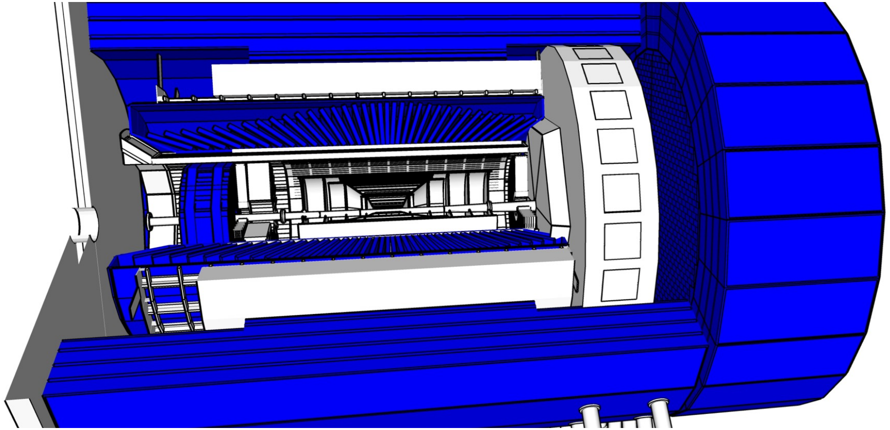
PAUL E REIMER

Argonne NATIONAL LABORATORY

ePIC Calorimetry WG

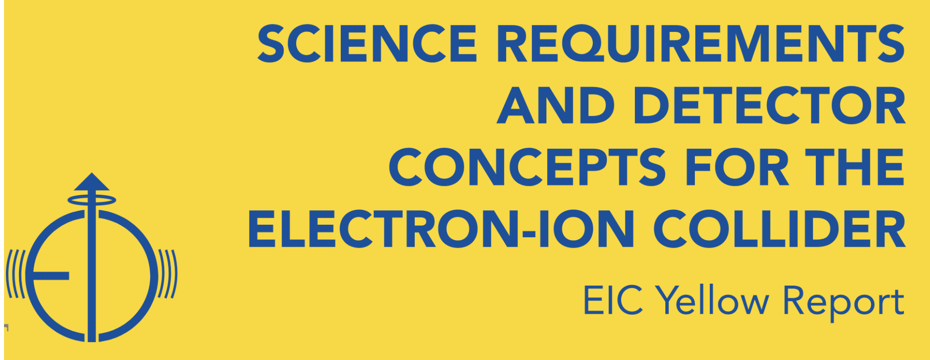


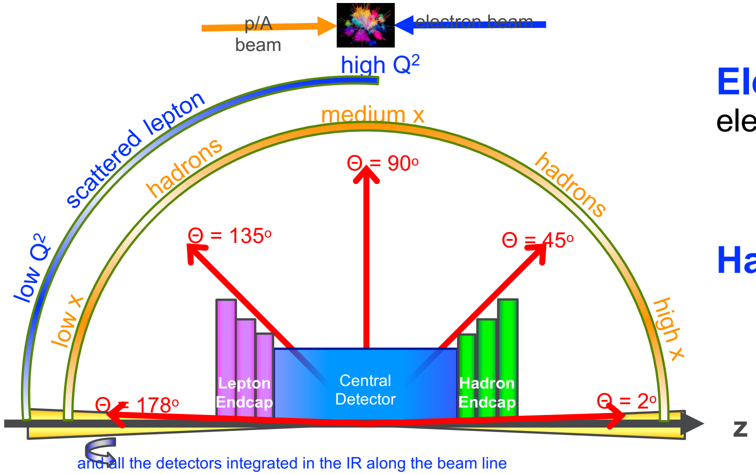
Newport News, VA
10 January 2023
Thanks to Calo WG, Conveners and esp. Alexander Kiselev, Alexander Baxilevsky and Elke C Aschenauer whose slides I've borrowed

This work was partially supported under grant DE-AC02-06CH11357 from the US Department of Energy, Office of Nuclear Physics

CALORIMETRY

Why do we need what we need where it is?





Electromagnetic calorimeter → Measure photons (E, angle), identify electrons

PbWO$_4$ Crystals (backward), W/SciFi Spacal (forward)
Barrel: Pb/SciFi+imaging part or new Scintillating glass

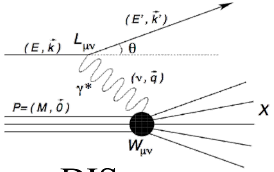
Hadron calorimeter → Measure charged hadrons, neutrons and K_L^0

challenge achieve ~50%/√E + 10% for low E hadrons (<E> ~ 20 GeV)
Fe/Sc sandwich with longitudinal segmentation

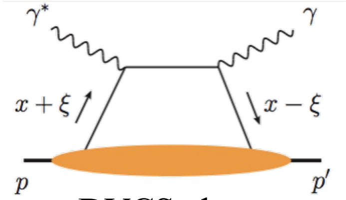
E&M Calorimetry

Electron/photon PID, energy, angle/position:

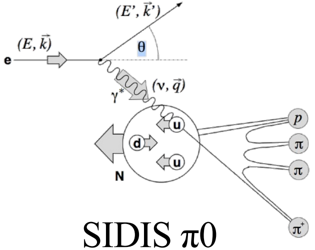
Coverage (in rapidity and energy), resolution, e/π, granularity, projectivity



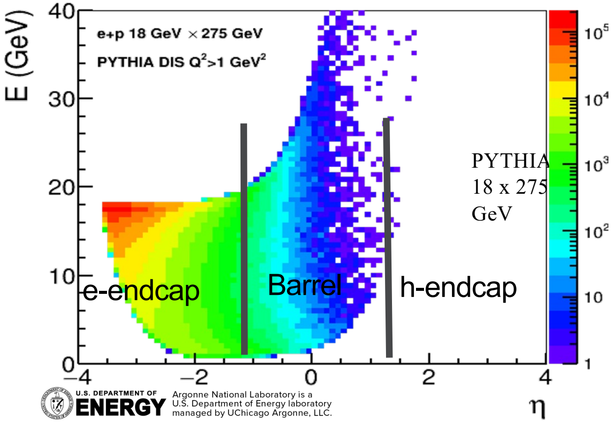
DIS e

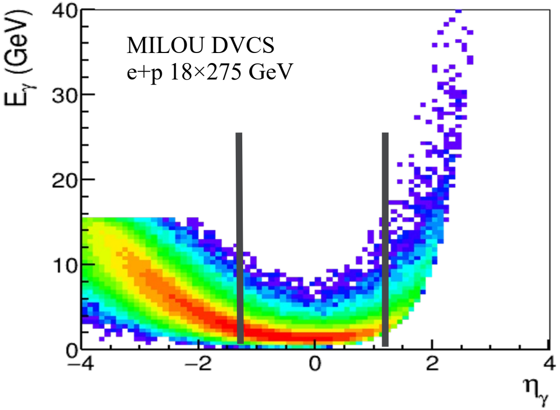


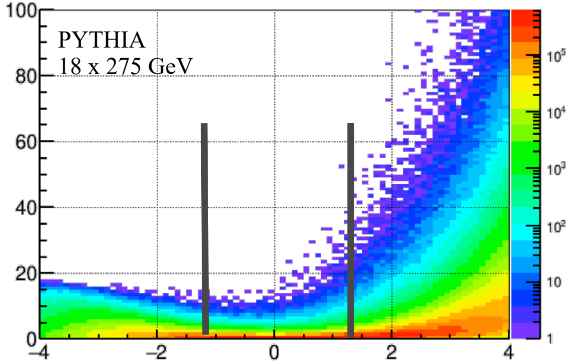
DVCS photons



SIDIS π0



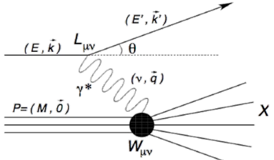




E&M Calorimetry

Electron/photon PID, energy, angle/position:

Coverage (in rapidity and energy), resolution, e/π, granularity, projectivity



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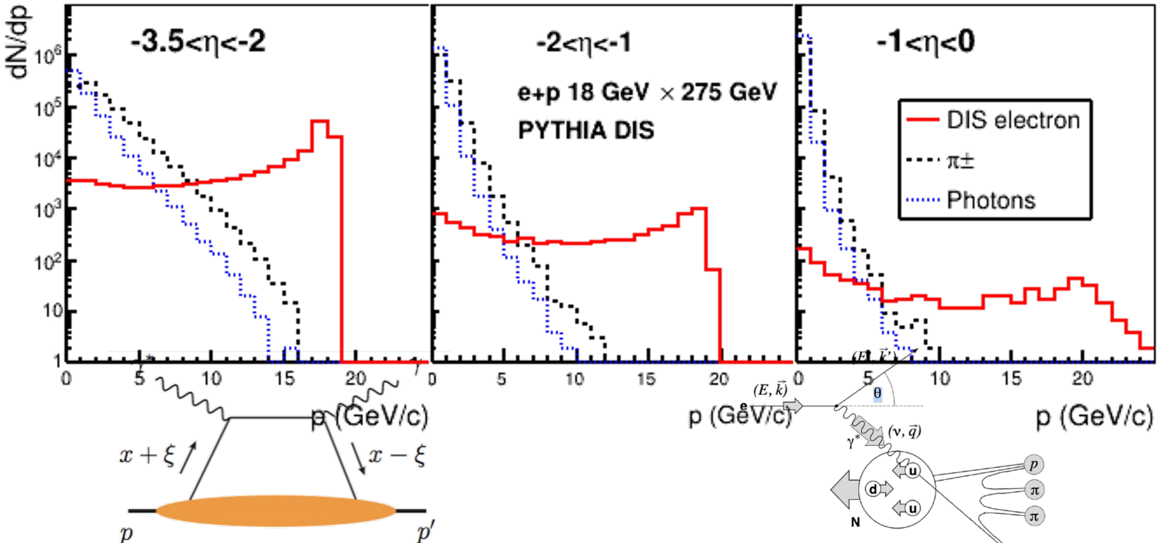
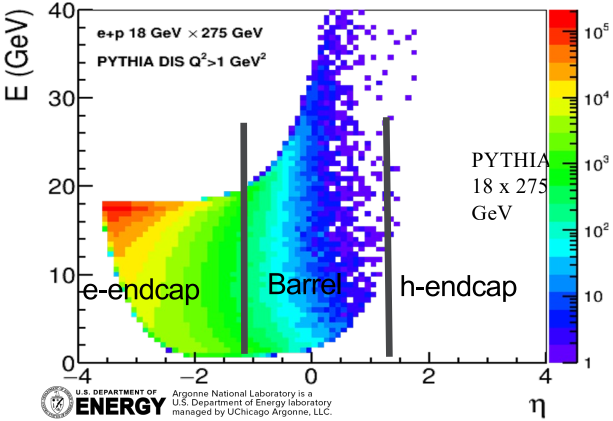
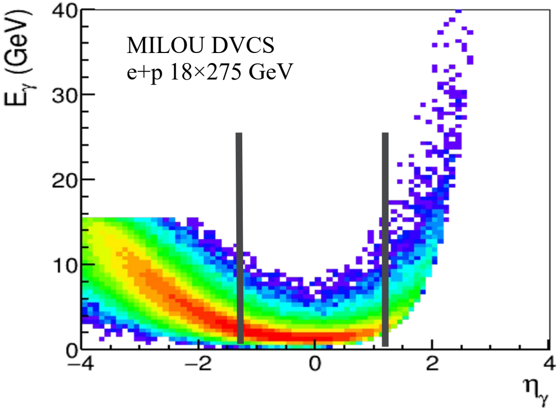
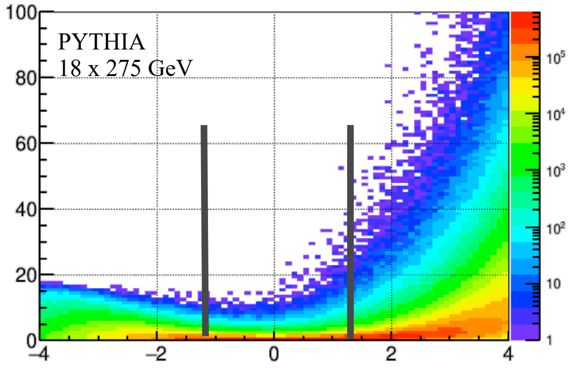


DVCS photons

SIDIS π0







E&M Calorimetry

As documented in YR and
"General, Functional, and Performance Requirements for the EIC Detector Systems"

	σ_E/E	E range, GeV	$\pi^{\pm}$ suppression (w/other subsystems)	π^0/γ discr.
e-endcap	$\frac{(2-3)\%}{\sqrt{E}} \oplus (1-2)\%$	0.05−18 GeV	Up to 10^4	Up to 7 GeV/c
Barrel	$\frac{(7-10)\%}{\sqrt{E}} \oplus (1-3)\%$	0.05−50 GeV	Up to 10^4	Up to 10 GeV/c
h-endcap	$\frac{(10-12)\%}{\sqrt{E}} \oplus (1-3)\%$	0.1−100 GeV	Up to 10^4	Up to 50 GeV/c

- Continuous acceptance (particularly from e-endcap to barrel)
- Minimal material budget on the way from the vertex (particularly for e-endcap to barrel)
- Photosensors and FEE tolerate magnetic field
- Operate at full luminosity and expected background conditions (rad. dose, neutron flux)

E-ENDCAP: $PBWO_4$

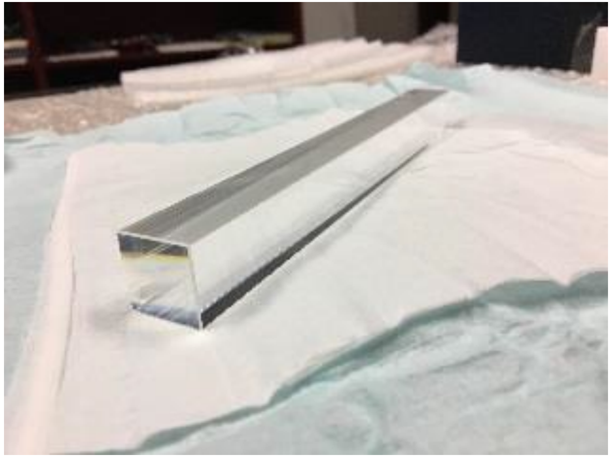
Well established technology

Compact & High granularity: $2 \times 2 \times 20$ cm^3

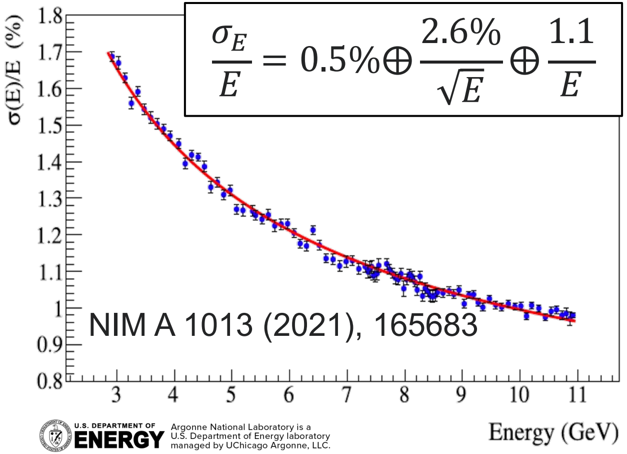
High resolution: $\frac{\sigma_E}{E} = (0.4 - 1)\% \oplus \frac{(2-3)\%}{\sqrt{E}}$

Excellent e/π capabilities: π suppres. a few 10^3

Radiation hard: >1000 krad



Temperature sensitive: d(LightYield)/dT = -(2-3)%/°C



Jlab-PrimEx eta/NPS PWO EMCal prototype

Consortium with >10 institutions

Extensive experience from recent PANDA (GSI) and CMS (CERN)

H-ENDCAP: W/SCIFI

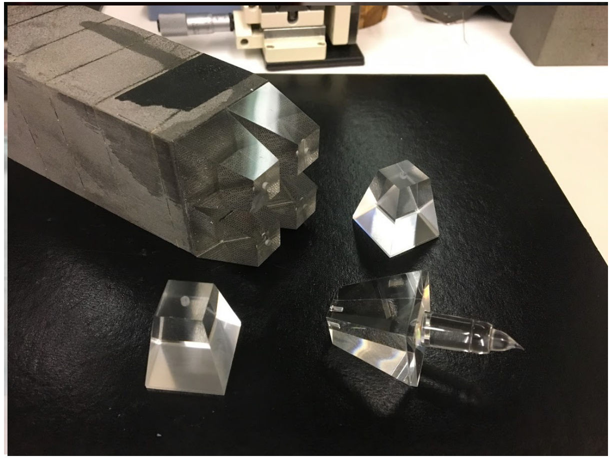
Established technology: sPHENIX barrel EMCal

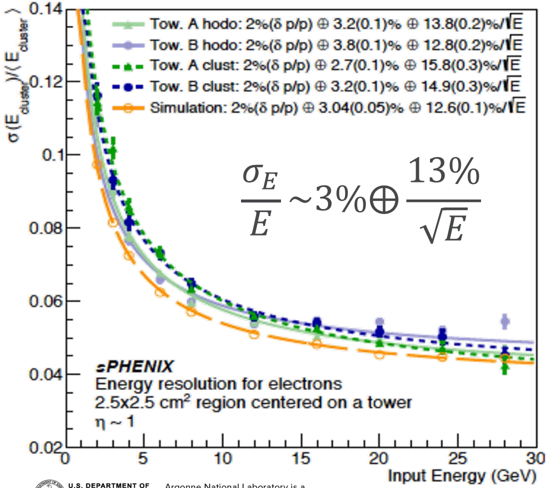
Compact: X_0 = 0.7cm

High granularity: R_m = 2cm

Sampling Fraction: 2-3%

Modest Resolution: $\frac{\sigma_E}{E} \sim 3\% \oplus \frac{13\%}{\sqrt{E}}$



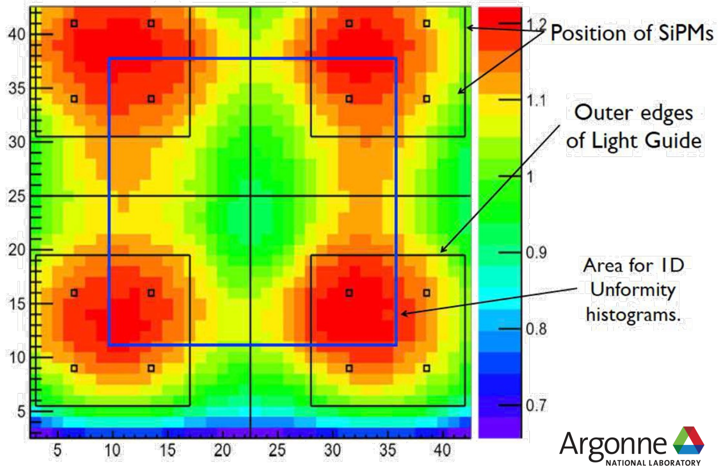


$\frac{\sigma_E}{E} \sim 3\% \oplus \frac{13\%}{\sqrt{E}}$

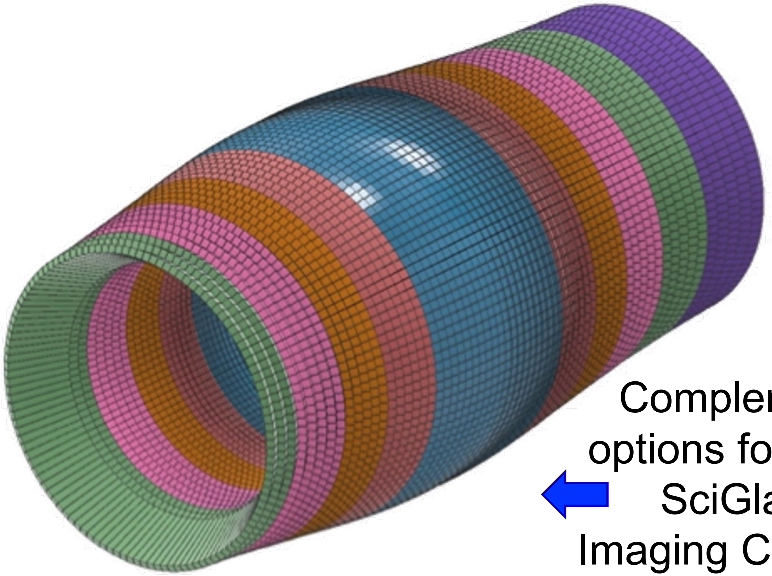
BNL-sPHENIX:
W/SciFi

R&D:

Improve light collection eff. and uniformity

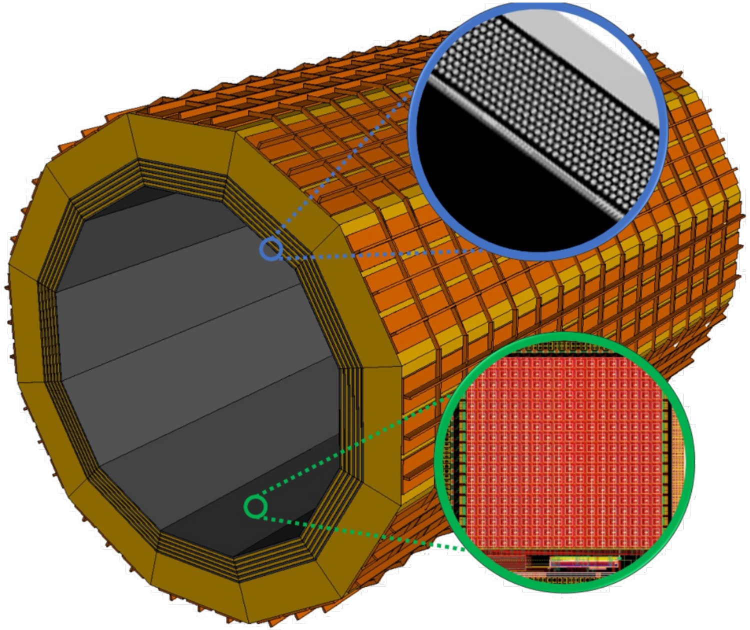


Barrel: Two Options



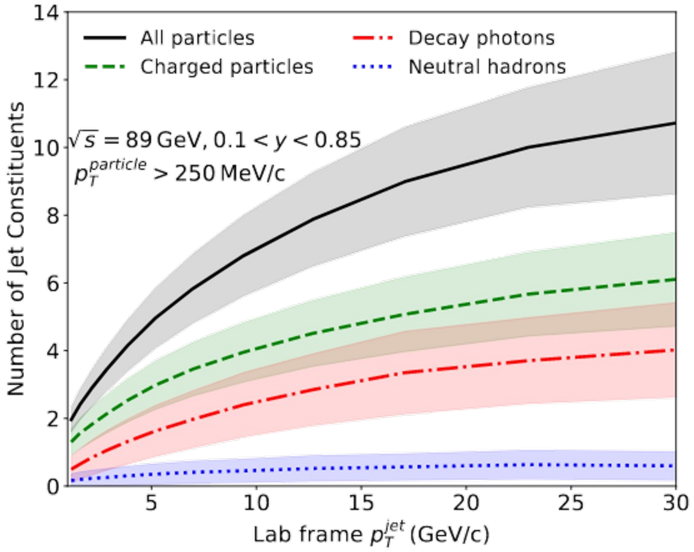
Discussion in the following two talks by Joshua Crafts (CUA) and by Maria Zurek (ANL)

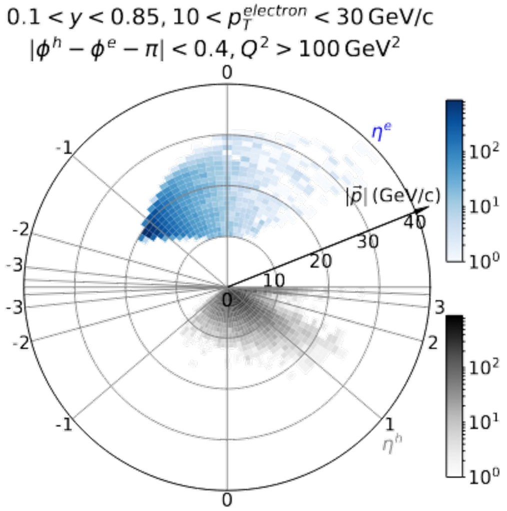
Complementary options for BECAL: SciGlass or Imaging Calorimeter

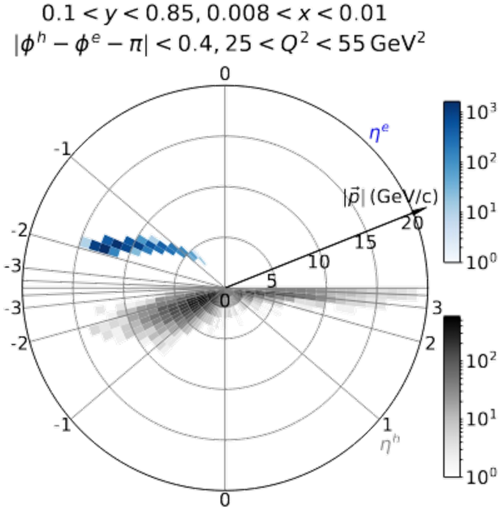


Hadronic Calorimetry

- Energy resolution driven by particle flow reconstruction
- Granularity driven by neutral cluster isolation and jet substructure measurements





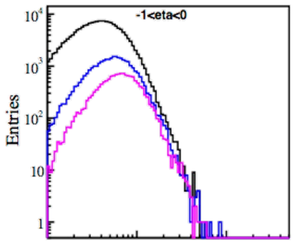


soft, low multiplicity jets

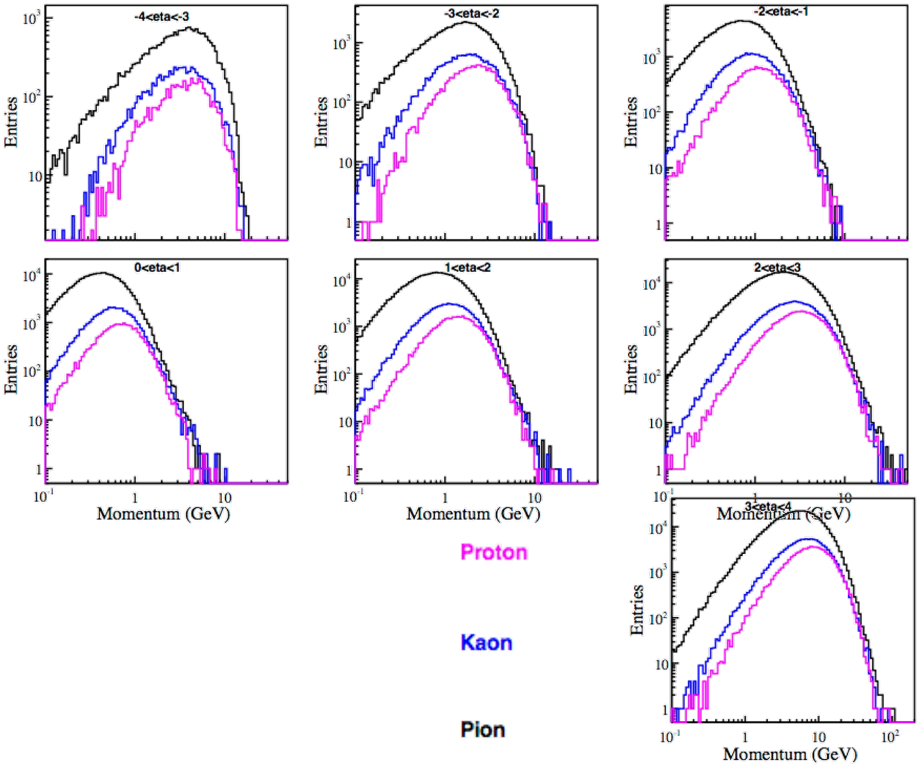
low energy hadrons
(except for the very forward region)

Hadronic Calorimetry

- Yields vs momentum for a 20 x 250 GeV configuration, -4 < η < 4



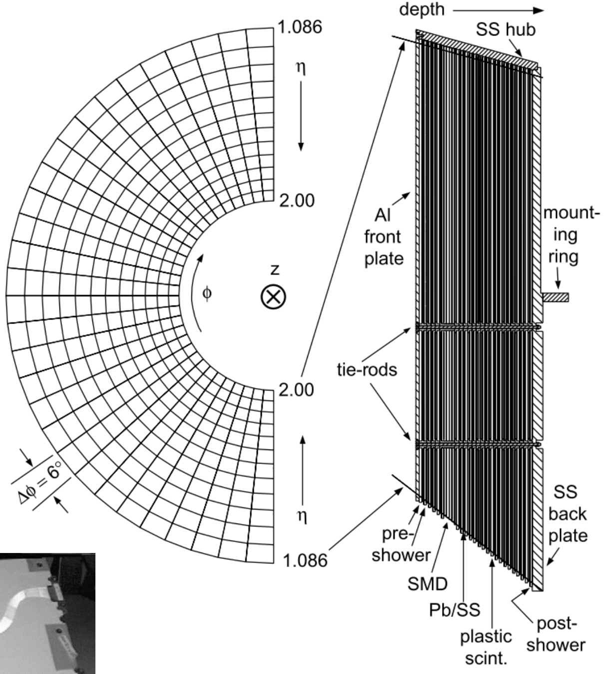
$E_{\min} = 500\ \text{MeV}$	Ideal	Acceptable
η	σ_E/E %	σ_E/E %
$-3.5 < \eta < -1.0$	$45/\sqrt{E} + 7$	$50/\sqrt{E} + 10$
$-1.0 < \eta < +1.0$	$85/\sqrt{E} + 7$	$100/\sqrt{E} + 10$
$+1.0 < \eta < +3.5$	$35/\sqrt{E}$	$50/\sqrt{E} + 10$

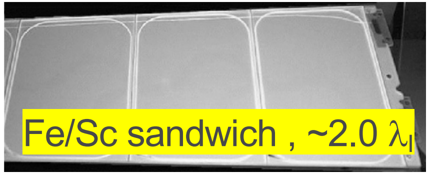


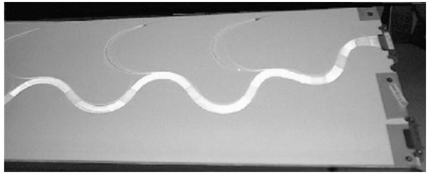
Backward Hadronic Calorimeter

- Recycle scintillating plates from STAR
  - Embedded WLS fibers
  - SiPM readout
- Replace lead absorber by steel
- Full depth ~440mm only
  - It is indeed a tail catcher
  - High energy resolution is not needed
- Acceptance $-4 < \eta < -1$

STAR EEMC





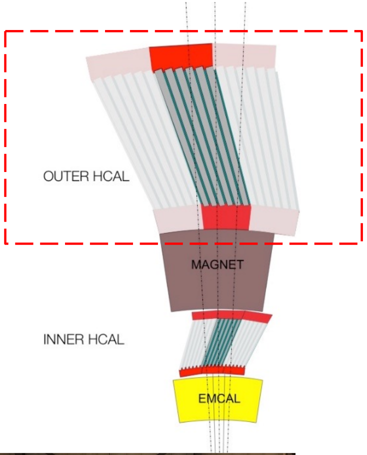


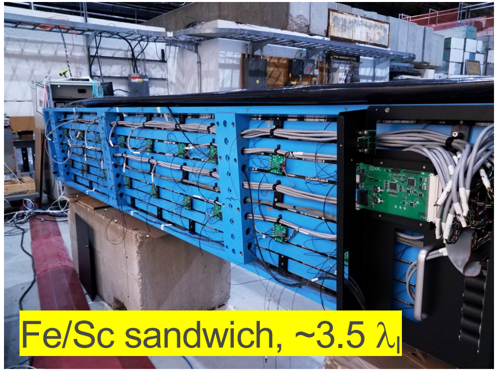
Talk by Leszek

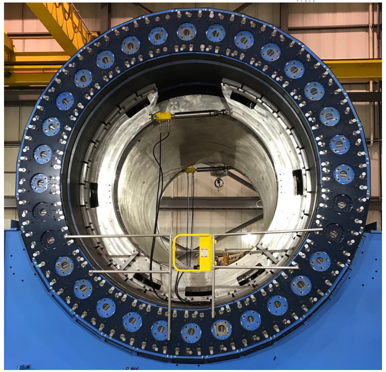
BARREL HADRONIC CALORIMETER

- Partly reuse sPHENIX barrel calorimeter
  - Replace SiPMs
  - Upgrade electronics

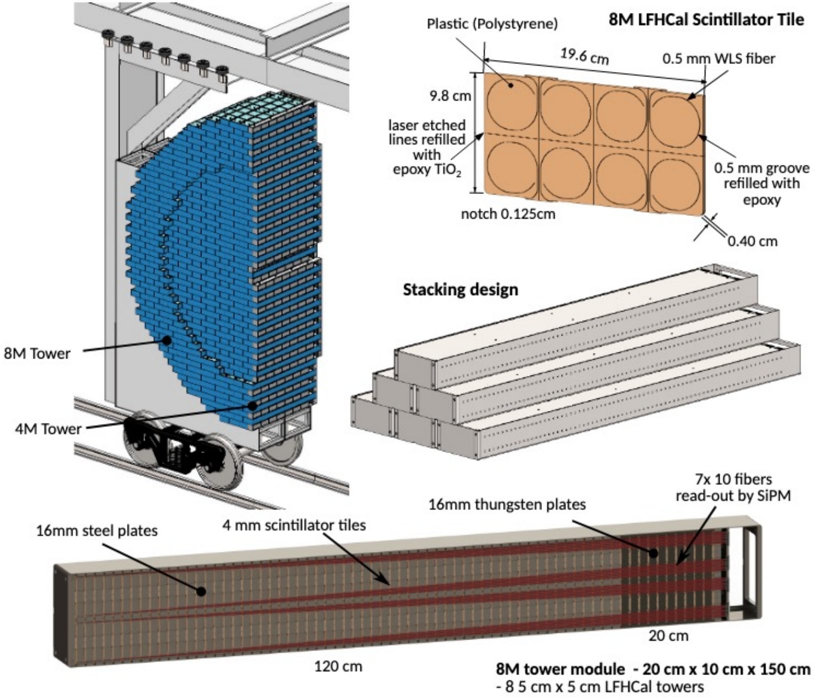
- Moderate energy resolution suffices
- Acceptance $-1 < \eta < 1$





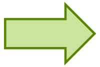


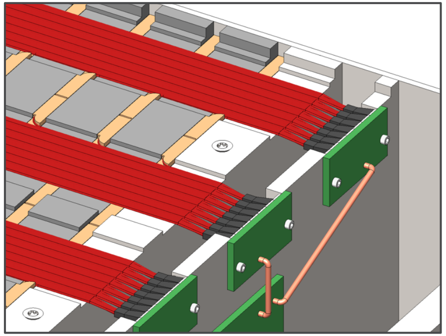
Forward Hadronic Calorimeter



Fe/Sc + W/Sc sandwich , ~6.9 λ_I

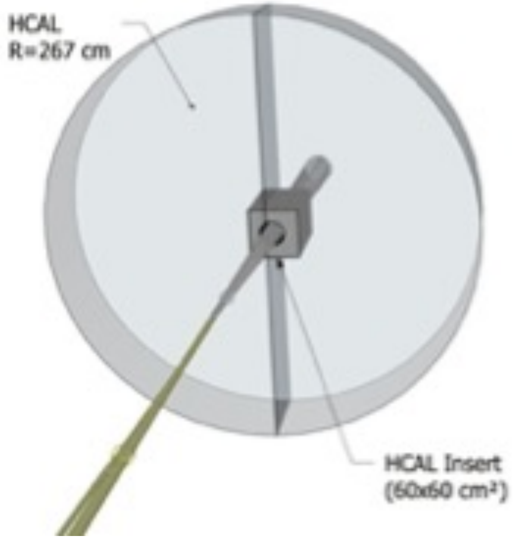
- New innovative design
  - High 3D granularity
- High energy resolution
- Acceptance $1 < \eta < 4$

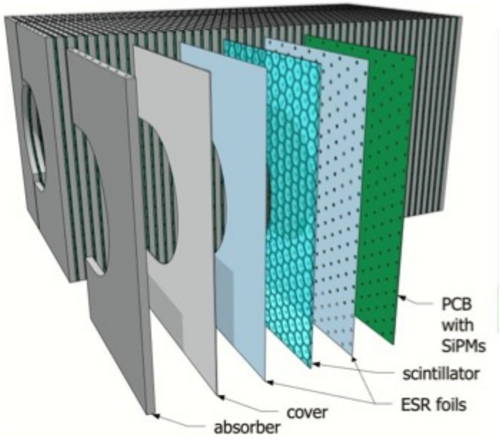


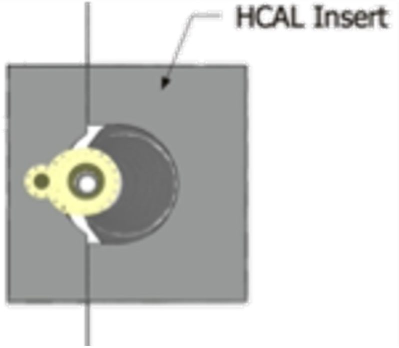


Forward HCAL Insert

- Measure low angle high η particles
- See final talk by Miguel Arratia in this session

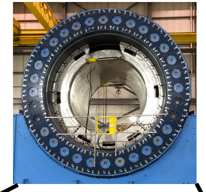




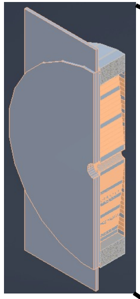


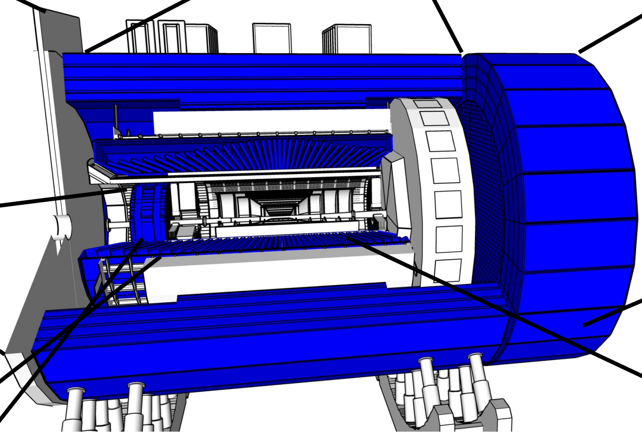
EPIC CALORIMETRY

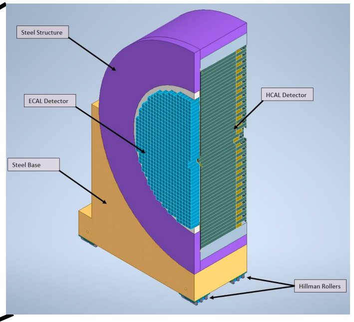
Barrel HCAL
(sPHENIX re-use)



Backwards HCal
Steel/Sc Sandwich
tail catcher

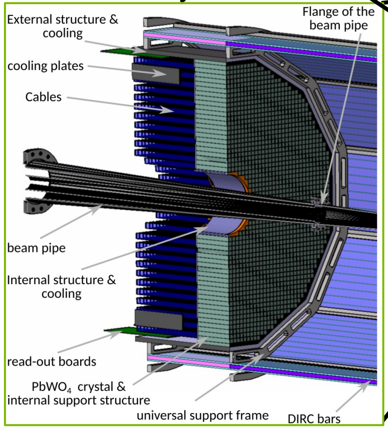




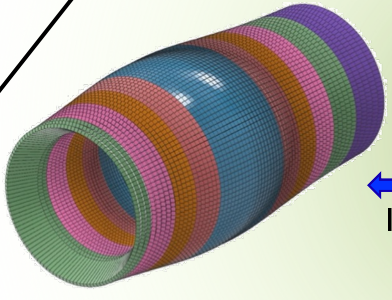


High granularity
W/SciFi EMCal
Longitudinally separated HCAL
with high-η insert

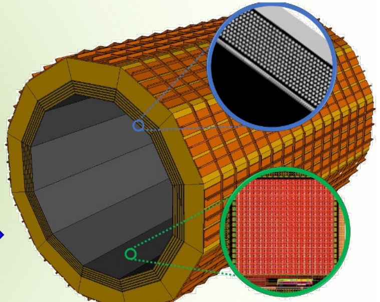
Backwards EMCal
PbW04 crystals



PbSc
Layer

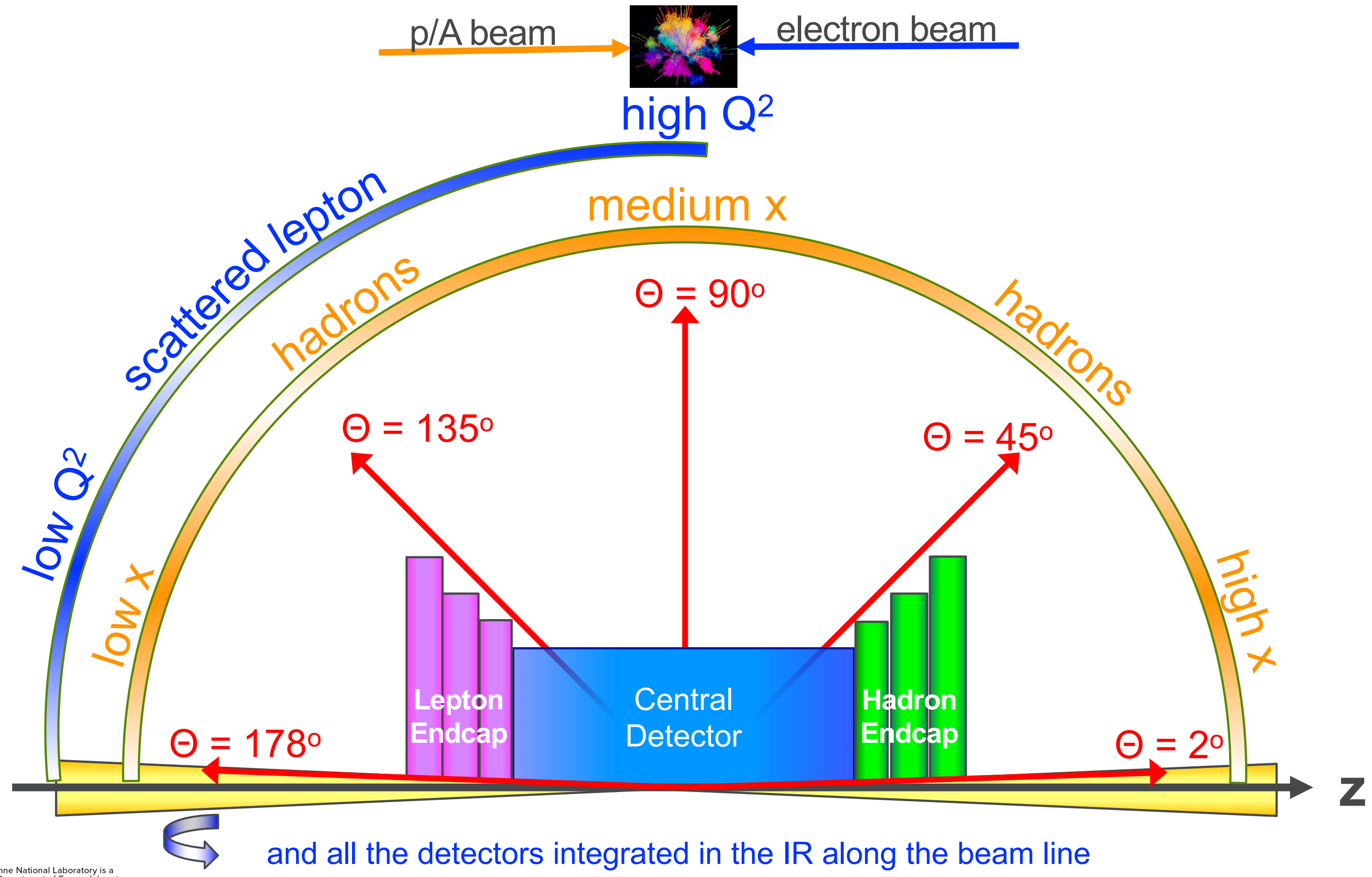


Complementary
options for BECAL:
SciGlass or
Imaging Calorimeter



Imaging
Layer

slide from E.C. Aschenauer


p/A beam
electron beam
high Q²
medium x
scattered lepton
hadrons
hadrons
low Q²
low x
high x
Θ = 90°
Θ = 135°
Θ = 45°
Θ = 178°
Θ = 2°
Lepton Endcap
Central Detector
Hadron Endcap
z
and all the detectors integrated in the IR along the beam line