Ultimate Performance Parameters for the EMCAL

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sPHENIX General Meeting
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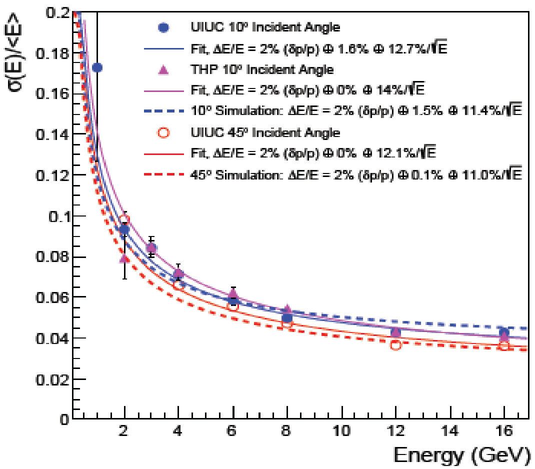
Do we need to change our EMCAL UPPs ?

- At the time of the original sPHENIX MIE (May 2012) we came up with a number for the required resolution for the EMCAL of "15%/√E". This was based on what we thought we needed to measure jets and the upsilon at that time.
- A lot has happened since then…
- We've now gone through 4 beam tests of two different calorimeter designs (one with the "optical accordion" and three with the W/SciFi SPACAL)
- We have now measured the energy resolution in great detail for both projective and non-projective blocks

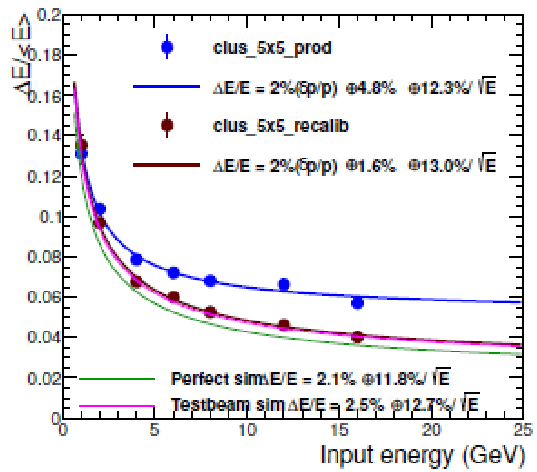
Beam Test Results

2016 **Beam Centered on a single tower** 2017

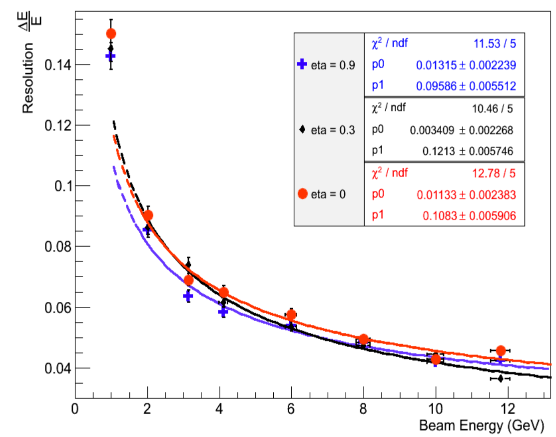
2014 - UCLA



1D Projective (η = 0)

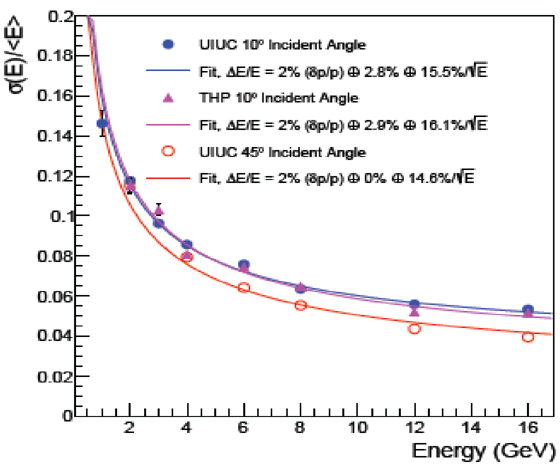


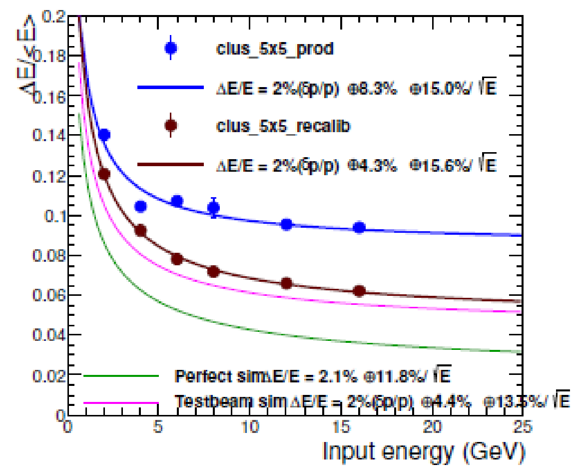
2D Projective (η ~ 0.9)



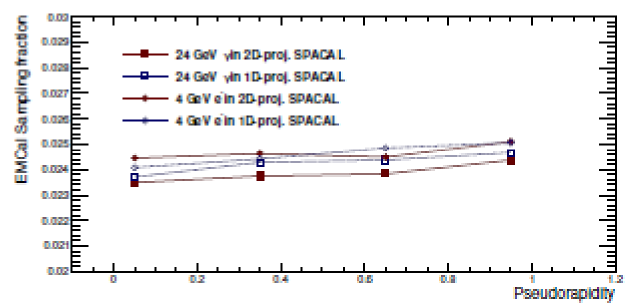
1D Projective (η = 0, 0.3, 0.9)

O.Tsai (2014)





Sampling fraction changes with rapidty



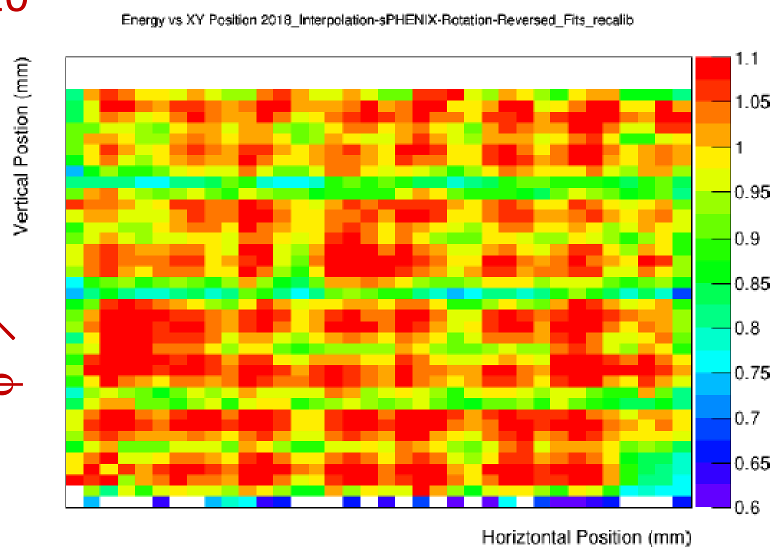
Beam spread over more than one block

Lessons Learned from V2.1 Prototype

The non-uniformity in energy response across the detector was somewhat improved compared to the V2 prototype but is still quite significant.

ϕ tilt: 5°
η tilt: 10°

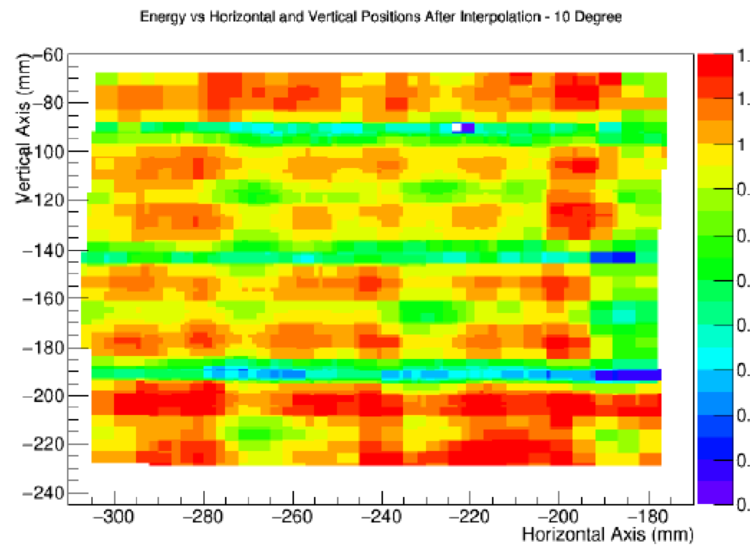
2018 sPHENIX Rotation Scan



ϕ ↑

η →

2017 10 Degree Tilted Scan



Conclusion: ϕ tilt is not enough. Probably need to increase ϕ tilt angle (5 deg → 10 deg). This has just been tested during the last few days at Fermilab

Specifying our energy resolution

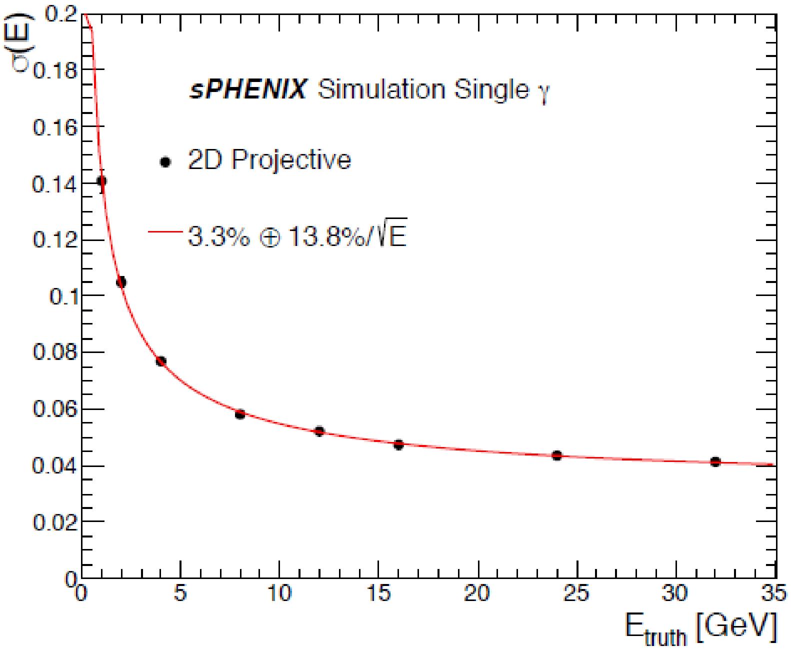
- Specifying our energy resolution simply as 15%/√ E makes no sense. It implies an unachievable resolution at higher energies. Any calorimeter expert (or even a non-expert) will question why don't specify a constant term in our energy resolution. This will determine our energy resolution at high energies and is directly related to the uniformity of response of the calorimeter and how well we can calibrate it and maintain that calibration.

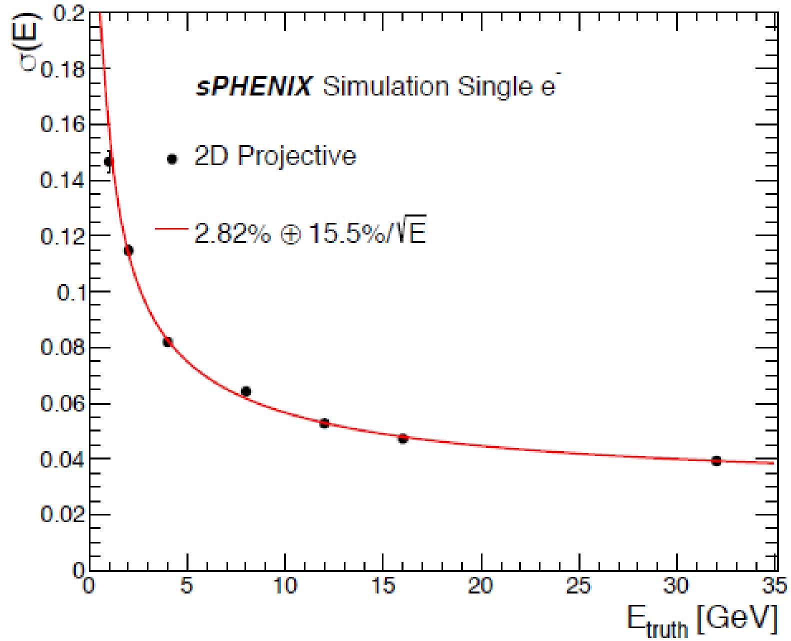
$$\sigma/E = a/\sqrt{E} \oplus c$$

- The actual detector response can best be determined using single particles which can be verified in the test beam.
- However, in heavy ion collisions, we have an additional "noise term" that comes from the underlying event

Simulations - single particle

J. Osborn



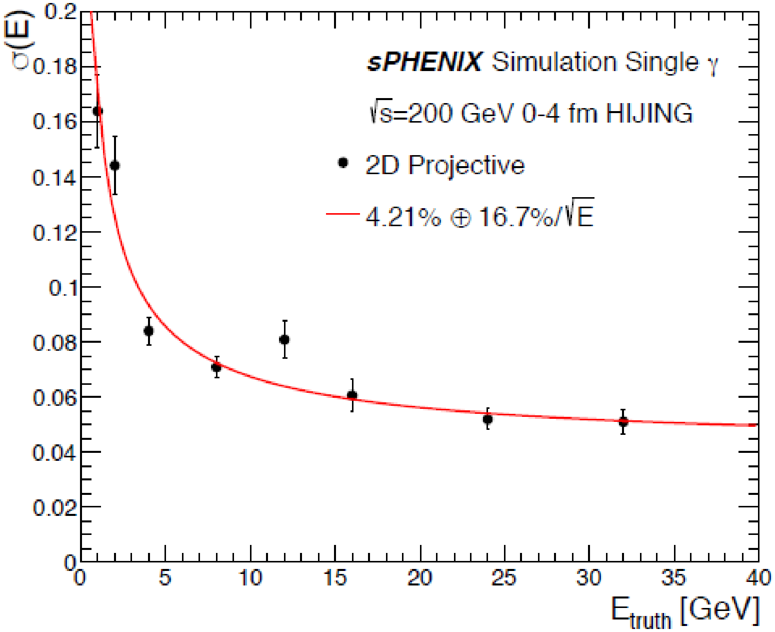


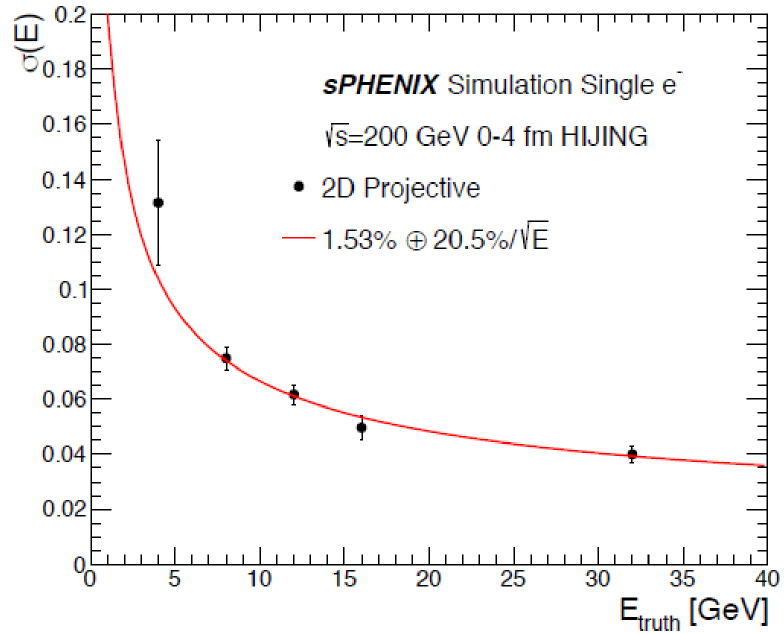
- Simulations run with full detector configuration, centralized production in /sphenix/sim/sim01/baseline/single_particle/spacal2d/fieldmap/
- $|z_{vtx}|<10$ cm

Not sure why photons give better resolution than electrons

Simulations - Hijing

J. Osborn

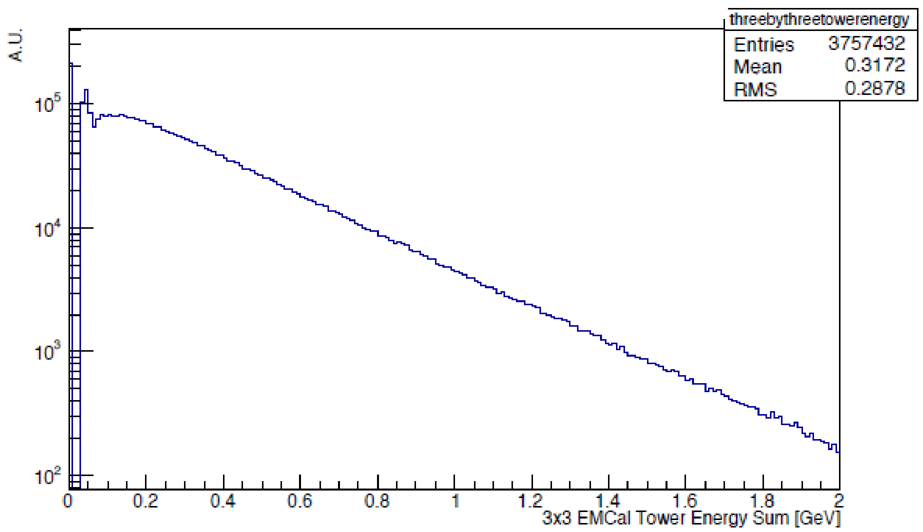




- Same single particles embedded into HIJING 0-4 fm
- Resolution degrades slightly
- Statistics starved at low energy due to 1/E term becoming dominant from the HIJING background

Contribution of the underlying event

3x3 tower sum in Central Hijing events (0-4 fm)



RMS = 288 MeV

However, S. Bazilevsky's better clusterizer only uses 4-5 towers, so the underlying event "noise" may only be ~ 200 MeV.

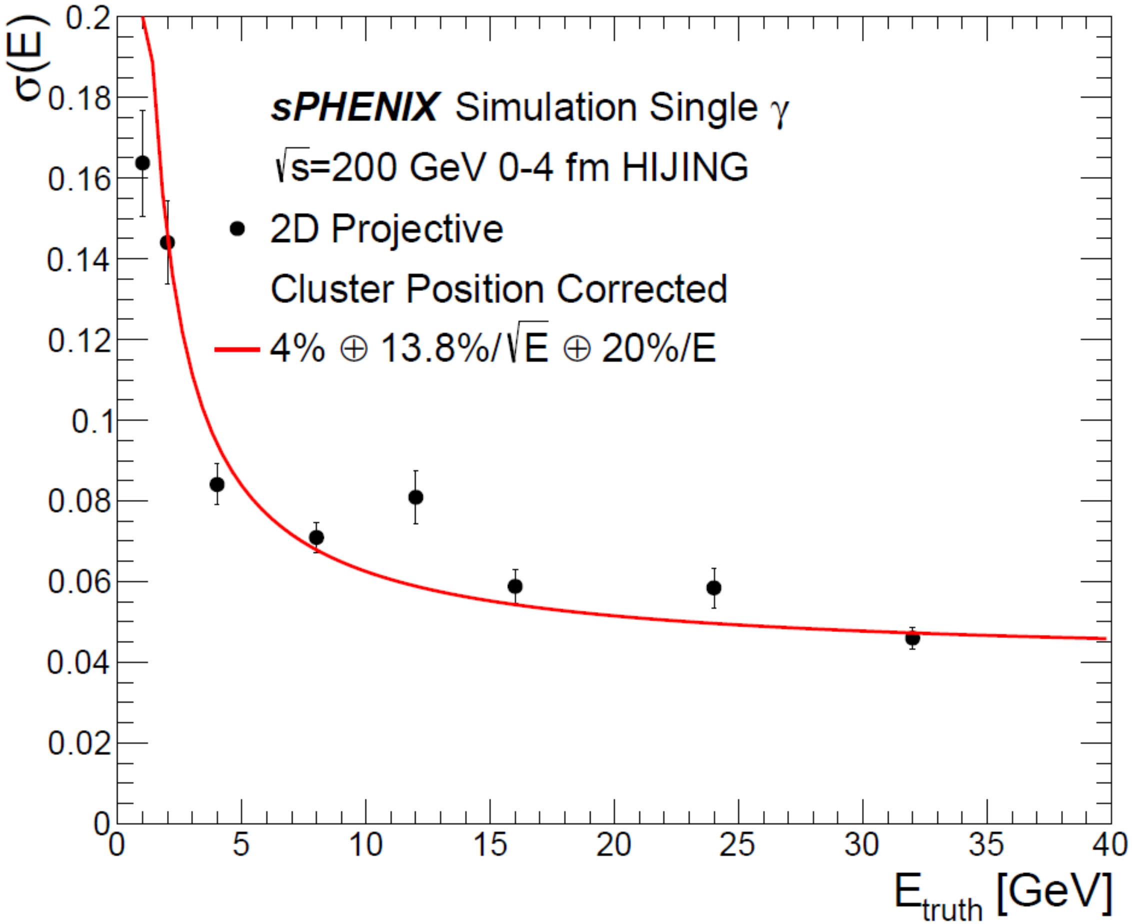
This term goes as 1/E

This would then give us a resolution of

$$\sigma/E = a/\sqrt{E} \oplus b/E \oplus c$$

Simulation with the underlying event

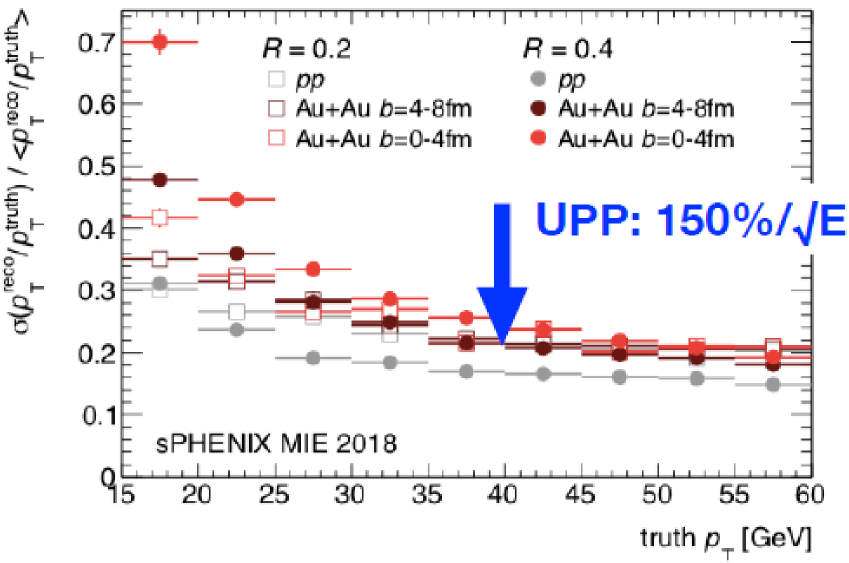
J. Osborn



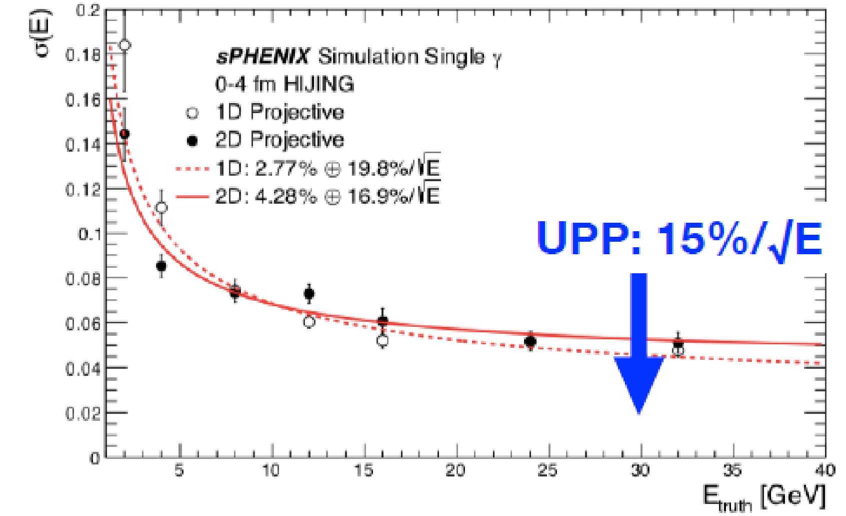
Performance simulation: Jet physics

Slide from Gunter's practice plenary talk

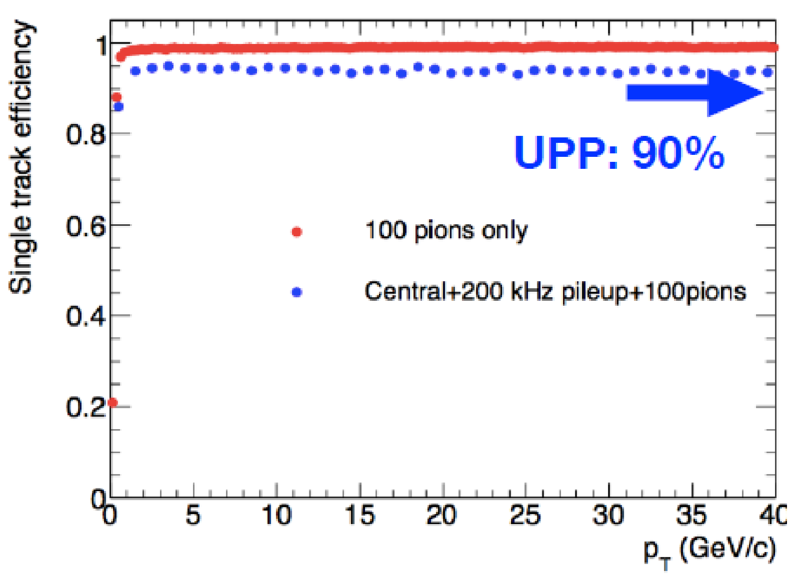
Single jet resolution (central Au+Au)



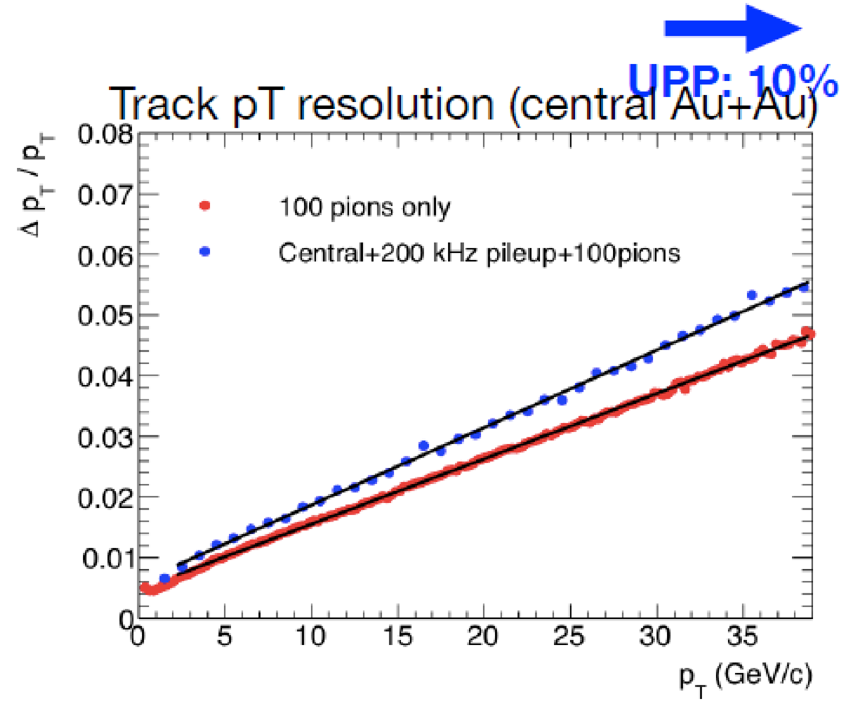
Single photon resolution (central Au+Au)



Tracking efficiency (central

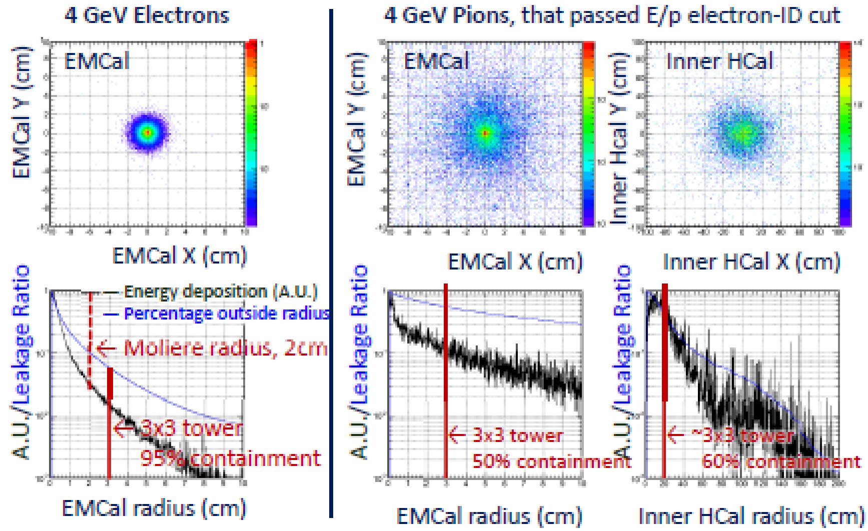


Track pT resolution (central Au+Au)



e/h separation (CDR)

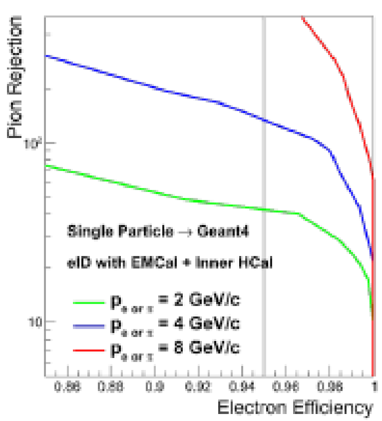
J. Huang

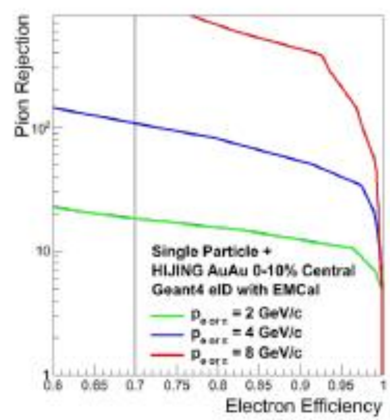


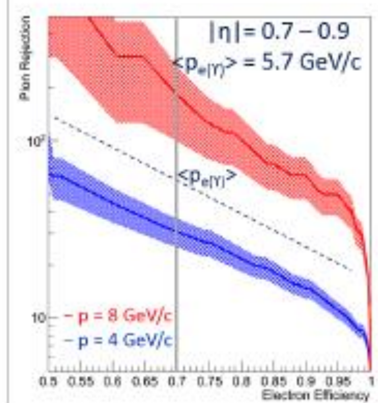
p+p

Pion rejection vs electron id probability

Central Au+Au Hijing





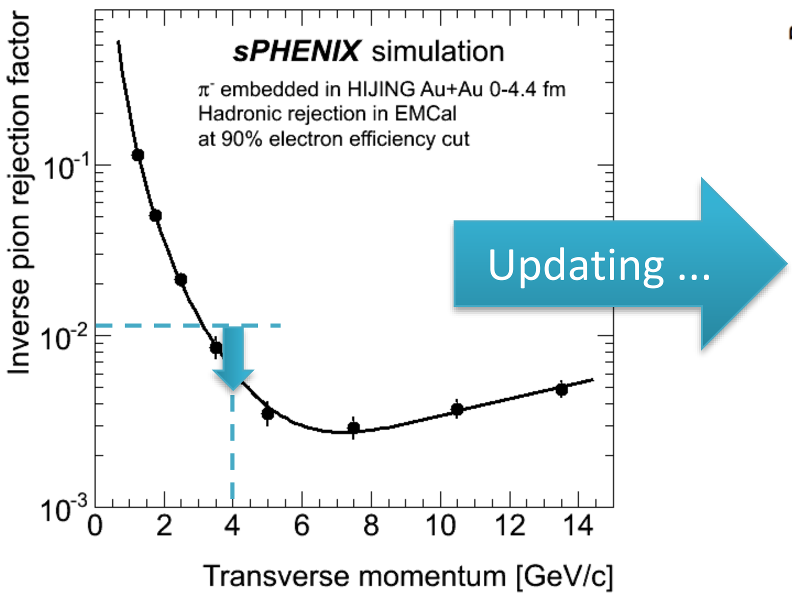


e/h separation (updated)

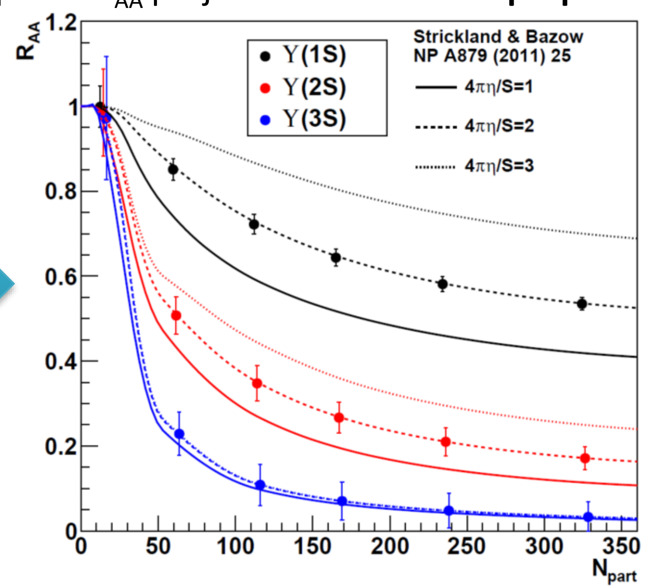
J. Huang
Directors Review Mar 2018

- Critical driving factor for EMCal design: Upsilon electron ID
- Satisfied detector requirement
  (>90:1-pion rejection @ p_T=4 GeV/c in central Au+Au collisions at 70% efficiency) CDR
- Updating Upsilon background and R_{AA} projections

Pion rejection
@ 90% efficiency
(higher than spec.)



Upsilon R_{AA} projections in **sPHENIX proposal**



Looks like we can achieve better 100:1 rejection at 90% efficiency at 4 GeV

Slide from Gunter's practice plenary talk

sPHENIX

Physics goals translate to Performance parameters

Physics goal	Analysis requirement*	Performance parameter
Maximize statistics for rare probes	Accept/sample full delivered luminosity	**Data taking rate of 15kHz in Au+Au running**
Precision Upsilon spectroscopy	Resolve Y(1s), Y(2s), (Y3s) states	**Upsilon(1s) mass resolution ≤ 100MeV in central Au+Au collisions**
High jet efficiency and resolution	Full hadron and EM calorimetry Jet resolution dominated by irreducible background fluctuations	**$\sigma/\mu \leq 150\%/\sqrt{E_{jet}}$ in central Au+Au for R=0.2 jets****
Full characterization of jet final state	High efficiency tracking for $0.2 < p_T < 40$GeV	**Tracking efficiency ≥ 90% in central Au+Au**** **Momentum resolution < 10% at 40 GeV****
Control over initial parton p_T	Photon tagging with energy resolution dominated by irreducible higher order processes	**Single photon resolution $\leq 15\%/\sqrt{E_\gamma}$****
Control over parton mass	*Precision vertexing for heavy flavor ID*	[this would be enabled by MVTX detector]

(*) informed by RHIC and LHC experience

(**) to be extracted using Au+Au, p+p data and simulations, following LHC examples

Updating our UPPs

- For the UPP for photons, rather than saying we require a single photon resolution of <15%/√ E, we can just say that we require a minimum energy resolution for photons (say <10%) for the minimum energy we plan to measure (say 15 GeV). This is something we should certainly be able to achieve
- For the UPP for the upsilon, we can just say that we will   have an e/h rejection of > 100:1, without even specifying the energy. If we can achieve this at 4 GeV, we should be able to do better at higher energies.
- I would further propose for the CDR that we specify our energy resolution as $\sigma/E = 16\%/\sqrt{E} \oplus 5\%$ for single particles and say we include a noise term of 20%/E for central HI events

Other suggestions ?