Backward Hadronic Calorimeter DSC report

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YOUTH AND SPORTS

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

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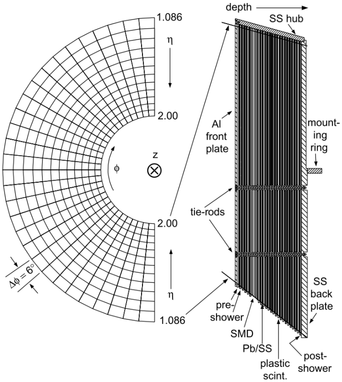
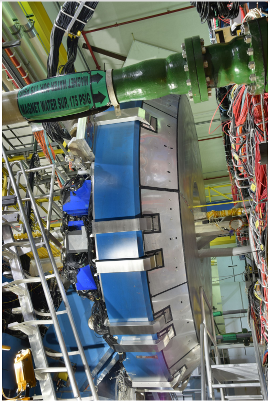
Outline

Requirements: https://eic.jlab.org/Requirements/

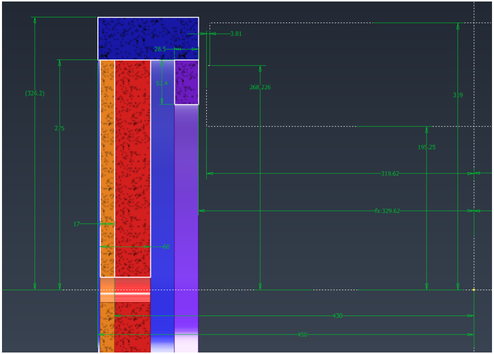
A future backward HCal shall provide functionality of a tail catcher for the high resolution e/m calorimeter in electron identification, as well as for jet kinematics measurement at small Bjorken x



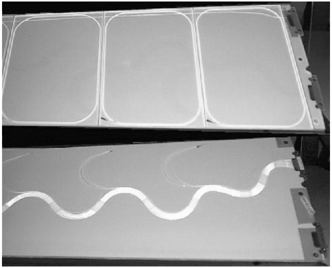


- Design considerations:
  - High efficiency for neutron detection
  - Good spatial resolution to distinguish neutral/charged hadrons
- Reuse STAR EEMC scintillator megatiles (expected to have lost only $\sim 5\%$ of light yield): https://doi.org/10.1016/S0168-9002(02)01971-X

- Sampling calorimeter with 10 alternating layers, $2.4\lambda^0$ (red), similar to Belle-II KLM:
  - stainless steel 4 cm
  - plastic scintillator 4 mm Kuraray SCSN-81
- Scintillator light guided by 0.83 mm WLS (Kuraray Y11-doped 200 ppm fiber)
- Light collection by SiPM:
  - Candidate (to verify): S14160-1315PS `https://www.hamamatsu.com/eu/en/product/optical-sensors/mppc/mppc_mppc-array/S14160-1315PS.html`
- Electronics to follow solutions of other calorimetry systems (HGCROCv3 or EICROC)

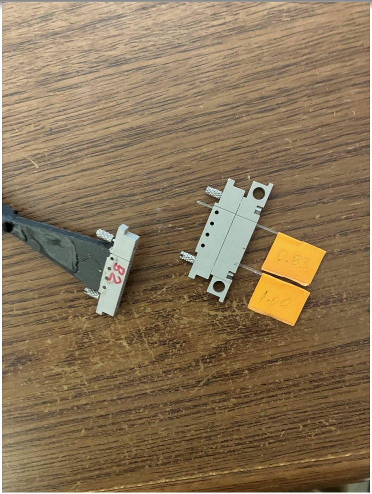


STAR EEMC 6° megatile - 12 tiles in η direction (radial) each



- nHCal decoupled from the magnetic steel ⇒ more flexibility

STAR EEMC megatile and connectors



Pictures thanks to Will Jacobs

- 12° megatile shown (2 rows of 12 tiles in η)
- 0.83 mm diameter WLS fiber contained in σ-shaped grooves
- New, modified connectors need to be made, coupling light to an array of 12 SiPMs each (1 fiber/SiPM, but multiple fibers/SiPM to be considered)
- May need to remain wrapped after disassembly of STAR

Status of backward HCal DSC

Detector Subsystem Leader

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Detector Subsystem Technical Contact

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Czech Technical University in Prague

- Subhadip Pal (PhD student)
  - simulations, part time
- Alexandr Prozorov (fresh PhD)
  - geometry, clustering, part time

Brookhaven National Laboratory

- Roland Wimmer, mechanical engineer
- other experts at BNL

- Looking now for institutions to join and more people to participate!
- Getting a lot of help from other people at BNL and CTU

Backwards HCAL

Version 4
Revised 7/27/2023

6.10.06.01 Backwards HCAL Level-4

Design Level-5
- Integration with solenoid
- Investigation of neutral hadron shower reconstruction techniques
- CTU Prague (Leszek Kosarzewski)

Absorber and Support Structures Level-5
- Cradle and support
- Tile frames
- Insertion mechanics
- BNL (Roland Wimmer)

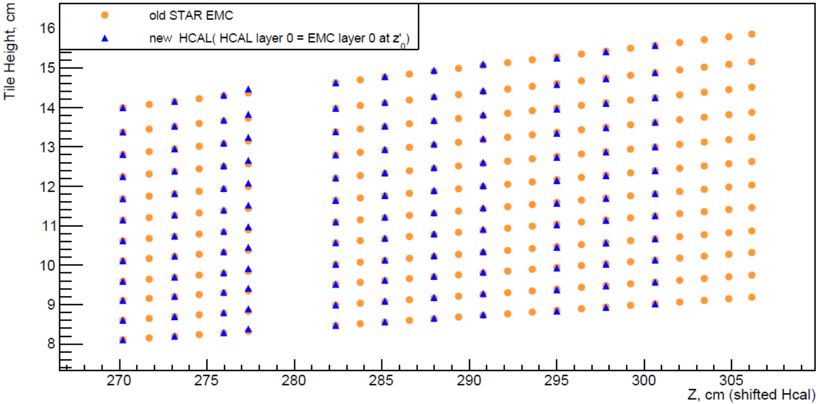
Scintillating Tiles Level-5
- Refurbishment at BNL?
- Beam tests at JLab/Europe/BNL?
- TBD

Photosensors Level-5
- Combined effort?
- Tests
- TBD

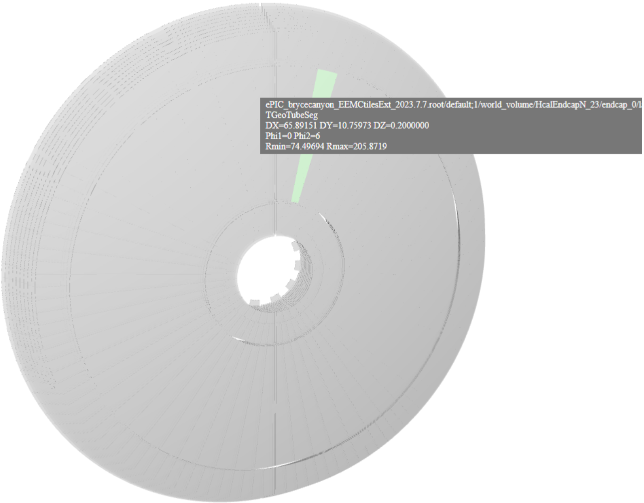
Readout Electronics Level-5
- Coordinated with forward HCAL
- TBD

Assembly and integration Level-5
- Absorber and cradle assembly
- Tile assembly
- Sector assembly
- Connection of WLS fibers
- Sector/tile insertion
- TBD

- Megatile selection algorithm by Alexandr Prozorov
- Selects megatiles from a layer, which matches the η of the first, to maintain projective structure
- STAR EEMC tiles provide acceptance in $-2.39 < \eta < -2.195$

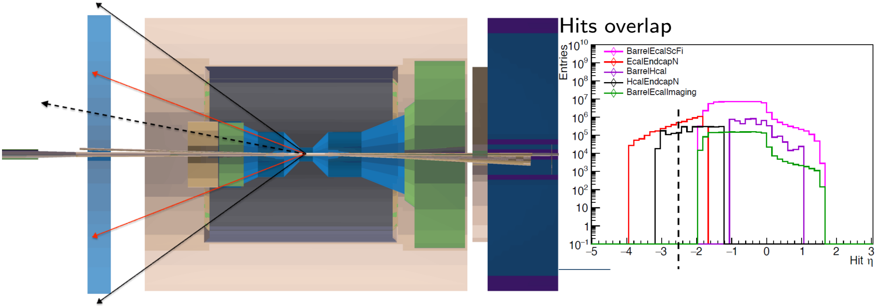


- Extrapolated tiles to cover the region close to beampipe and the outer region
  - extends acceptance to $-3.06 < \eta < -1.27$



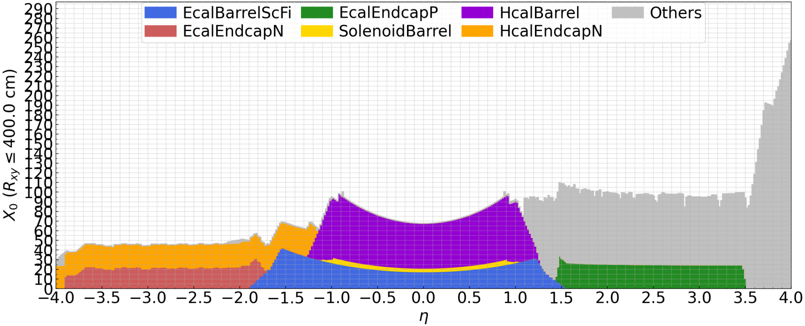
- Exact tile geometry implemented with absorber (no support structures)
- Added extrapolated inner and outer parts with a gap for connectors

Acceptance



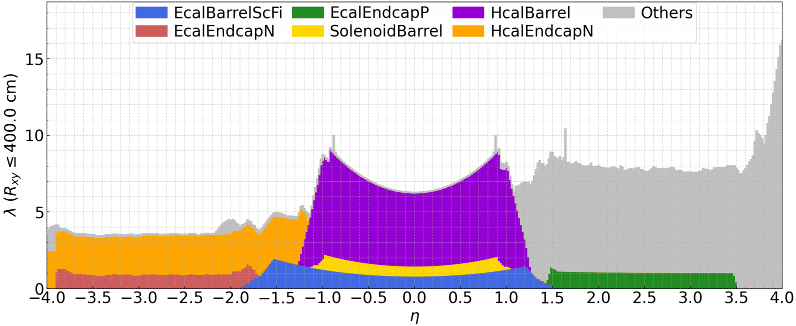
- Acceptance $-3.06 < \eta < -1.27$ - can still be extended to match the stainless steel absorber volume
- Overlaps with backward and barrel EMcals

Radiation length - brycecanyon geometry



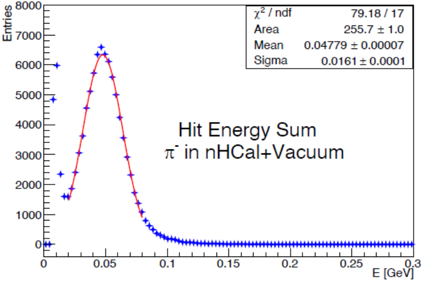
- $\sim 24X_0$ for backward HCal
- Scintillator tiles do not cover the same volume as steel absorber yet

Interaction length - brycecanyon geometry



- $\sim 2.4\lambda_0$ for backward HCal
- Scintillator tiles do not cover the same volume as steel absorber yet

Calibration - sampling fraction



NAME	VALUE	ERROR
Area	255.7	1.0
Mean	0.04779	0.00007
Sigma	0.0161	0.0001

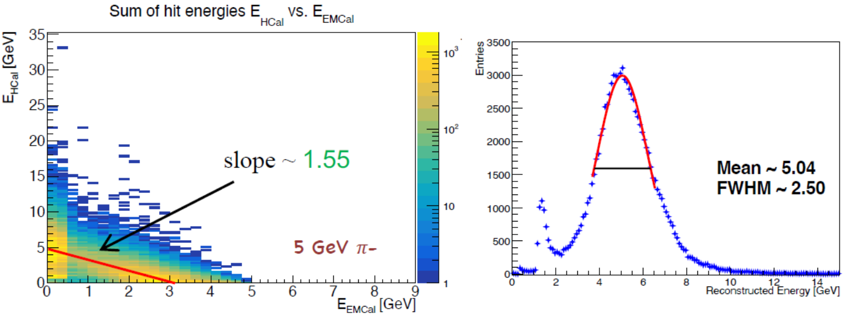
- ❑ nHCal is calibrated using π^-
- ❑ 1 π^- /event, 1mill events and p = 5 GeV
- ❑ θ = 170° and φ = 45°

Sampling Fraction (f)
= 0.04779/5.05
= 0.00946
~ 0.0095 +/- 1.4E-05

Study by Subhadip Pal

Calibration - energy sharing

- Study energy sharing between backward HCal and EMCal



$E_{reco} = 1.55 * E_{EMCal} + E_{HCal}$

Fitted a linear function to E_{HCal} vs. E_{EMCal} histogram to extract the energy sharing parameters

* $E_{Hcal}/f \equiv E_{HCal}$

Study by Subhadip Pal

Position resolution study - algorithm

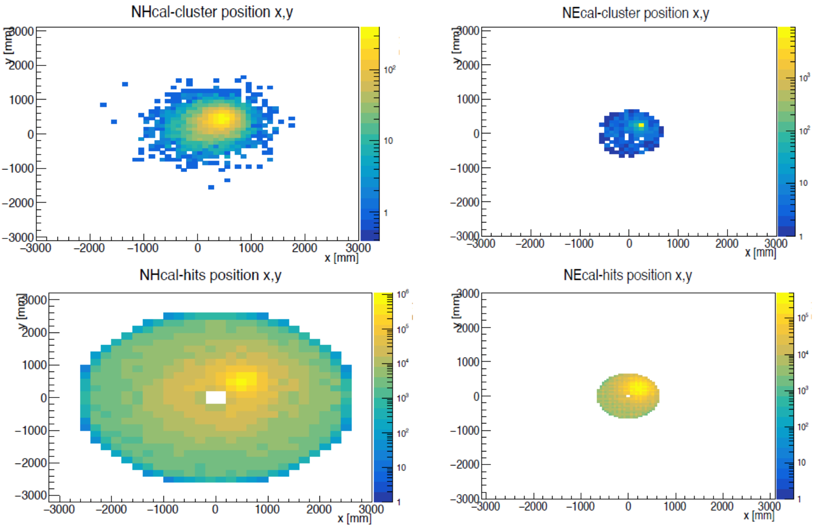
1. Simulated 1 neutron/event, $p = 5\,\mathrm{GeV/c}$
   - Angular direction:
     - $\theta = 170^\circ$ (2.967 rad)
     - $\phi = 45^\circ$ (0.785 rad)
2. Reconstructed clusters in both backward HCal and EMCal are combined with energy weights to have a combined angular position measurement

$$\theta_{RECO} = w_{EMCal}\theta_{EMCal} + w_{HCal}\theta_{HCal}$$

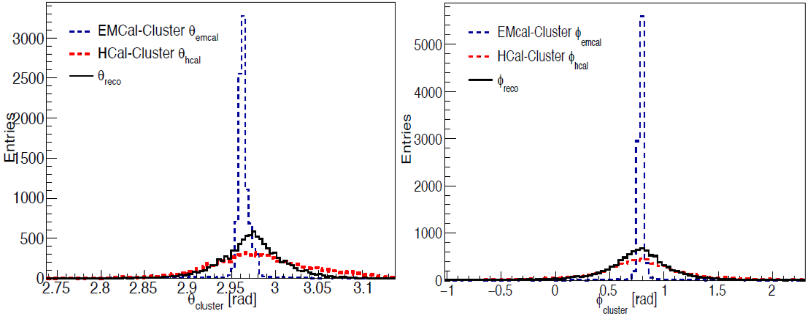
$$\phi_{RECO} = w_{EMCal}\phi_{EMCal} + w_{HCal}\phi_{HCal}$$

$$w_{EMCal} = \frac{1.55 E_{EMCal}}{E_{RECO}}, w_{HCal} = \frac{E_{HCal}}{E_{RECO}}$$

Position resolution study - hits



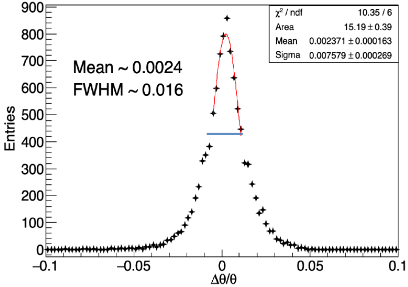
Study by Subhadip Pal

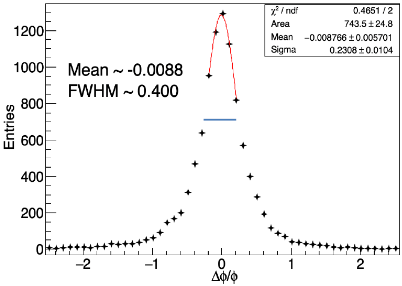


- Simulated 1 neutron/event, $p = 5\,\mathrm{GeV/c}$
- Angular direction:
  - $\theta = 170^\circ$ (2.967 rad)
  - $\phi = 45^\circ$ (0.785 rad)
- Much better resolution provided by backward EMCal
  - But HCal provides better response to hadrons

Study by Subhadip Pal

Angular resolution study

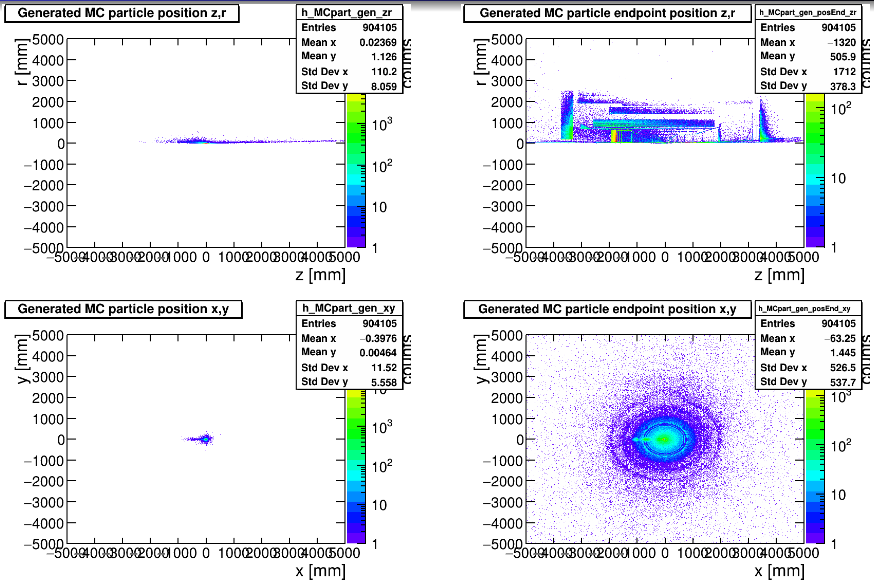




- Gaussian fits work only in a narrow range
- Much worse resolution in the ϕ direction
  - maybe due to proximity to beam

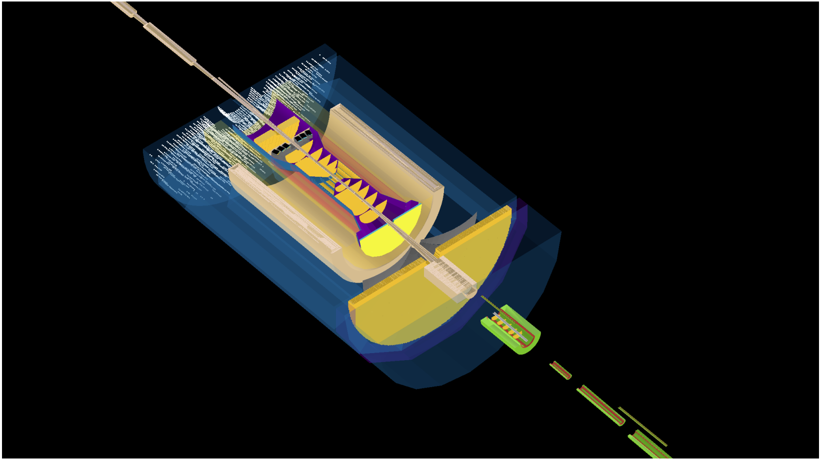
Study by Subhadip Pal

Primary particles(generated) - with nHCal hits



- Primary particles(generated, GenStat==1) with nHCal hits
- Investigating potential bugs and issues with basic particle distributions in full DIS/SIDIS events

Simple hit visualization



- Simple hit visualization
- May add MC particles or Reco tracks (need magnetic field map)
- More work needed

Summary

Conclusions

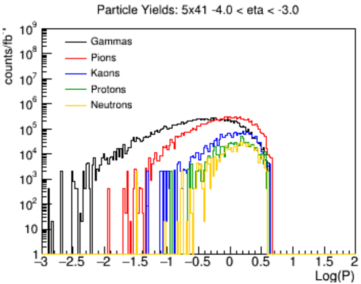
- Realistic geometry implemented in dd4hepp
- More flexibility in the design thanks to decoupling from flux return steel
- Response and calibration studied in simulations
- Position resolution tested with neutrons using backward HCal and EMcal as a combined system
- Tiles can be further extrapolated towards the beam

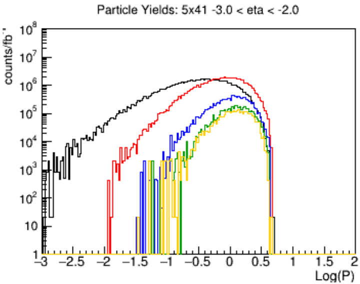
Next steps

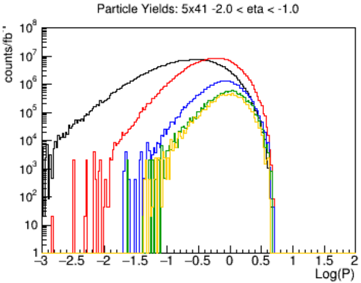
- Investigate potential bugs in hit-MC particle association
- Do a scan vs. η and ϕ for position resolution study
- Test clustering, track matching and neutral shower reconstruction in a realistic $e + p$ event
- Perform simulations of optical photon propagation
- Work with engineers to design support structures and FEE mounting

BACKUP

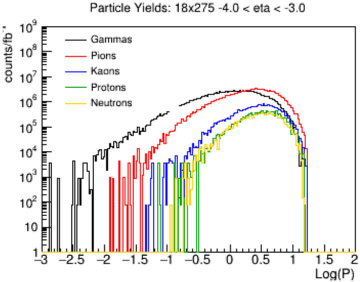
Jet particle distributions

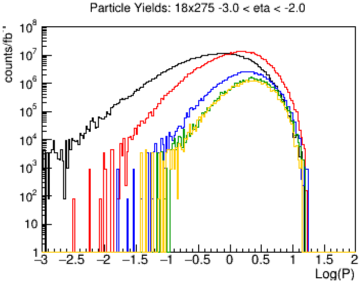


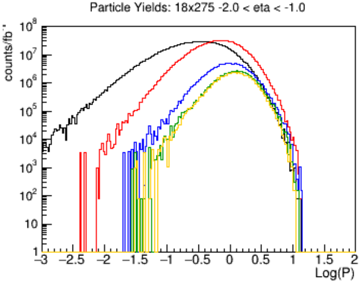




- Pythia simulation by Brian Page

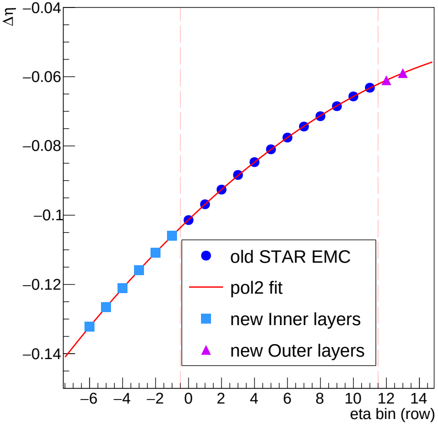


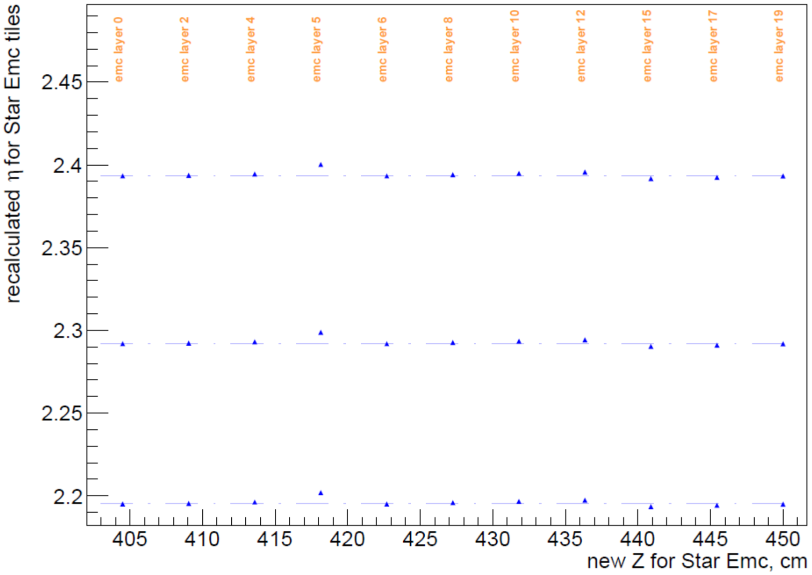




- Pythia simulation by Brian Page

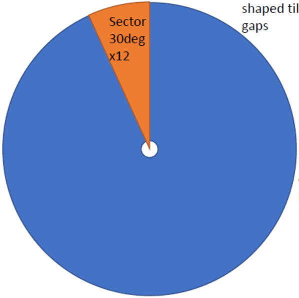
η bins extrapolation

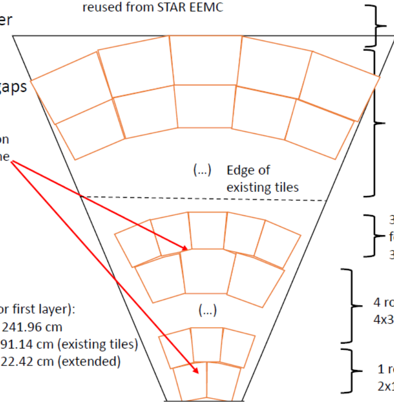



recalculated η for Star Emc tiles
new Z for Star Emc, cm
emc layer 0
emc layer 2
emc layer 4
emc layer 5
emc layer 6
emc layer 8
emc layer 10
emc layer 12
emc layer 15
emc layer 17
emc layer 19
2.45
2.4
2.35
2.3
2.25
2.2
405
410
415
420
425
430
435
440
445
450

Layout version 4 – full length sector with 12deg tiles

1. 12deg+6deg+12deg EEMC megatiles per outer sector
2. Inner part with tiles merged 5->3->2
3. Pentagon-shaped tiles used to fill the gaps





Total tiles:

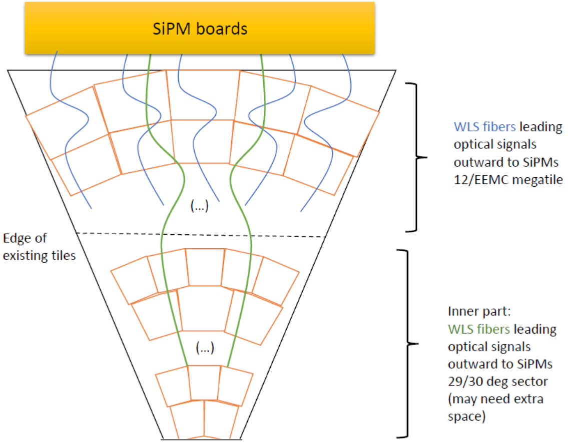
7200 existing ones + 3480 inner tiles = 10680 tiles

29 types x 10 layers = 290 different shapes of new tiles to be manufactured

Readout – version 2

Extra space needed for the testing/calibration system to send light pulses to the tiles. 2 options

- Add fibers to guide signal from diode/laser mounted outside the detector
- Add small diodes to the tiles



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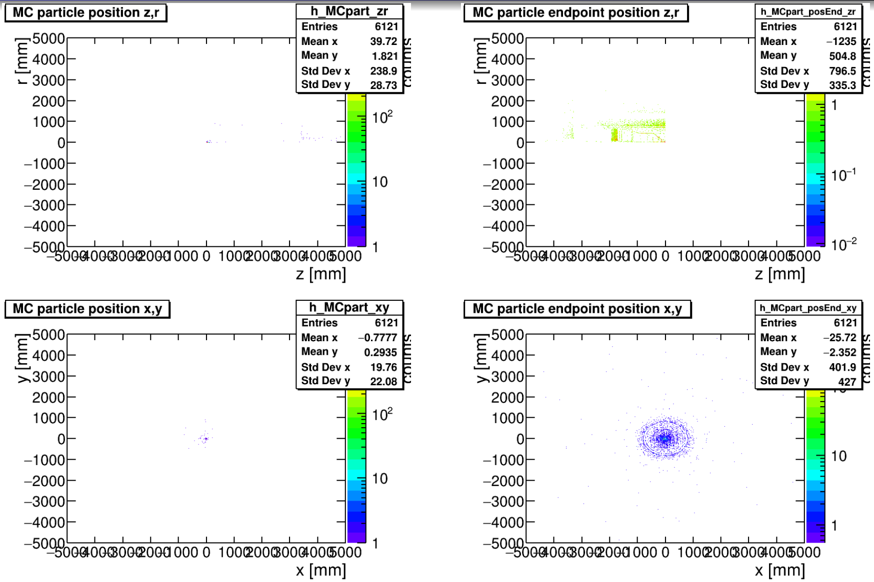
Particle distributions - with LFHCAL hits - start($z > 0$) and end points($z < 0$) (vertices)



- Particles with LFHCAL hits with start vertex $z > 0$ and stop vertex $z < 0$
- Still produce hits in LFHCAL! Backscatters? Non-trivial to debug, because not all