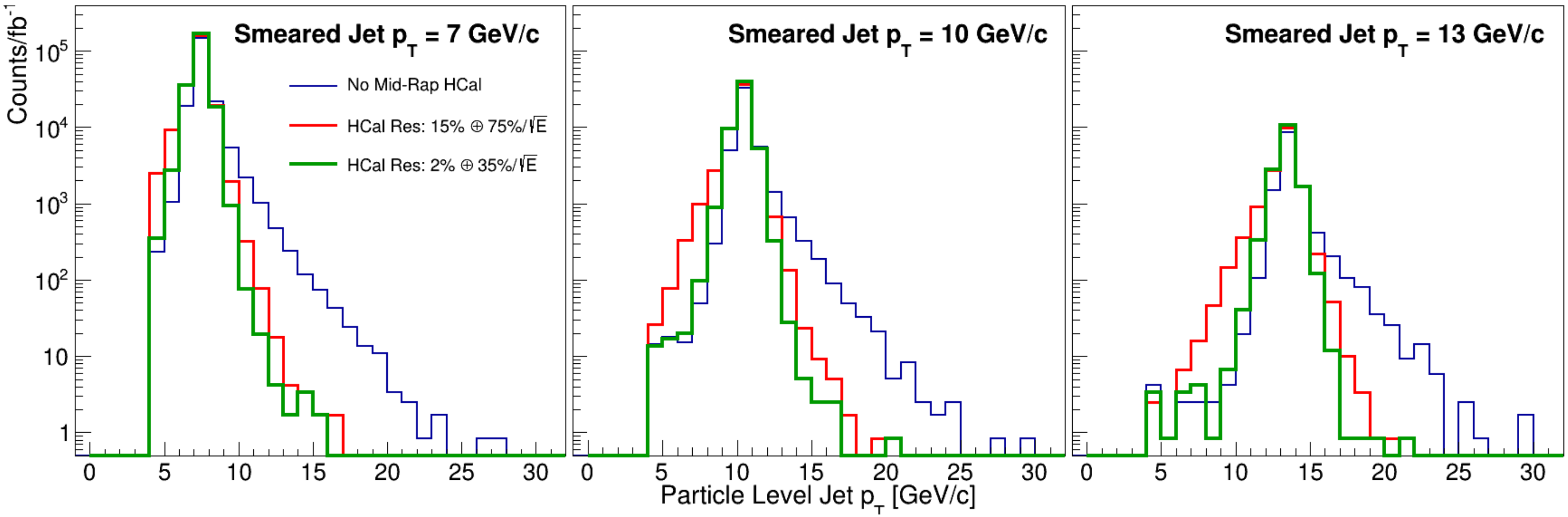
- Assumption: use tracker for all hadrons except long lived neutrals such as neutrons and K^0_Ls

Jet p_T Smearing



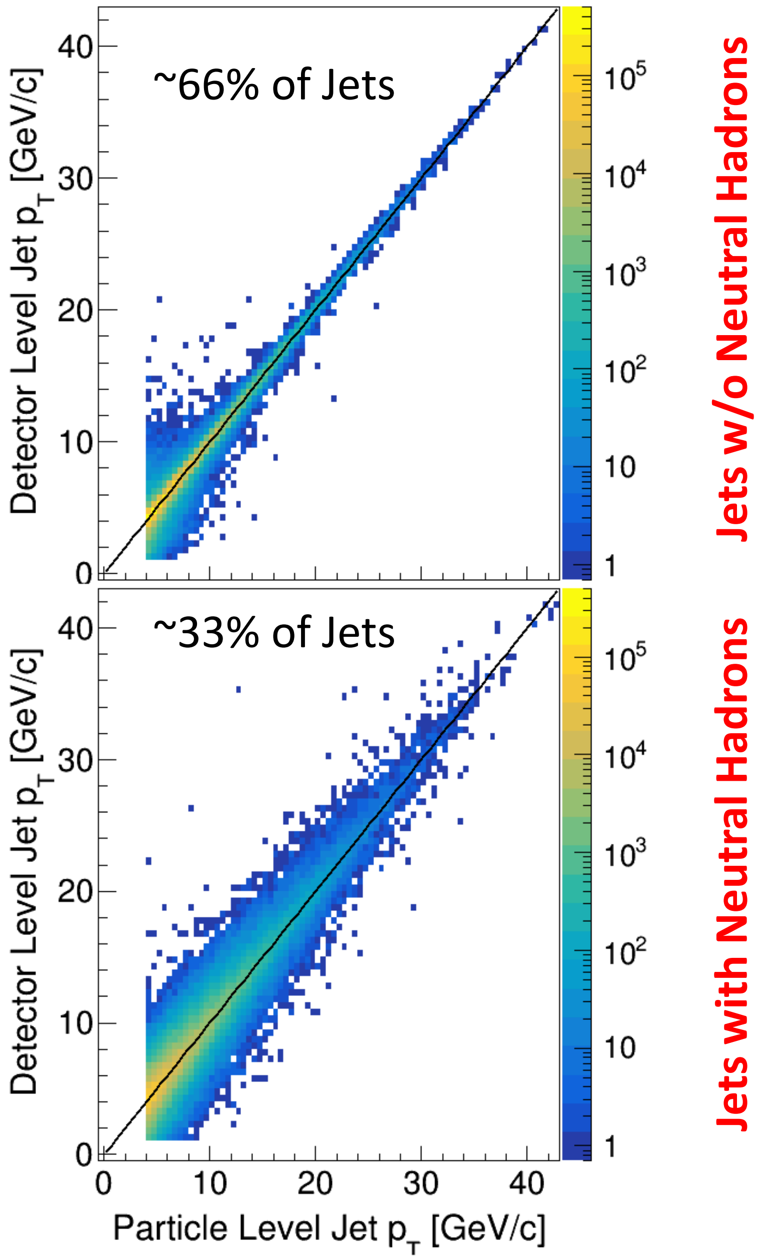
- Study jet p_T resolutions using smearing generator
- Smear particle momenta and energies based on detector characteristics
- Use BeAST detector parameters (baseline design does not include mid-rapidity hadron calorimeter)
- Also look at effects of track finding inefficiency, and mid-rapidity HCals – assume SPHENIX and ZEUS resolutions

Particle Level Projections



- Look at the true jet p_Ts which contribute to three specific detector level jet p_Ts
- Assume no mid-rapidity HCal, or the SPHENIX or ZEUS HCal resolutions
- The no Hcal case has a large tail of high pT particle level jets which contribute to lower pT detector jets due to the loss of neutral hadrons
- Lo Res Hcal reduces this high energy tail, but has a significant low energy tail

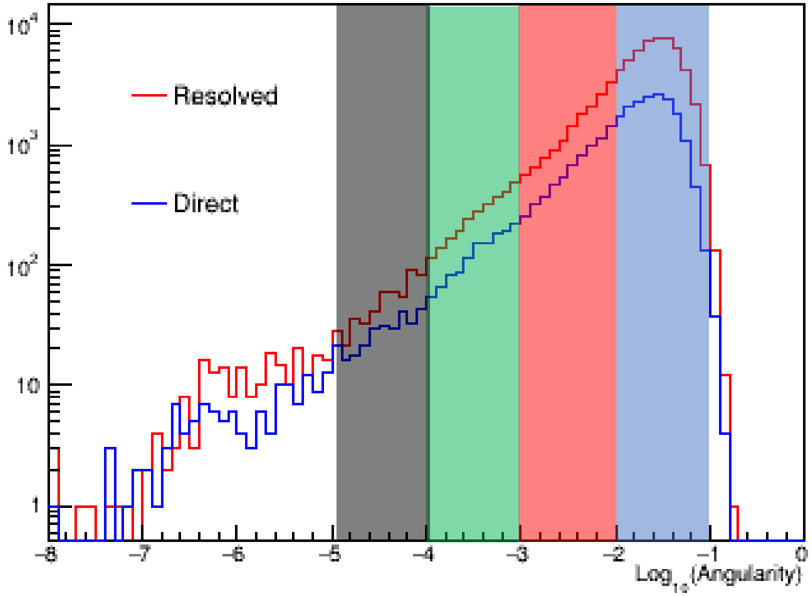
Neutral Hadron Veto



- A low energy resolution HCal may not improve jet energy resolution much, but may be useful as a neutral hadron veto
- Identify jets which contain neutral hadrons by finding energy clusters which do not have tracks pointing to them
- The roughly 66% of jets which do not contain neutral hadrons will have energy resolutions defined by the tracker and can have a very small correction
- Only apply a large correction to the 33% of jets which have neutrals

Angularity Overview

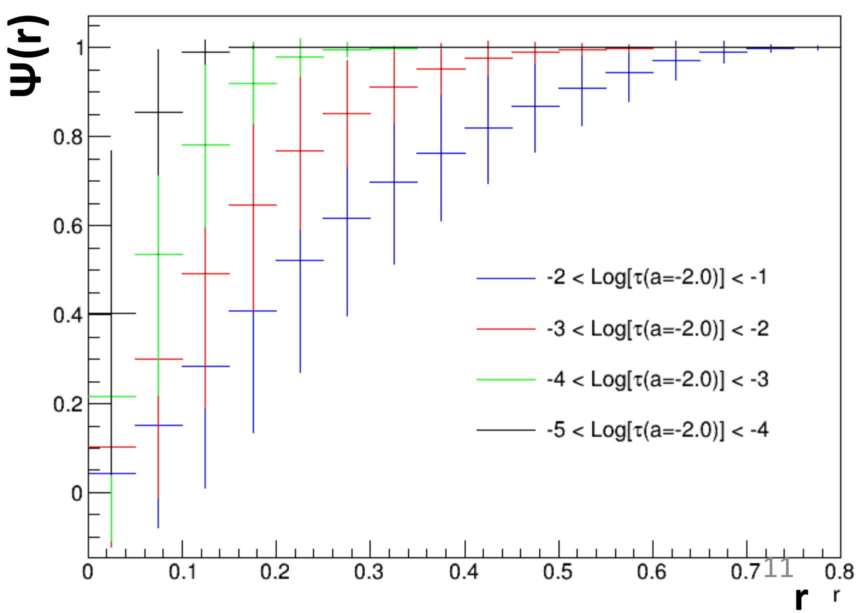
Angularity: R = 0.8; a = -2.0



$$\tau_a \equiv \frac{1}{p_T} \sum_{i \in J} p_T^i \left(\Delta R_{iJ}\right)^{2-a}$$

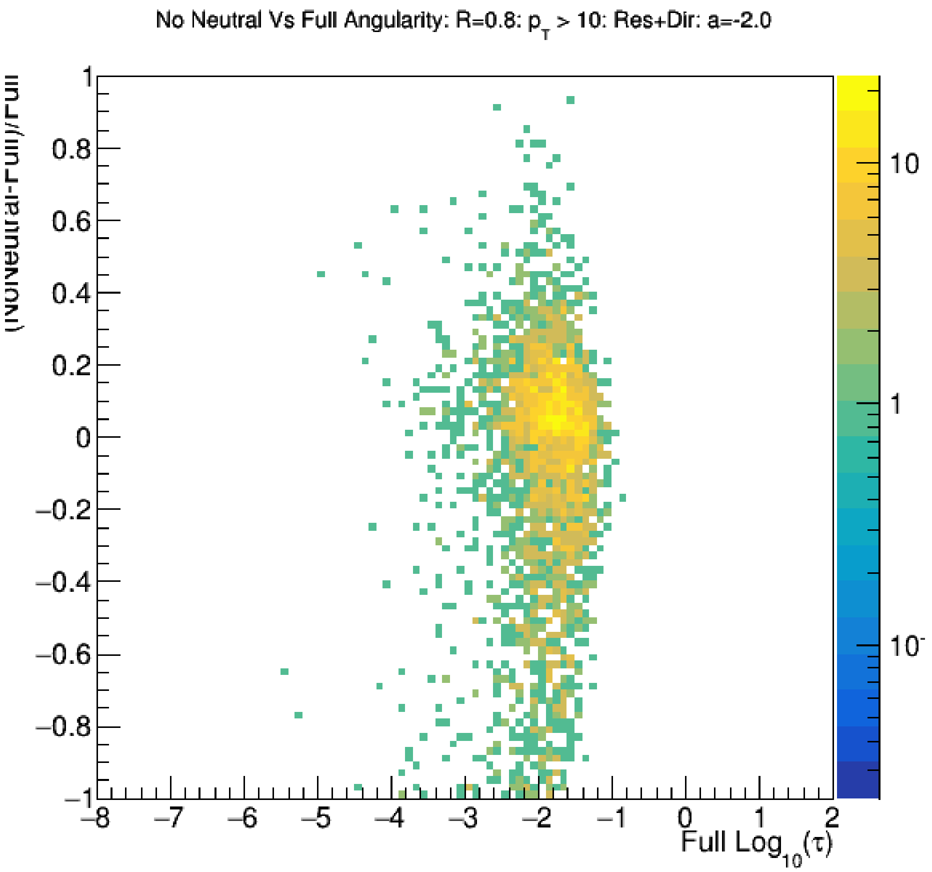
- Angularity sums over each p_T of the particles in the jet weighted by the distance of the particle from the jet thrust axis
- The 'a' parameter controls how heavily the distance is weighted

Jet Profile



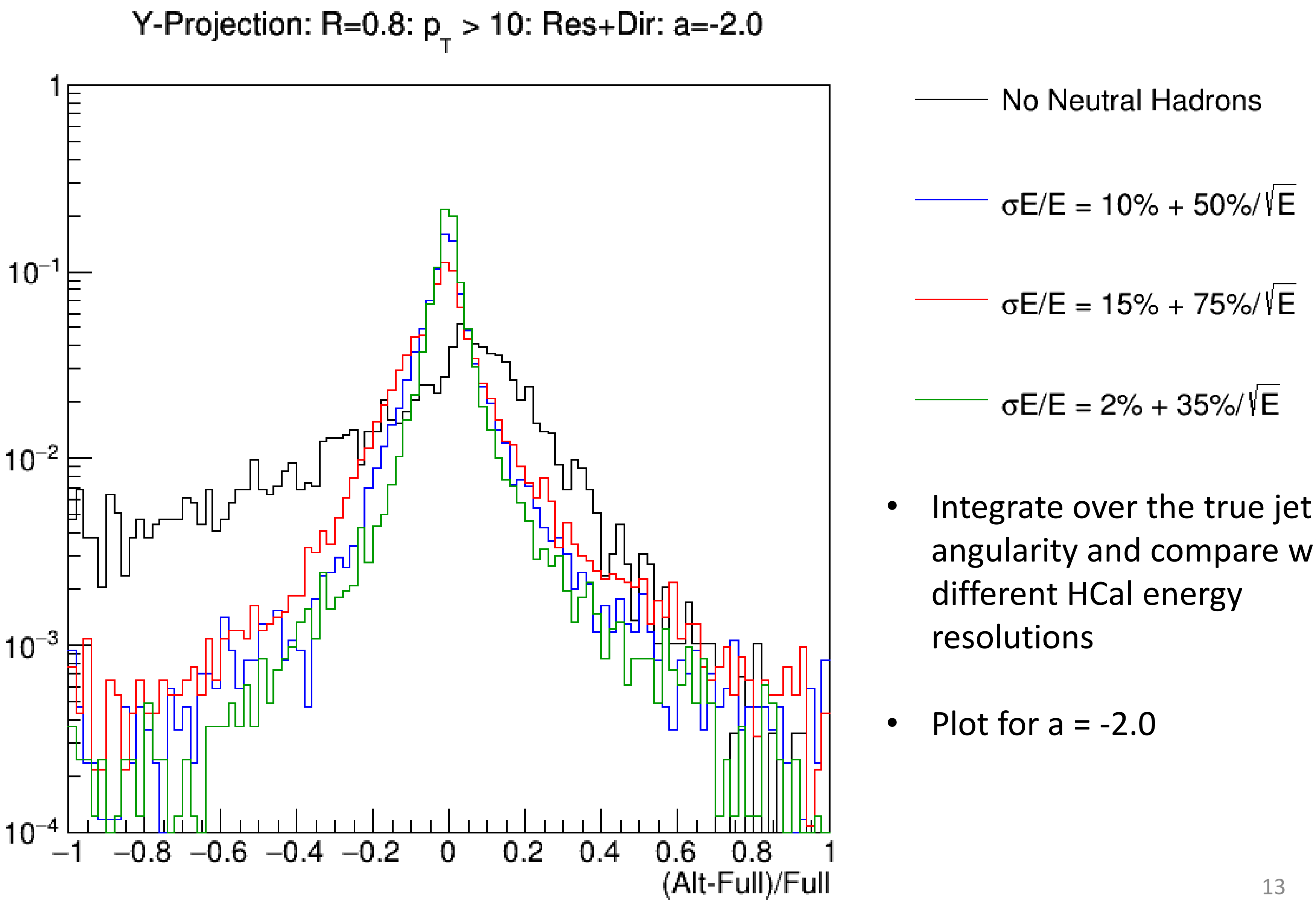
- Log of the angularity spectrum with 'a' = -2.0 is shown above for resolved and direct jets with R = 0.8
- The jet profiles of the jets in the 4 colored regions are shown to the right
- Jet Profile is the fraction of p_T contained in a radius 'r' from the center of the jet
- For a given 'R' and 'a', jets with lower angularity are more collimated

Angularity Fluctuations



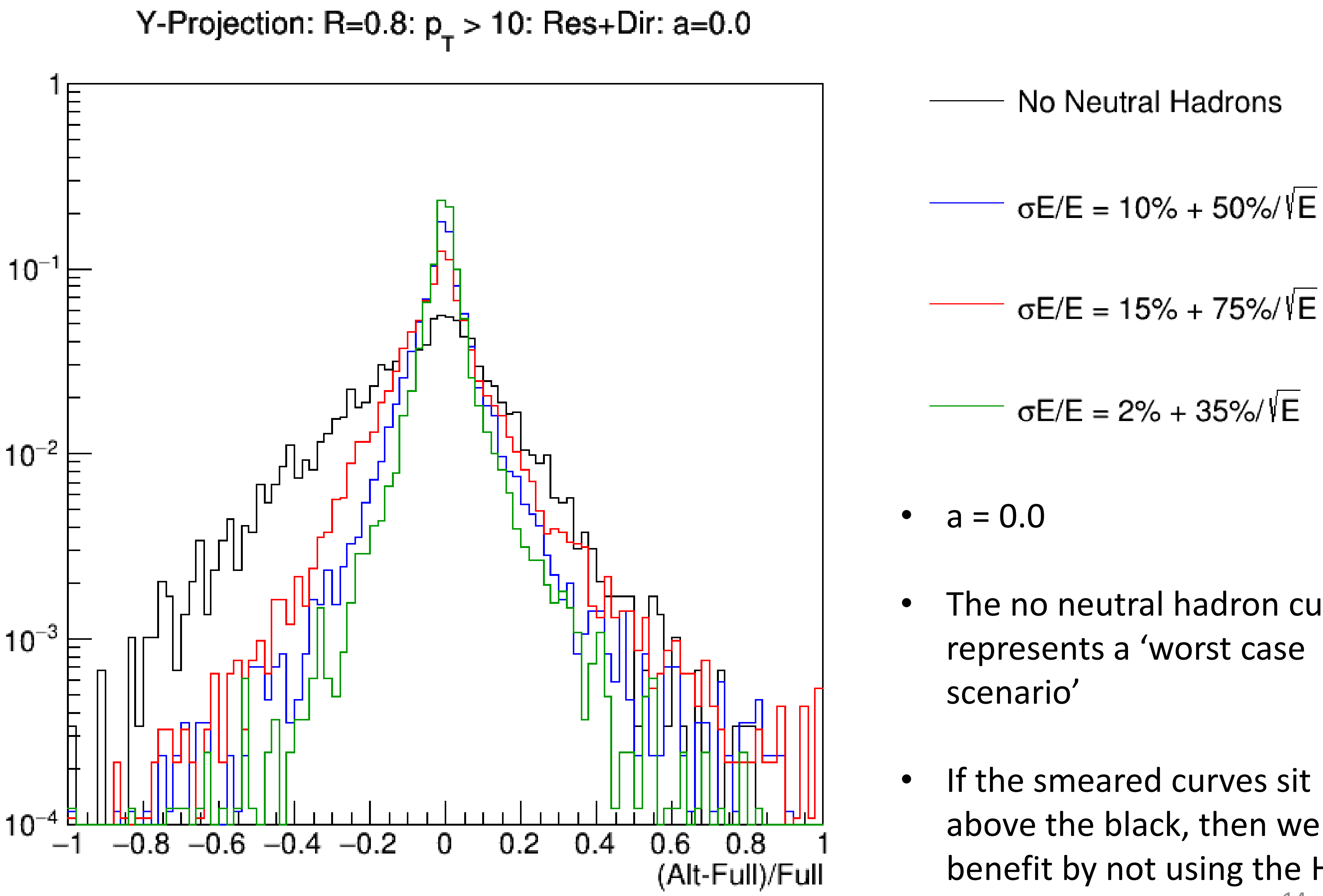
- Study angularity fluctuations induced by non-detection or smeared detection of neutral hadrons
- Start with full particle level jet and then remove or smear energy of neutral hadrons in jet
- Require particle level p_T > 5 GeV and altered jet p_T > 10 GeV
- Plot (Altered – Particle)/Particle jet angularity for all eligible jets with neutral hadrons vs particle level angularity

Angularity Fluctuations



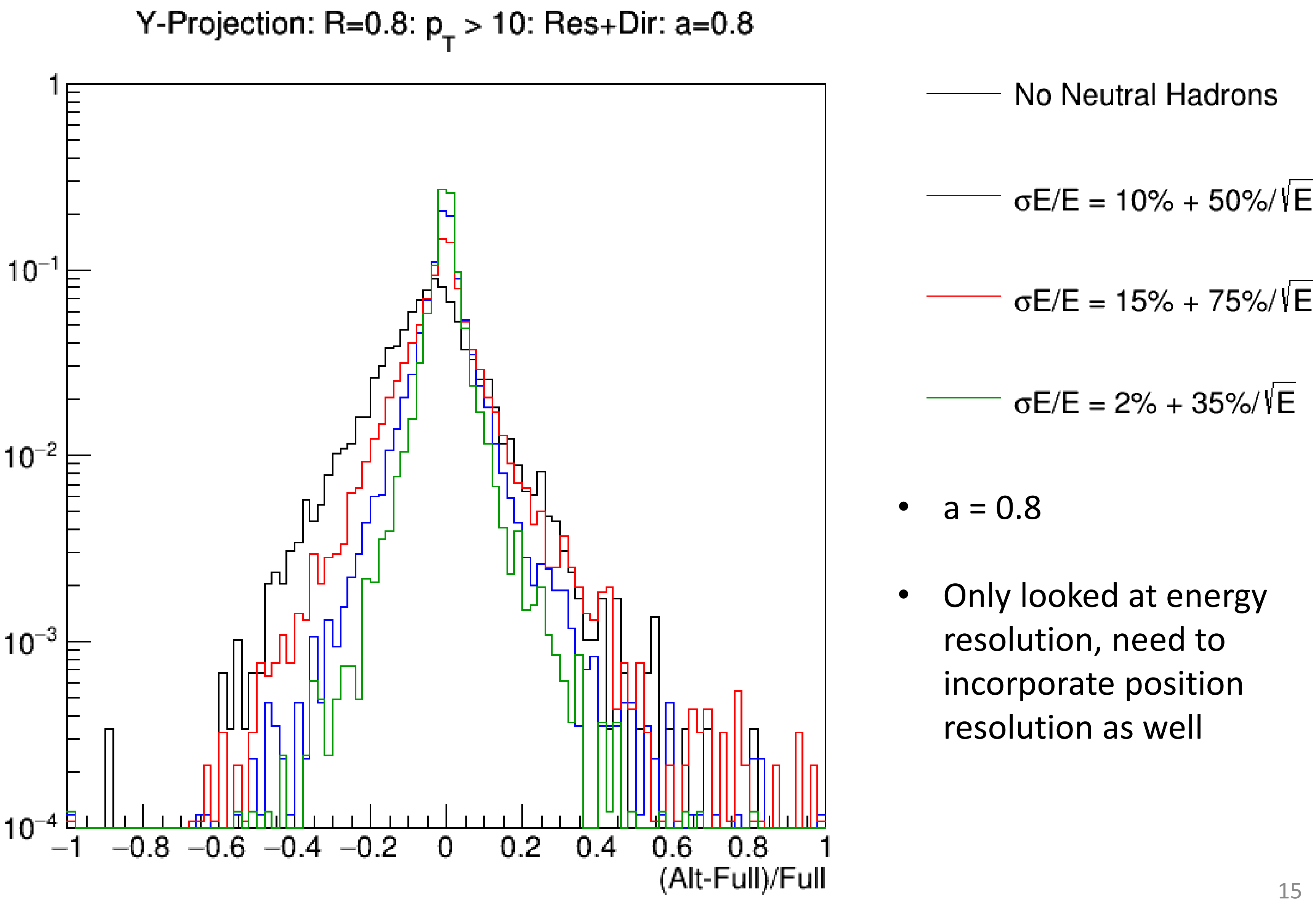
- Integrate over the true jet angularity and compare with different HCal energy resolutions
- Plot for a = -2.0

Angularity Fluctuations



- a = 0.0
- The no neutral hadron curve represents a ‘worst case scenario’
- If the smeared curves sit above the black, then we benefit by not using the HCal info

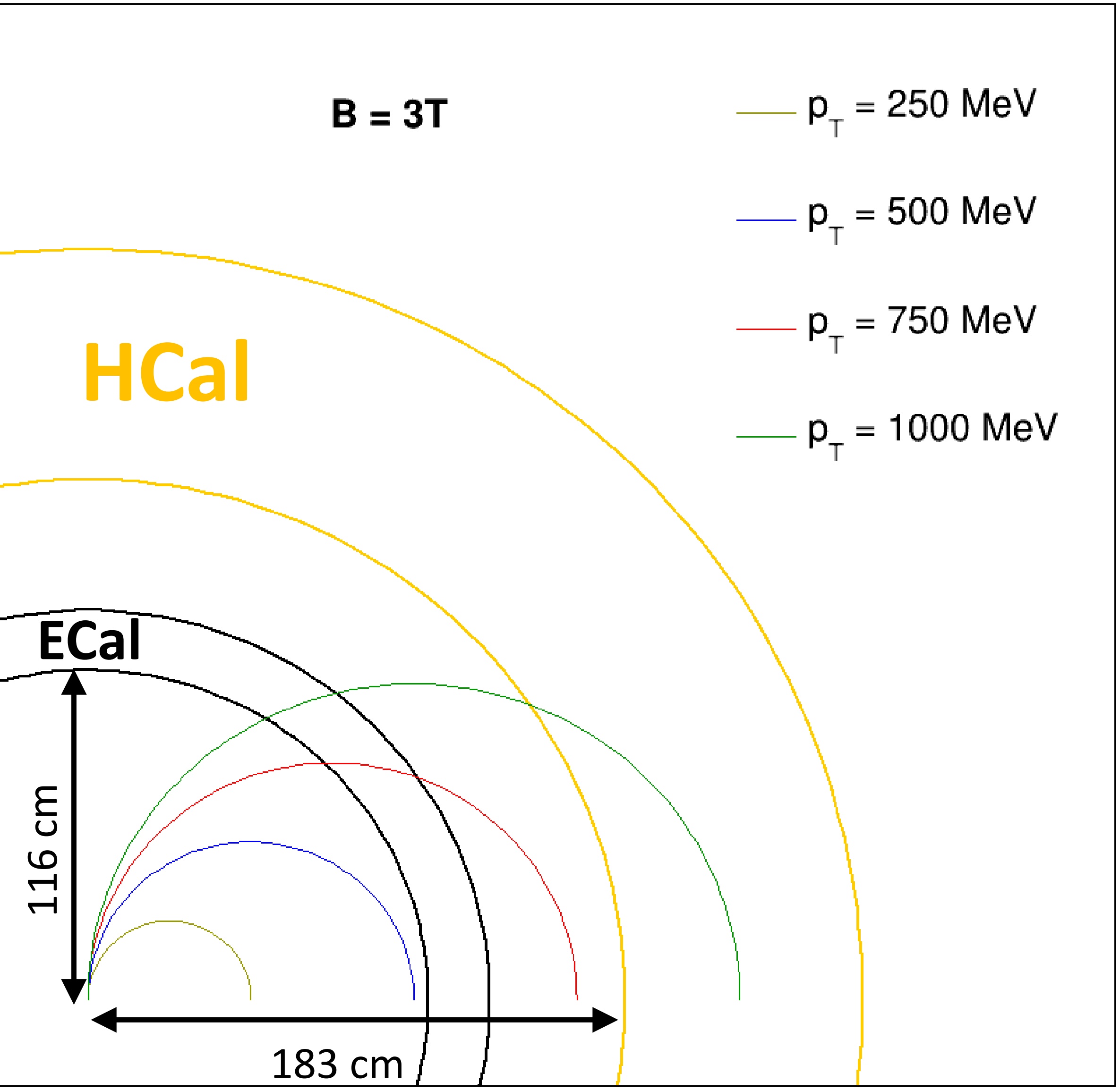
Angularity Fluctuations



- a = 0.8
- Only looked at energy resolution, need to incorporate position resolution as well

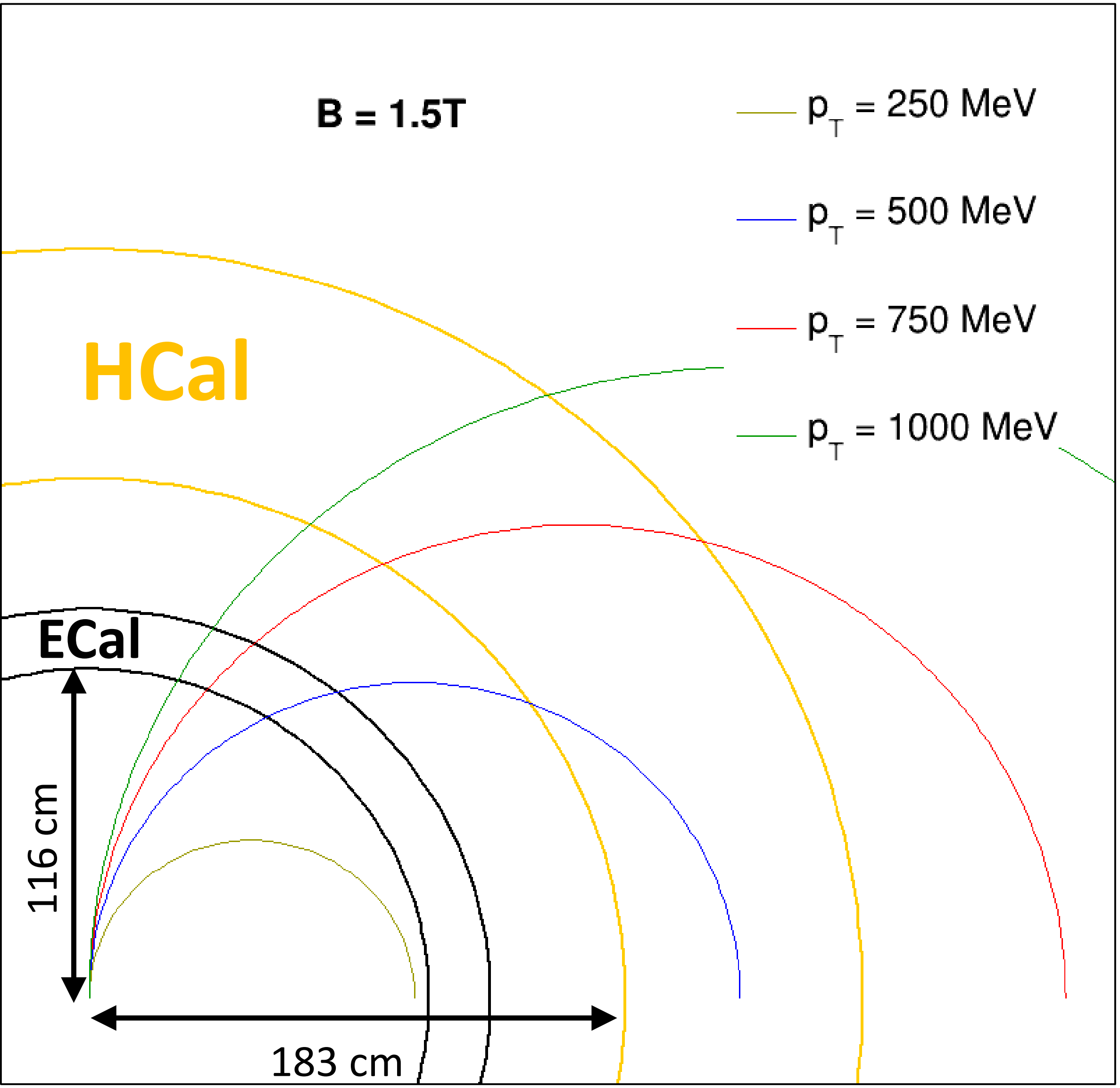
B Field Strength

Low p_T Particle Acceptance

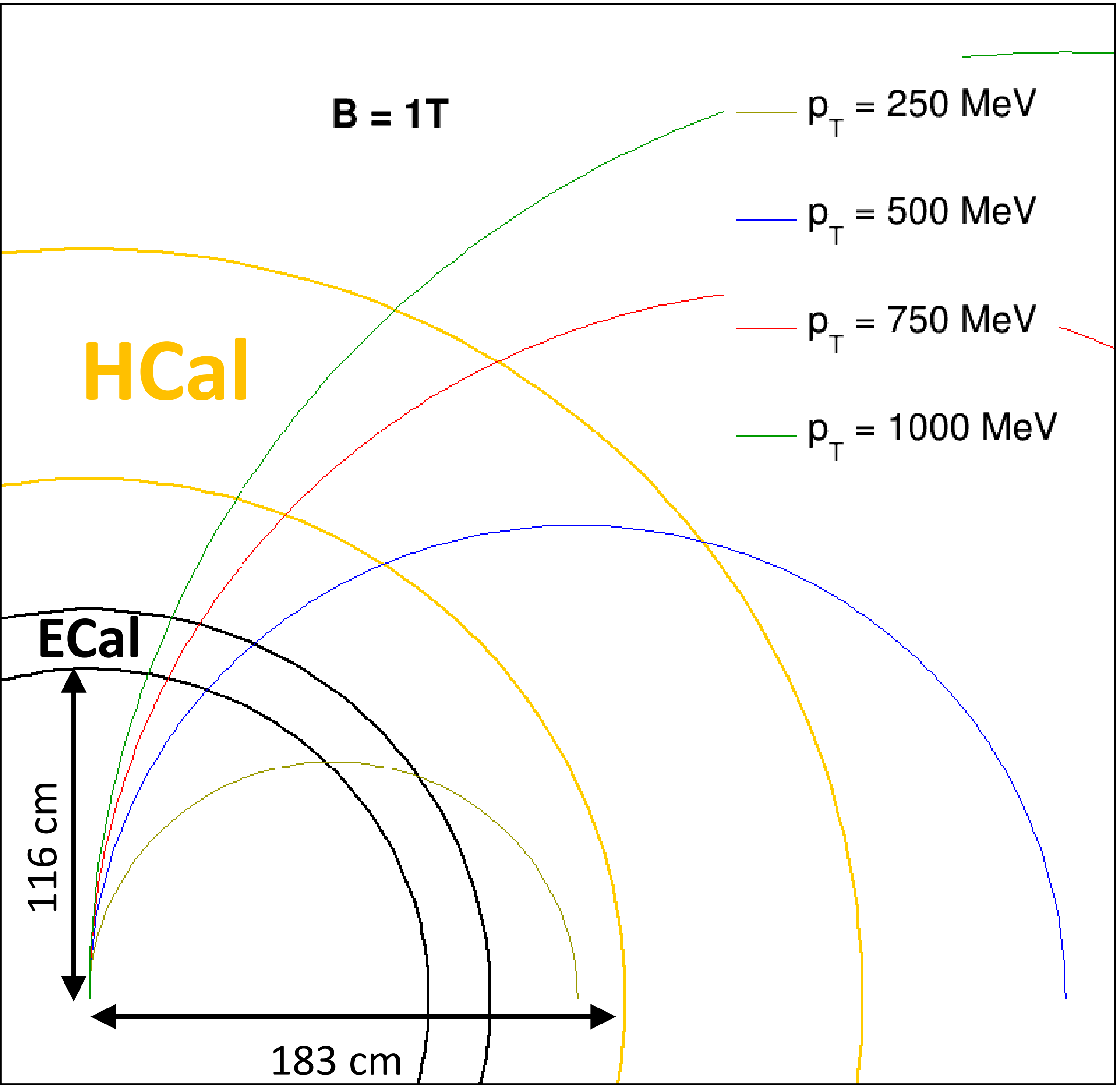


- Many detector designs, including BeAST, include a large solenoidal magnetic field
- This provides good momentum resolution but limits acceptance for low p_T particles
- Need to reach ~500 MeV to just reach the ECal
- Here we assume rough BeAST dimensions

Low p_T Particle Acceptance

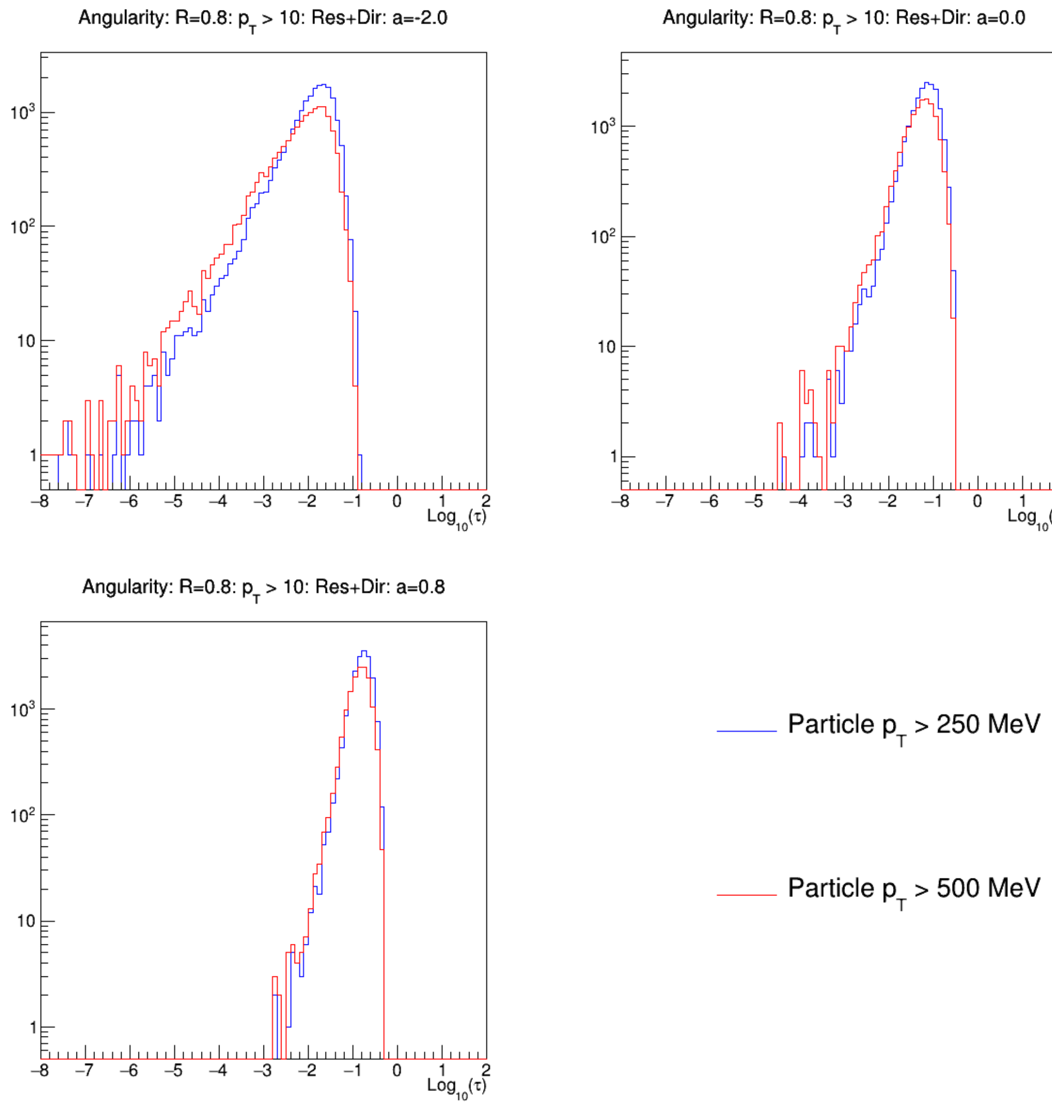


Low p_T Particle Acceptance



- As field decreases, acceptance for low momentum particles increases
- Need to study the trade-offs with track momentum resolution, especially at high pseudorapidity

Particle Acceptance and Angularity



$$\tau_a \equiv \frac{1}{p_T} \sum_{i \in J} p_T^i \left(\Delta R_{iJ}\right)^{2-a}$$

- Study the effect of reduced low p_T acceptance on angularity
- Compare jets found with minimum particle p_T of 250 MeV to those with minimum particle p_T of 500 MeV
- Cuts made at jet finder level
- See minimal changes in angularity spectra – jets with higher cutoff are slightly more collimated

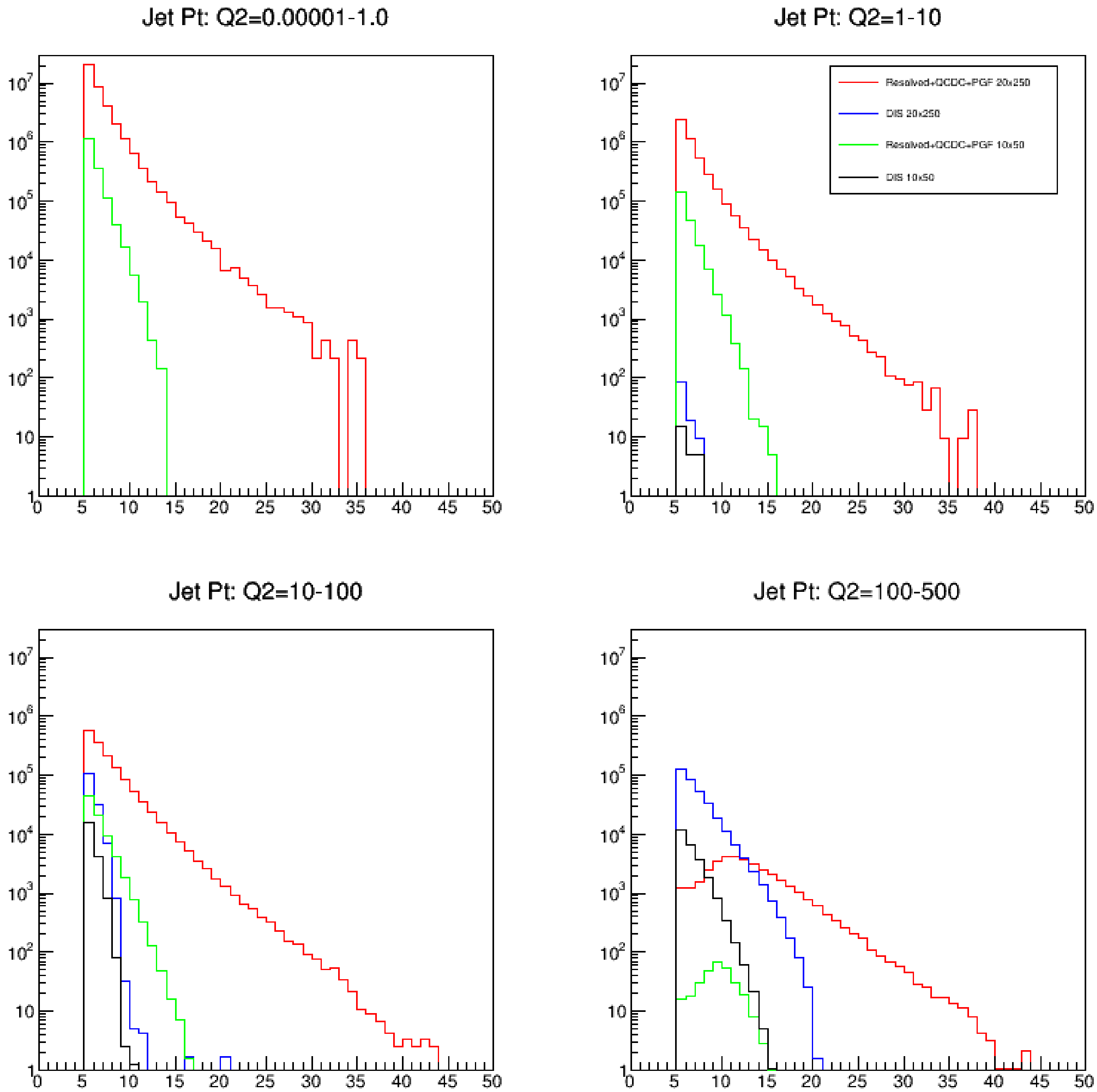
PID

- EIC detectors need strong PID capabilities for SIDIS program – can this be a benefit for jet measurements?
- Jet finder takes as input particle 4-momentum – tracker provides momentum but not energy
- Need to get energy from HCal or make assumptions about the particles being tracked
- If HCal energy resolution is poor (or if there is not full coverage) maybe it is advantageous to use PID instead
- If momentum is found from tracker and mass of particle is known by identifying its species, then 4-momentum is determined
- Have not studied this at all yet – currently just an idea

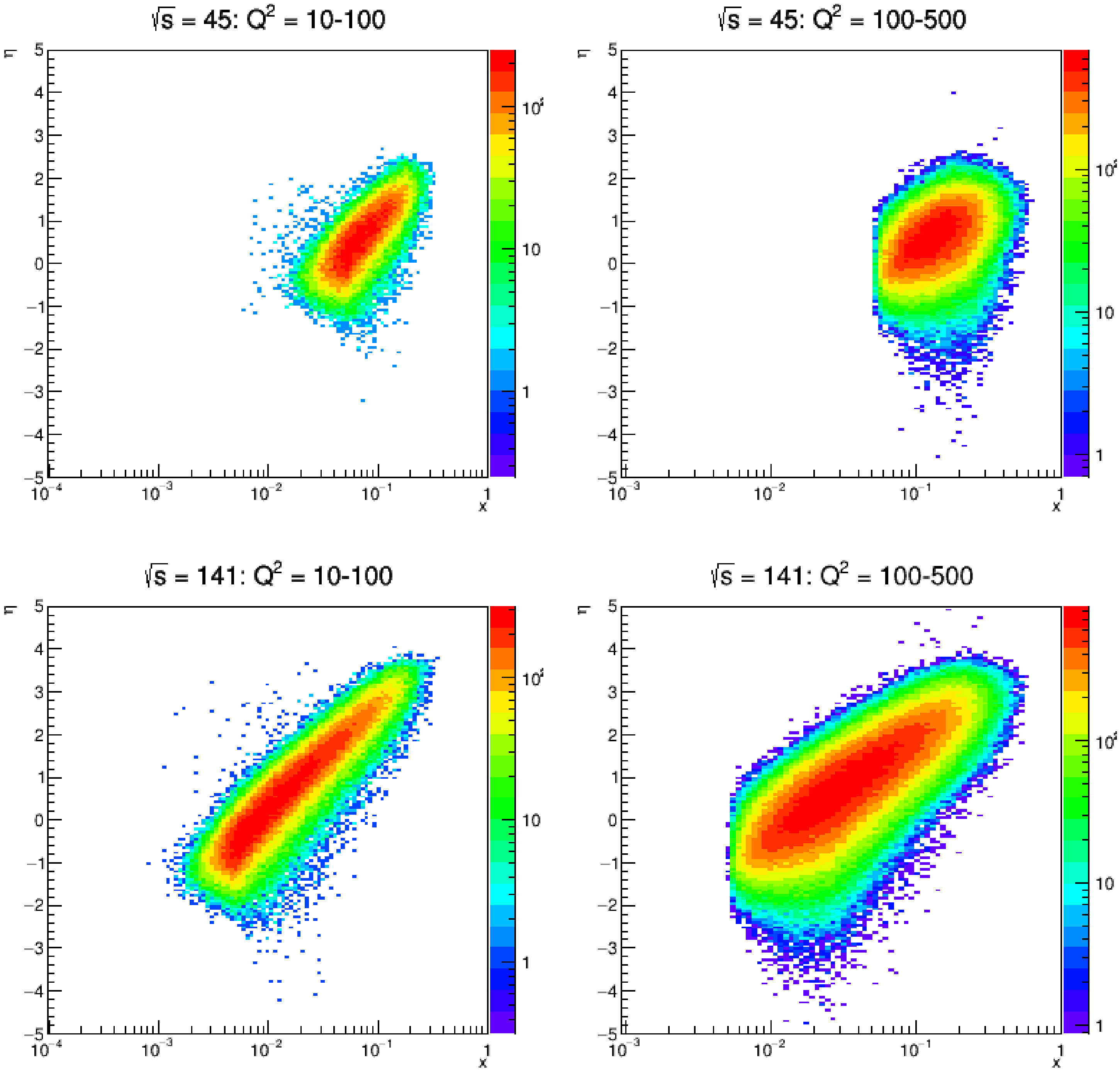
Summary

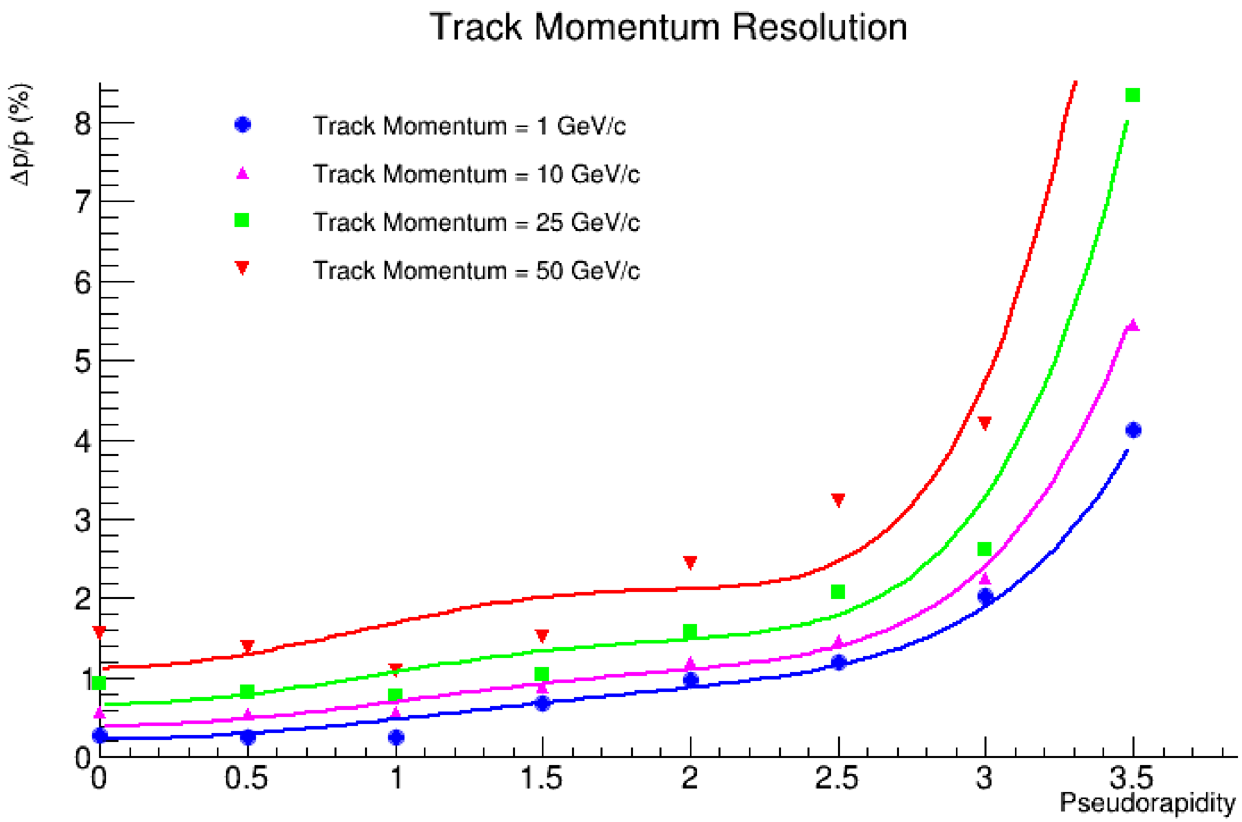
- It (probably) won't be long until calls go out for collaboration formation and detector designs take concrete form
- Those of us interested in jets need to be able to articulate what is necessary in order to accomplish the physics we are interested in (also need to understand what we can compromise on if need be)
- Due to low particle energies, will likely need very good Hcal resolution to 'directly' affect jet resolution, however, even info from low res HCal can help if used in the right way
- Need to better understand how resolutions (both energy and especially spatial effect substructure observables – full simulation tools would be great help (if available in time)
- Need to better understand the tradeoffs involved in reducing magnetic field strength
- For substructure: need a better understanding of the size of nuclear matter effects we want to study – need input from theory and MC communities

Backup



Jet Pt: Q2=0.00001-1.0
Jet Pt: Q2=1-10
Resolved+QCDC+PGF 20x250
DIS 20x250
Resolved+QCDC+PGF 10x50
DIS 10x50
Jet Pt: Q2=10-100
Jet Pt: Q2=100-500

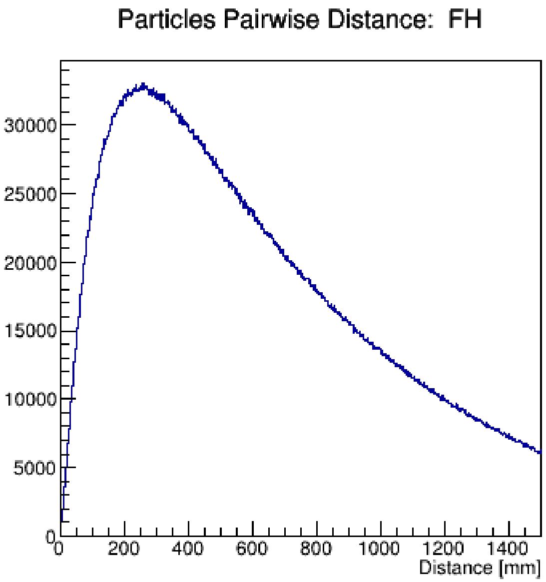

√s = 45: Q² = 10-100
√s = 45: Q² = 100-500
√s = 141: Q² = 10-100
√s = 141: Q² = 100-500
η
x

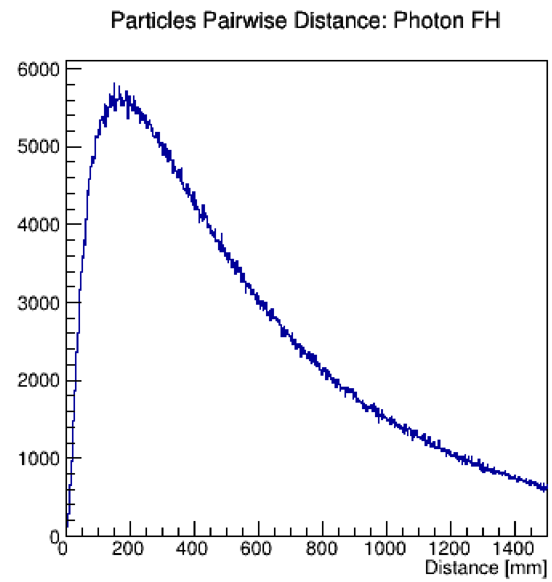


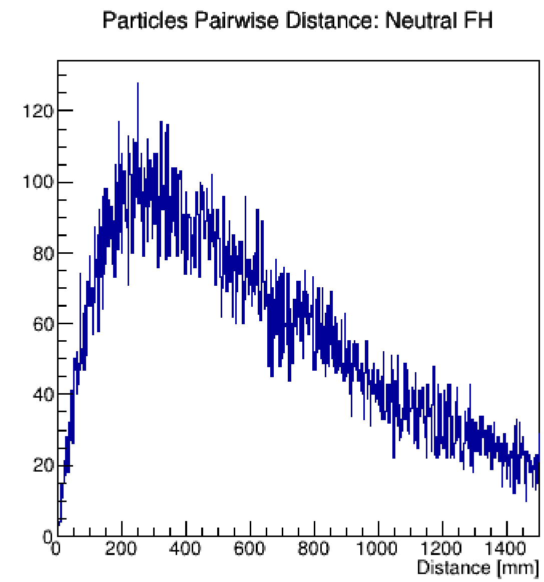
Component	Pseudorapidity Range	Resolution
Back EMCal	$-4.0 < \eta < -2$	$\frac{1.5\%}{\sqrt{E}} \oplus 1\%$
Mid-Back EMCal	$-2 < \eta < -1$	$\frac{7\%}{\sqrt{E}} \oplus 1\%$
Mid EMCal	$-1 < \eta < 1$	$\frac{10\%}{\sqrt{E}} \oplus 1\%$
Fwd EMCal	$1 < \eta < 4.0$	$\frac{10\%}{\sqrt{E}} \oplus 1\%$
Fwd/Back HCal	$1 < \|\eta\| < 4.0$	$\frac{50\%}{\sqrt{E}} \oplus 10.0\%$
Lo Res Mid Hcal	$-1 < \eta < 1$	$\frac{75\%}{\sqrt{E}} \oplus 15\%$
Hi Res Mid Hcal	$-1 < \eta < 1$	$\frac{35\%}{\sqrt{E}} \oplus 2\%$

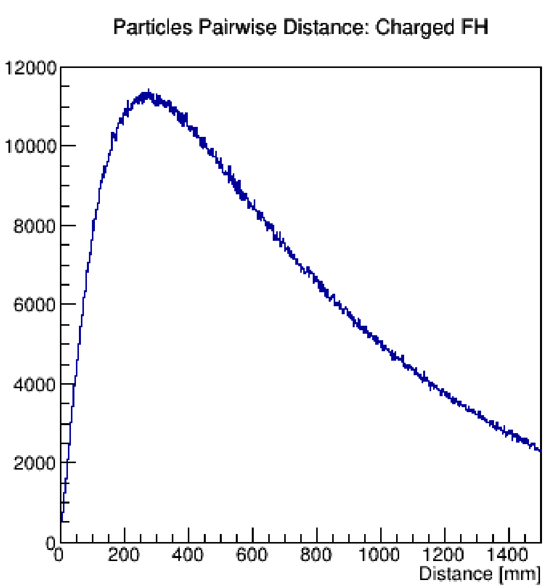
TABLE I. Different Calorimeter setups used in the simulations

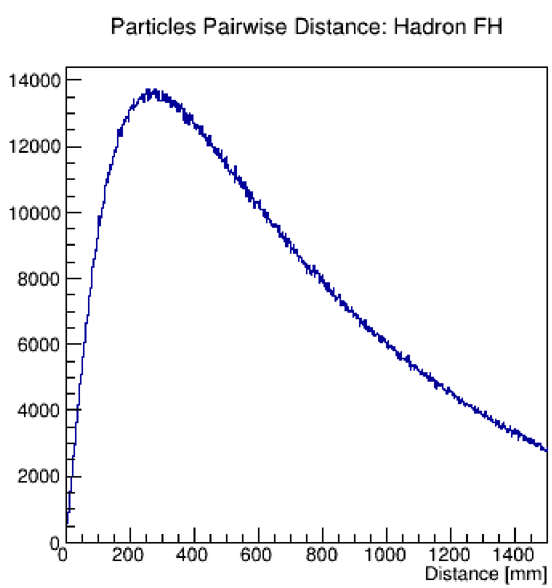
Particle Distances: Forward



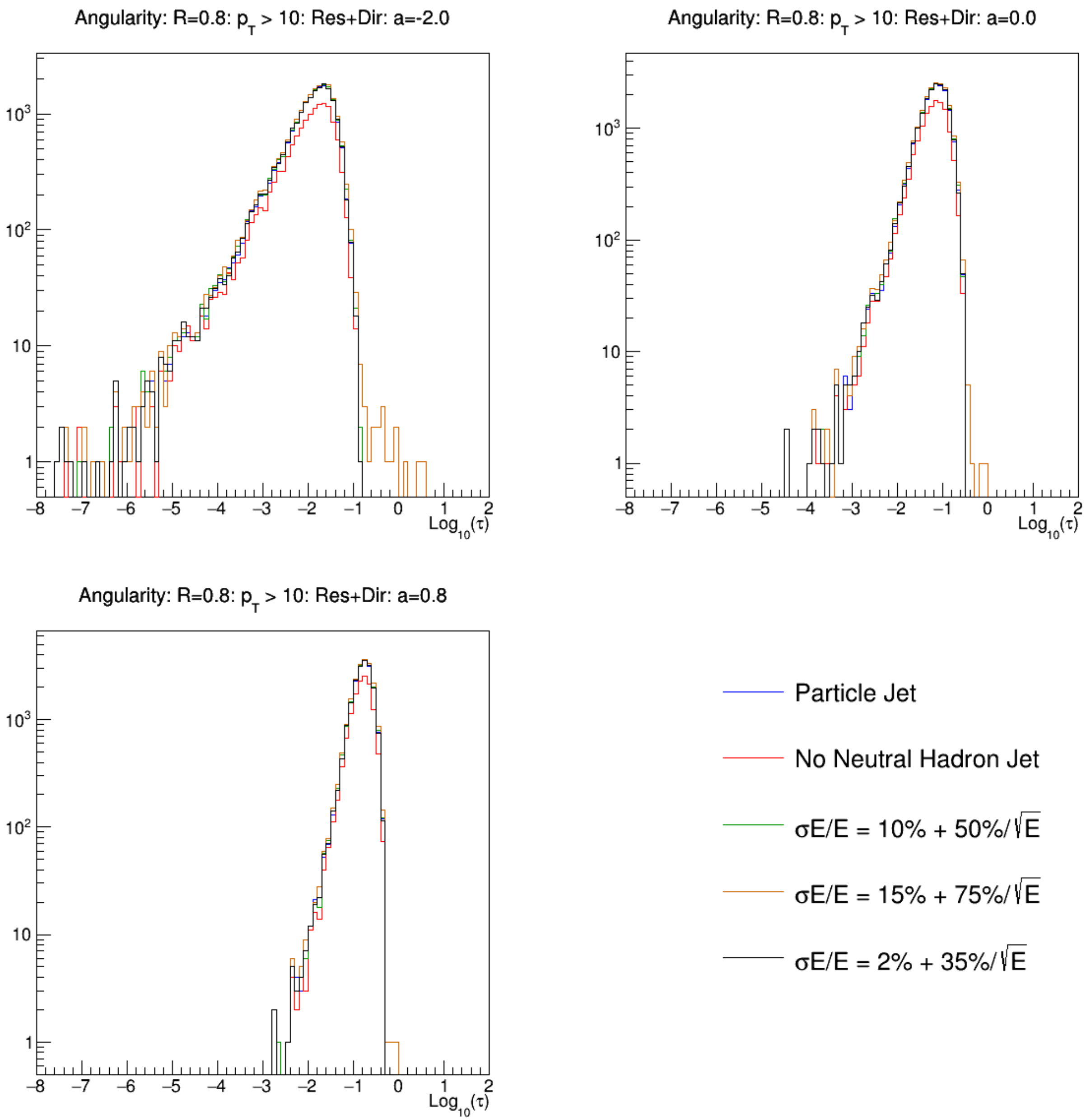


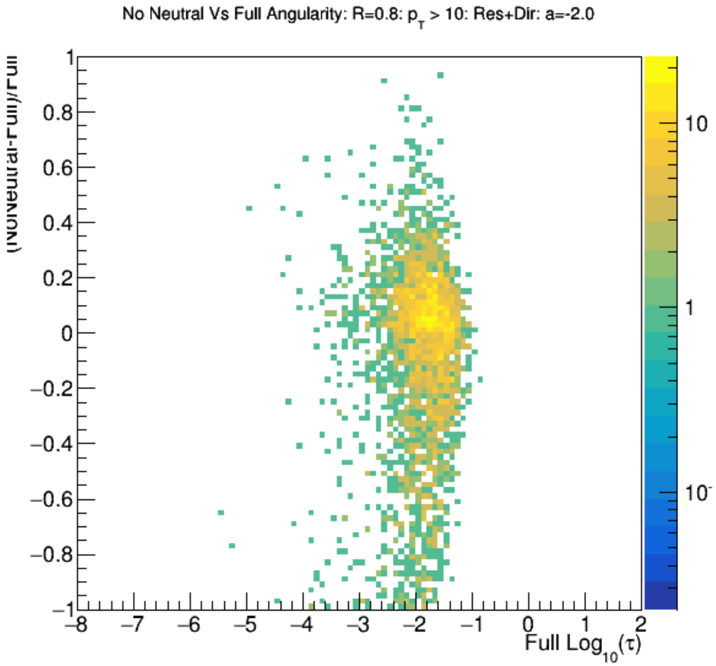


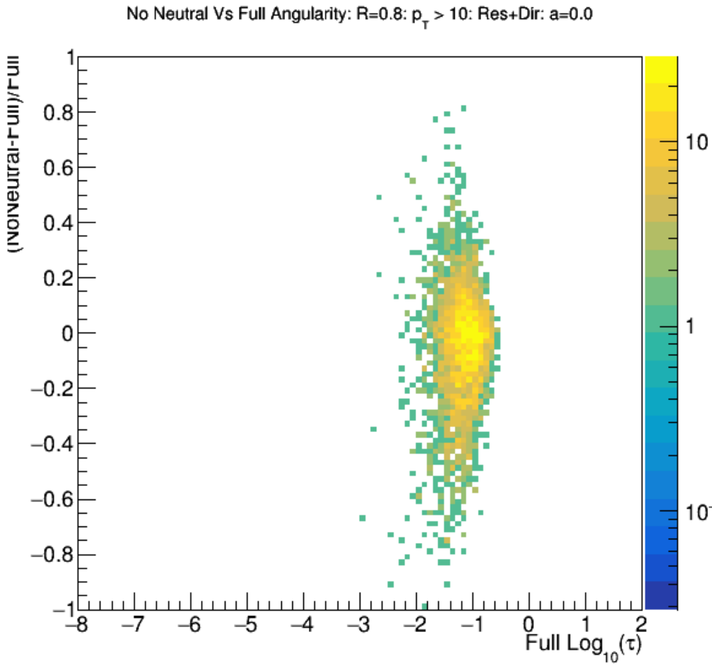




HCal


Angularity: R=0.8: p_T > 10: Res+Dir: a=-2.0
Angularity: R=0.8: p_T > 10: Res+Dir: a=0.0
Angularity: R=0.8: p_T > 10: Res+Dir: a=0.8
$Log_{10}(\tau)$
Particle Jet
No Neutral Hadron Jet
$\sigma E/E = 10\% + 50\%/\sqrt{E}$
$\sigma E/E = 15\% + 75\%/\sqrt{E}$
$\sigma E/E = 2\% + 35\%/\sqrt{E}$


No Neutral Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=-2.0
(NoNeutral-Full)/Full
Full $Log_{10}(\tau)$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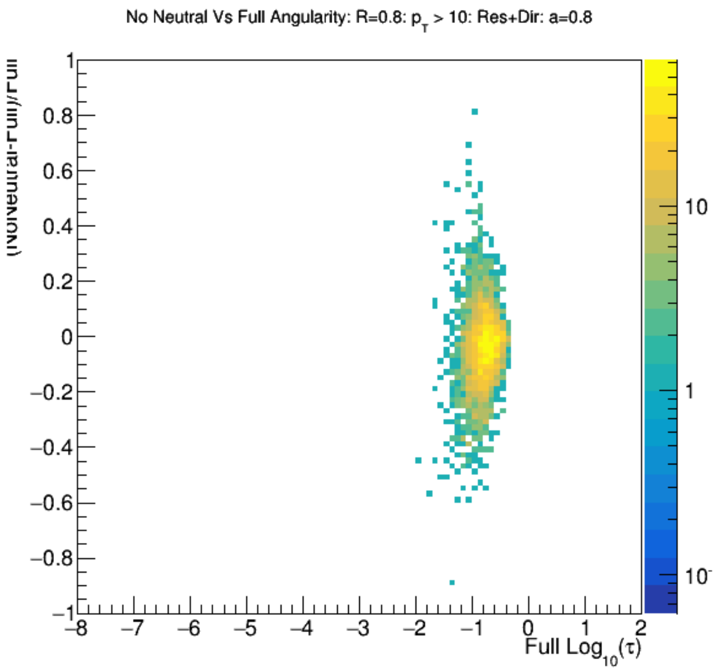
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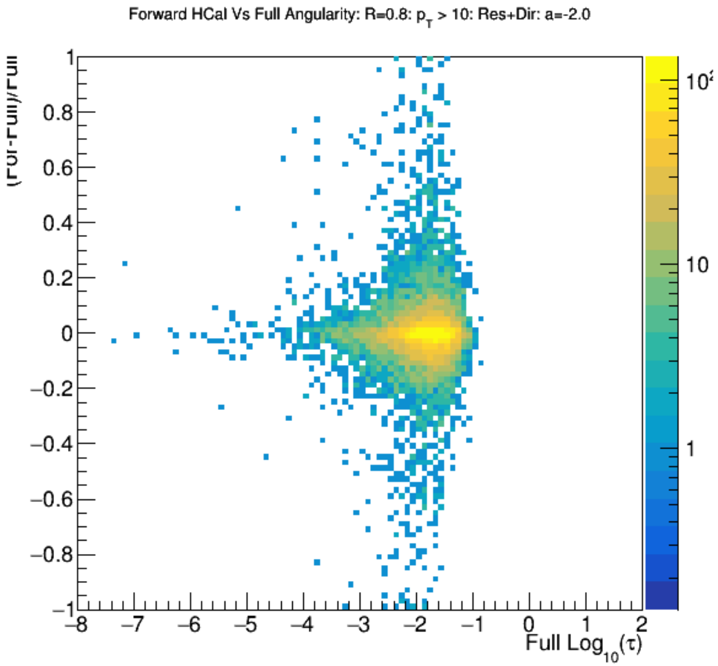
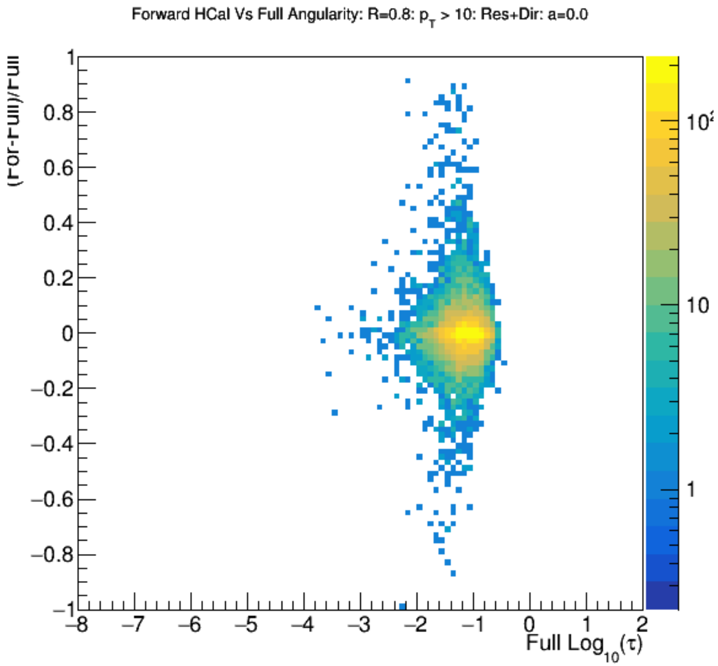

Forward HCal Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=-2.0
(For-Full)/Full
Full $Log_{10}(\tau)$


Forward HCal Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=0.0
(For-Full)/Full
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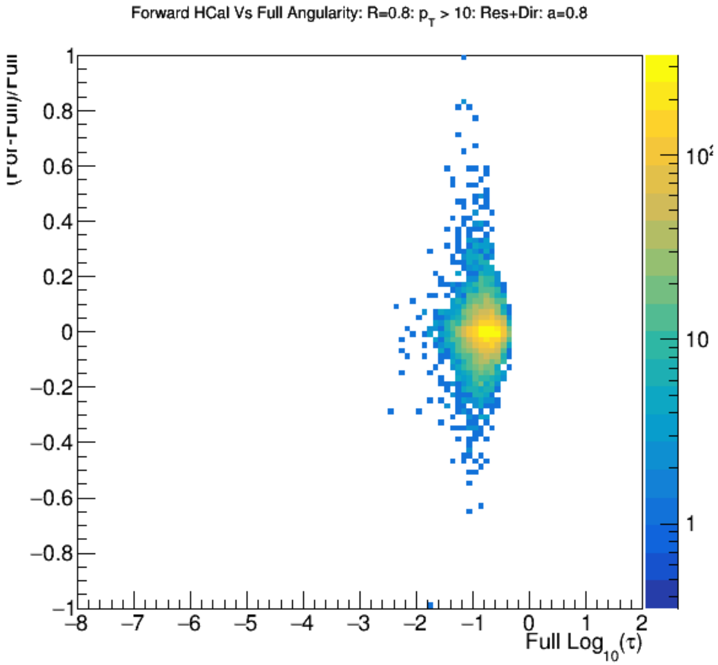
Forward HCal Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=0.8
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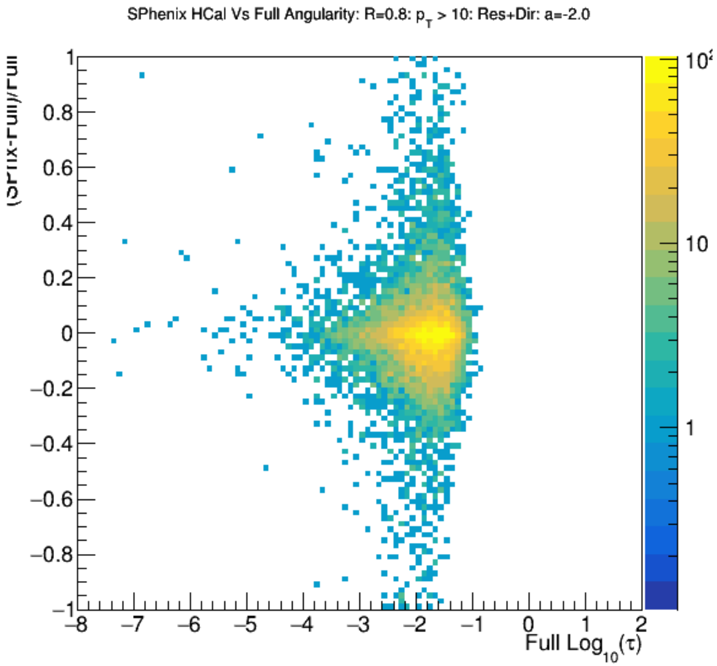
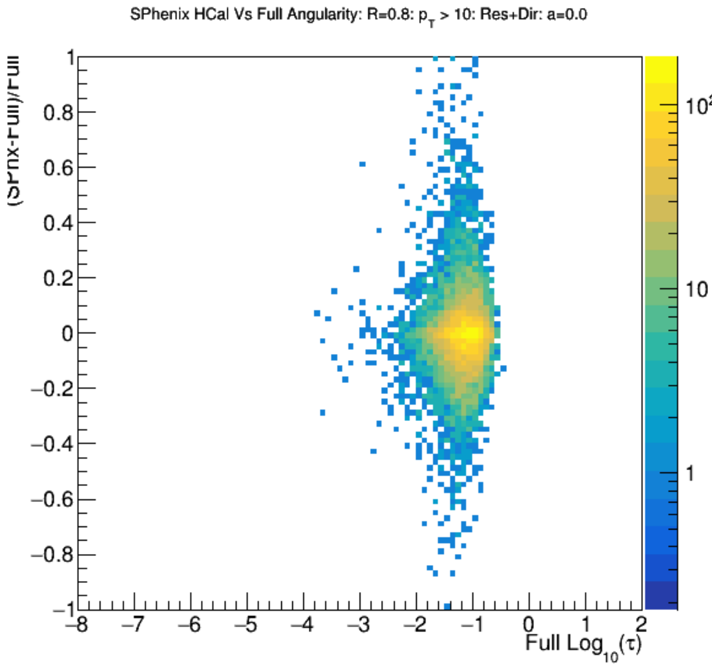

SPhenix HCal Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=-2.0
(SPhx-Full)/Full
Full $Log_{10}(\tau)$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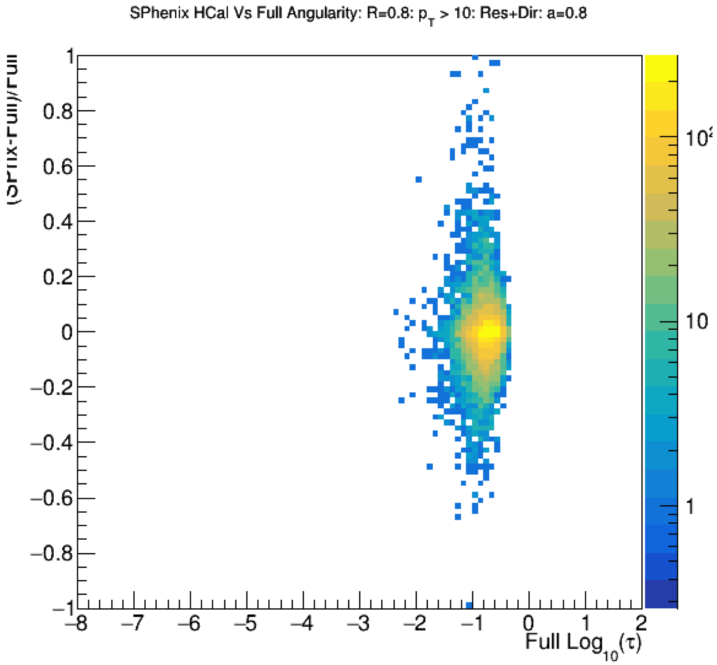
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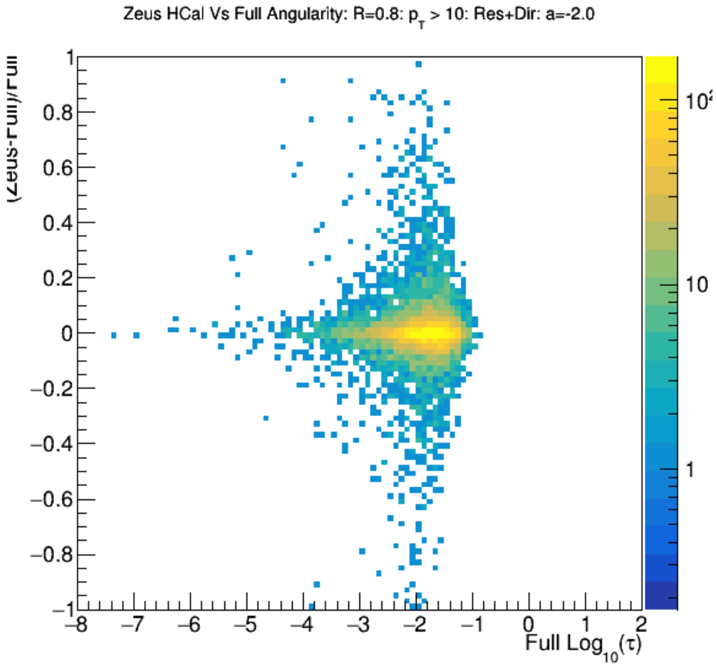
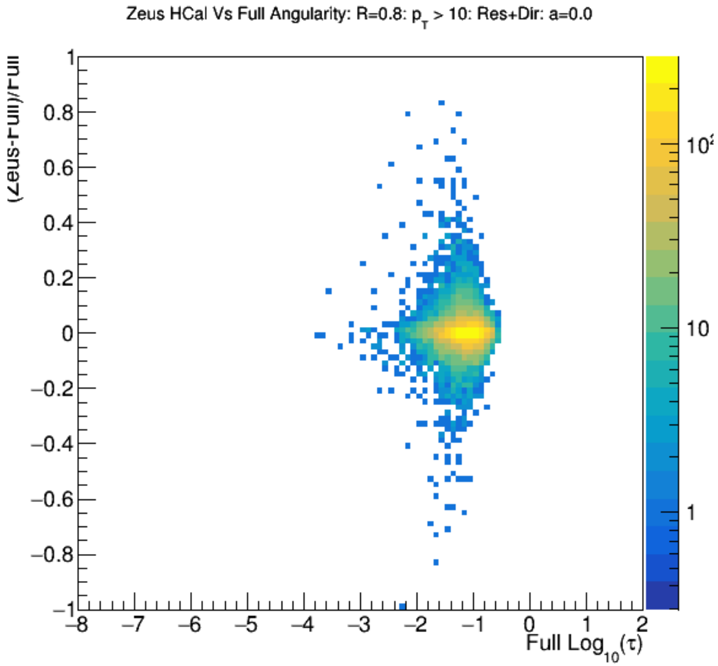
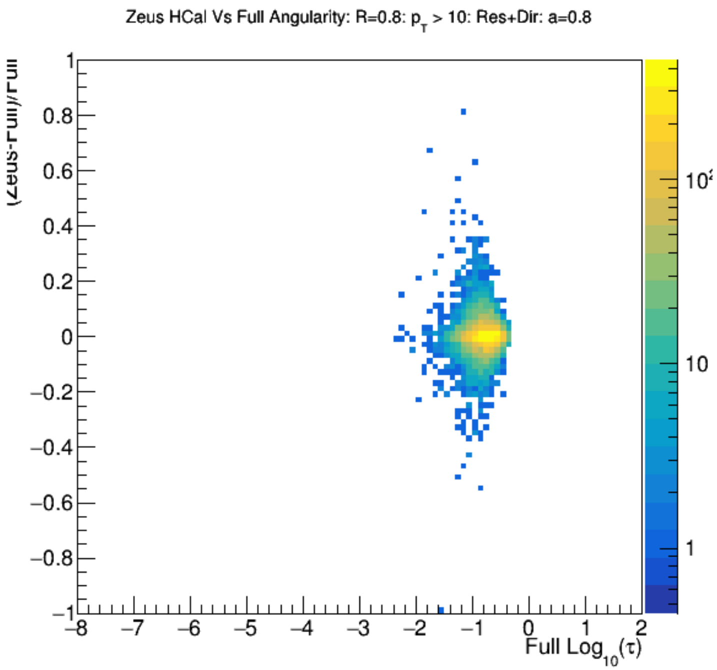

Zeus HCal Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=-2.0
(Zeus-Full)/Full
Full $Log_{10}(\tau)$


Zeus HCal Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=0.0
(Zeus-Full)/Full
Full $Log_{10}(\tau)$


Zeus HCal Vs Full Angularity: R=0.8: p_T > 10: Res+Dir: a=0.8
(Zeus-Full)/Full
Full $Log_{10}(\tau)$