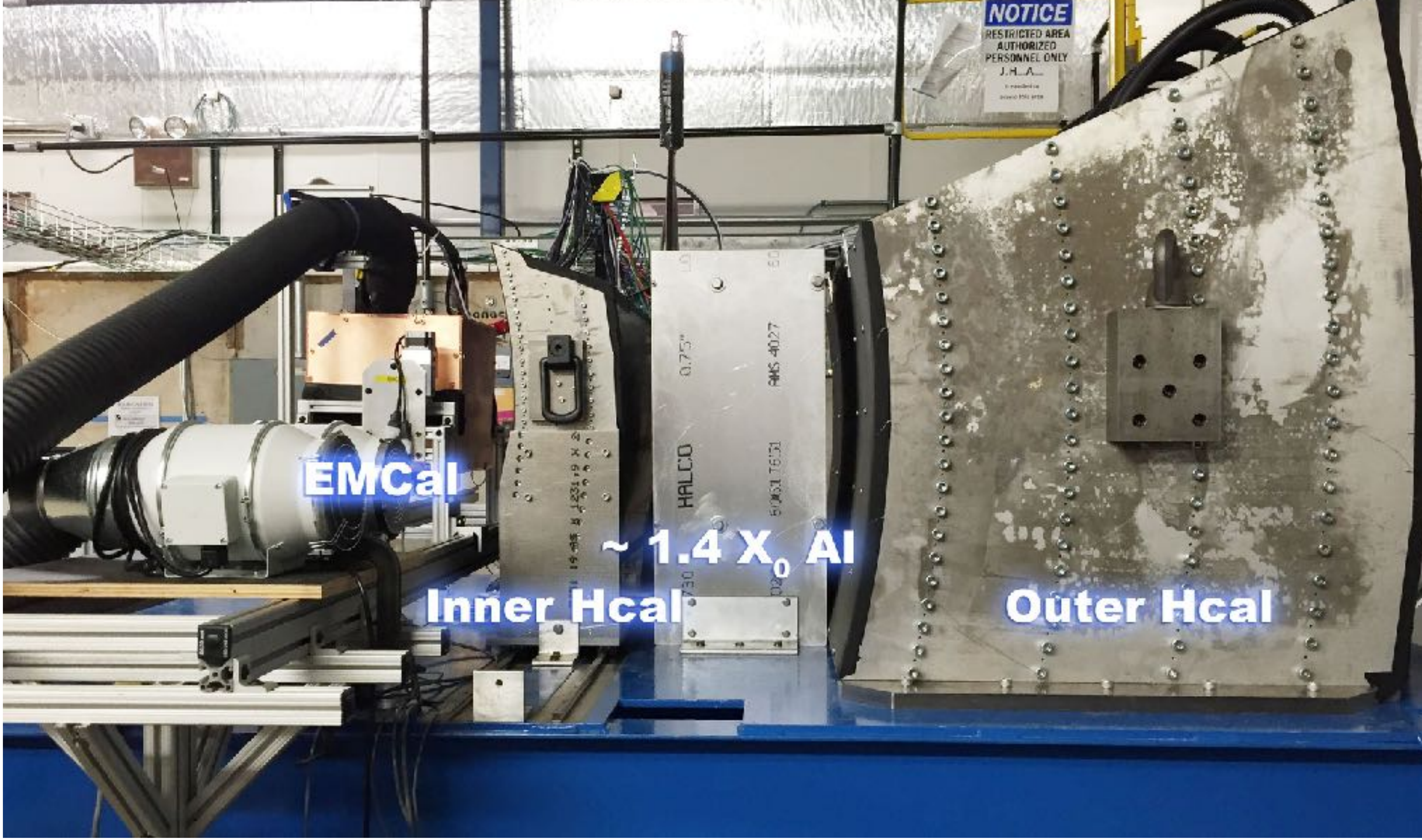

Status and Test Beam Results for the sPHENIX Calorimeter System

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for the sPHENIX Collaboration

November 1, 2016

ILLINOIS
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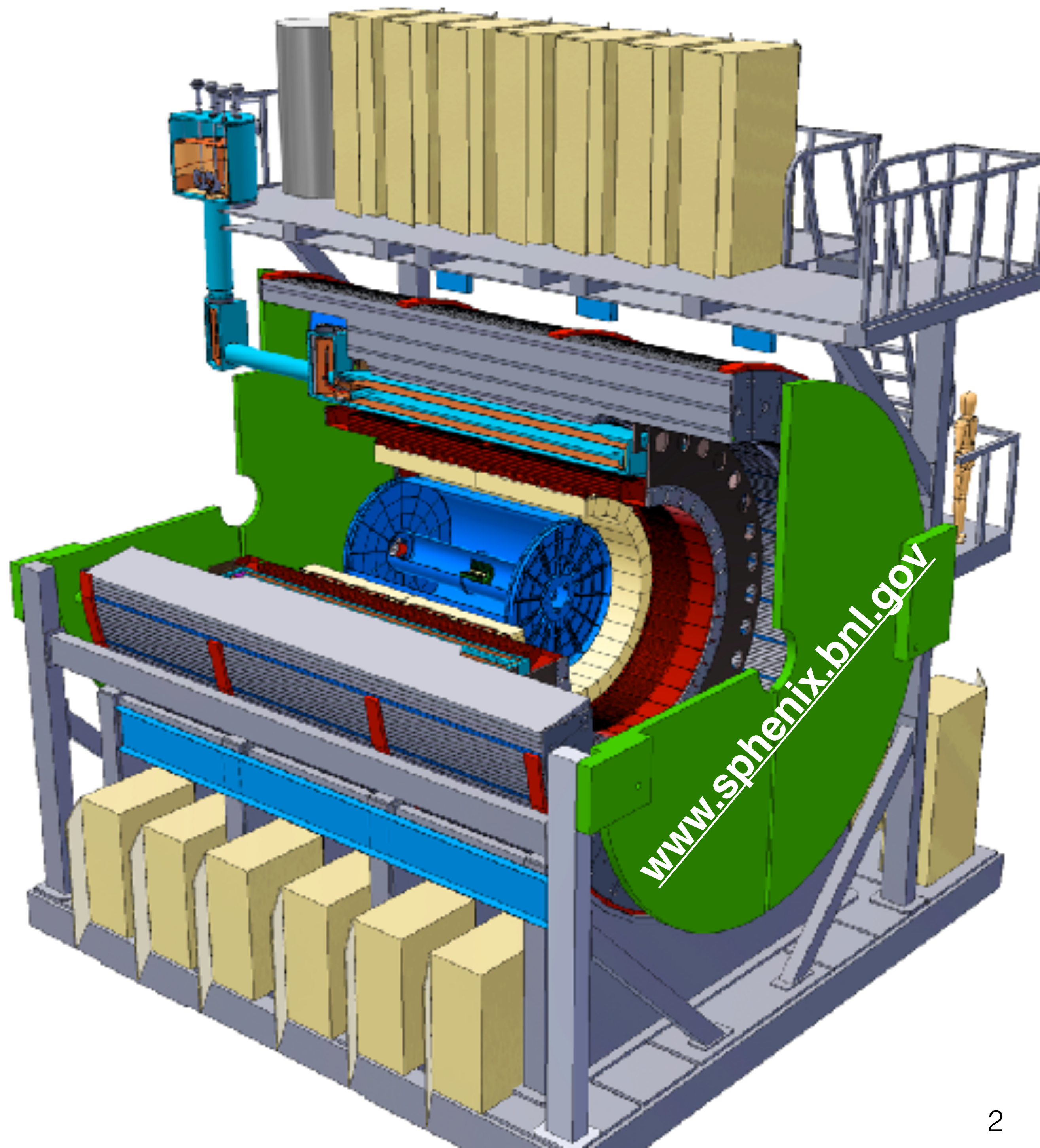
what is sPHENIX

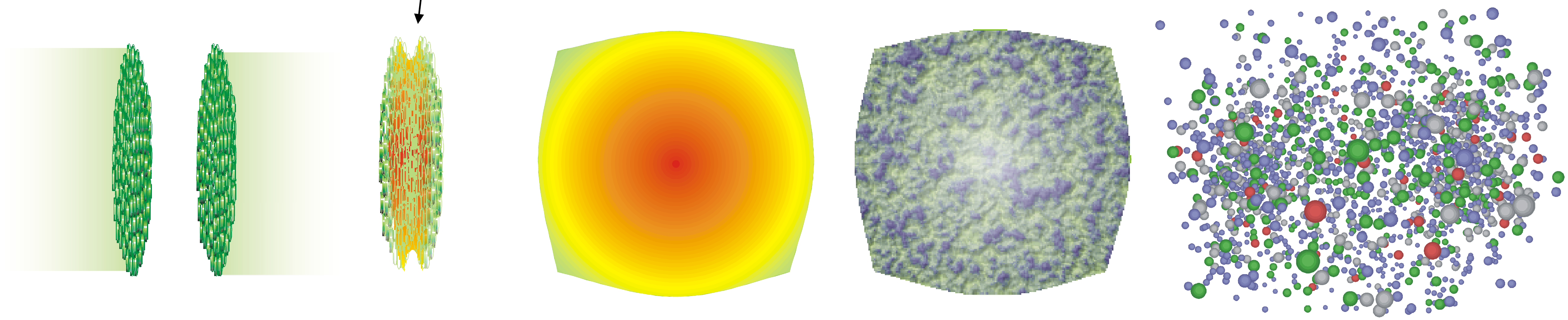
jet and hard probes optimized detector at RHIC for gold-gold collisions

- high rate
- large uniform acceptance for jets, photons and upsilons
- excellent tracking and full hadronic and electromagnetic calorimetry
- first data: 2022
- 200 collaborators / 60 institutions



physics

jets, photons created



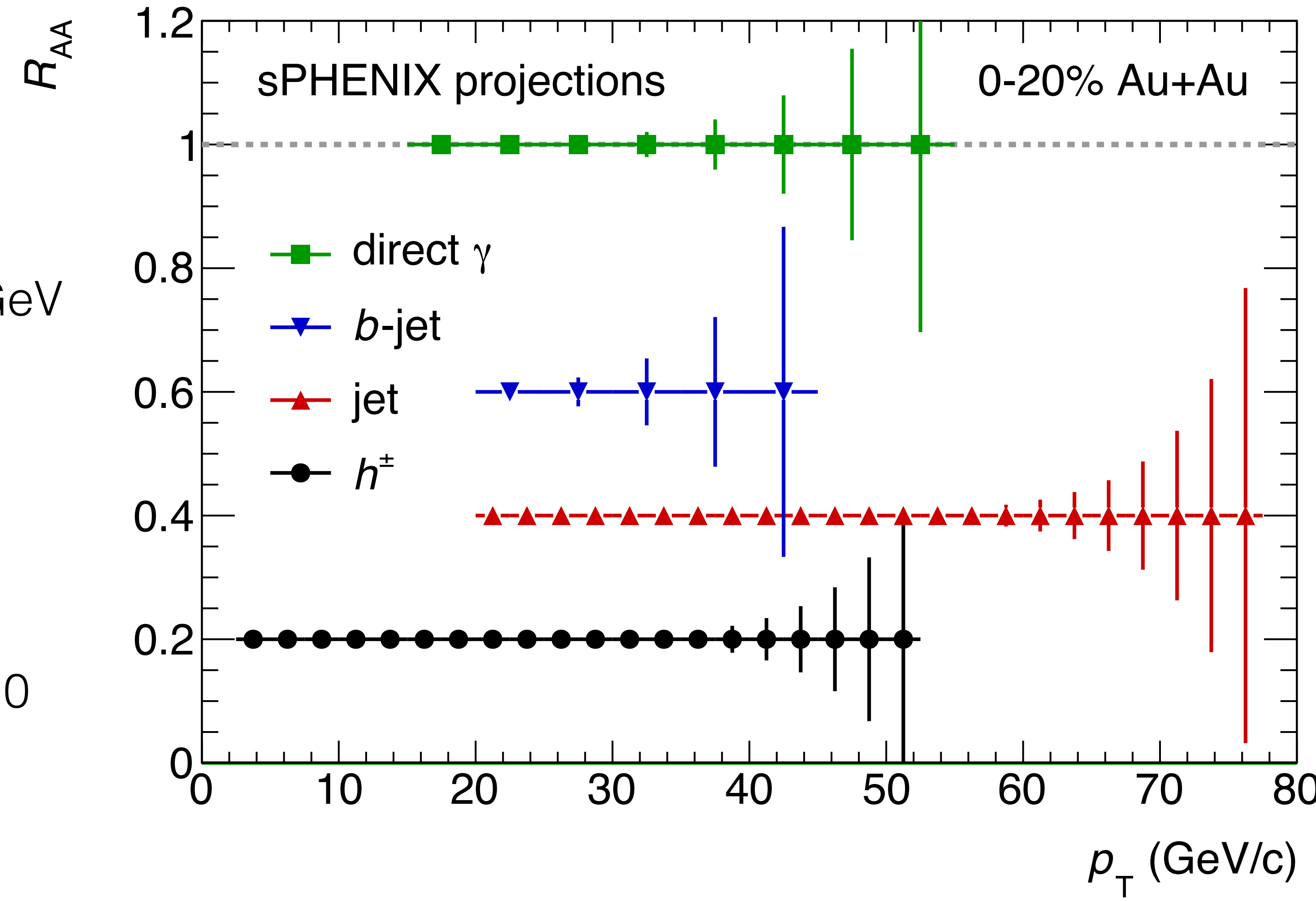
low viscosity fluid
T = ~400 MeV

strategy: use jets & photons to probe the physics of the plasma

calorimeter requirements

EMCal

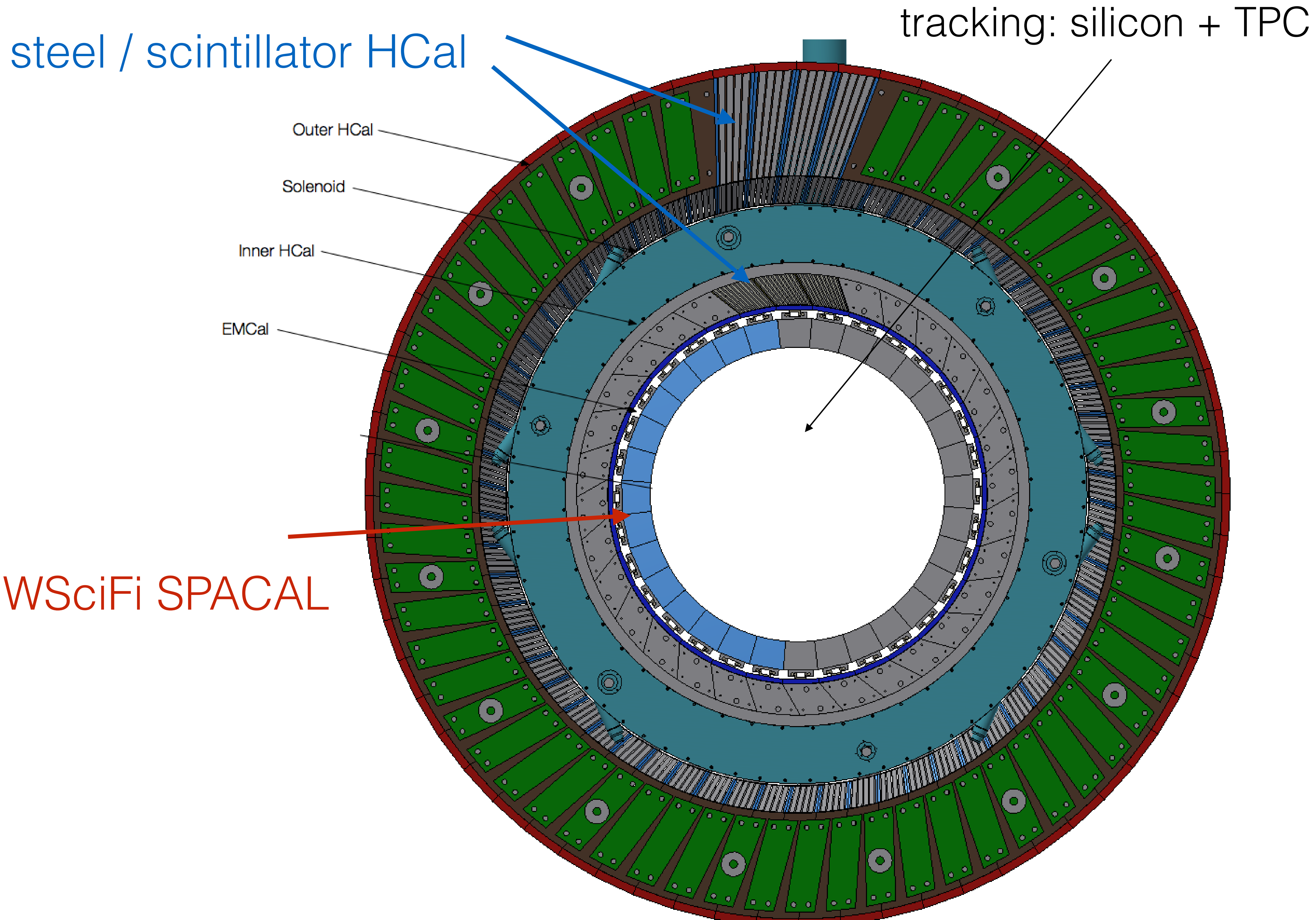
- **electron ID**:
  - ε > 70%
  - hadron rejection: > 90:1 in AuAu @ p_T = 4 GeV
- **photons**:
  - < 15 % / √E
  - Δη x Δϕ = 0.024 x 0.024
  - trigger rejection in pp & pA > 100 for Eγ > 10 GeV



EMCal + HCal

- **jets:**
  - JER < 120% / √E (pp/pA)
  - JER < 150% / √E (AA)
  - jet trigger in pp / pA

sPHENIX: calorimeters



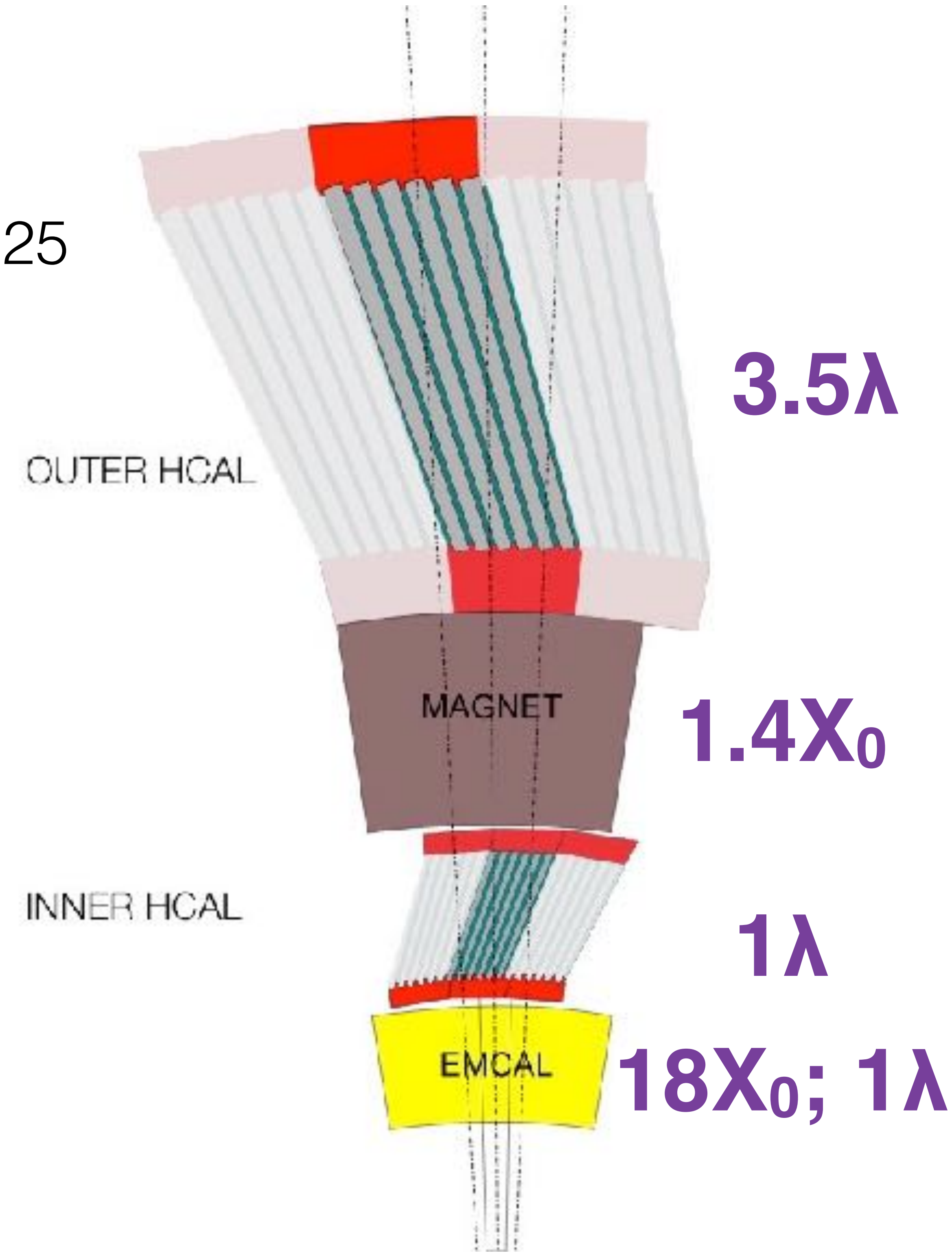
cross section of the calorimeter

EMCal

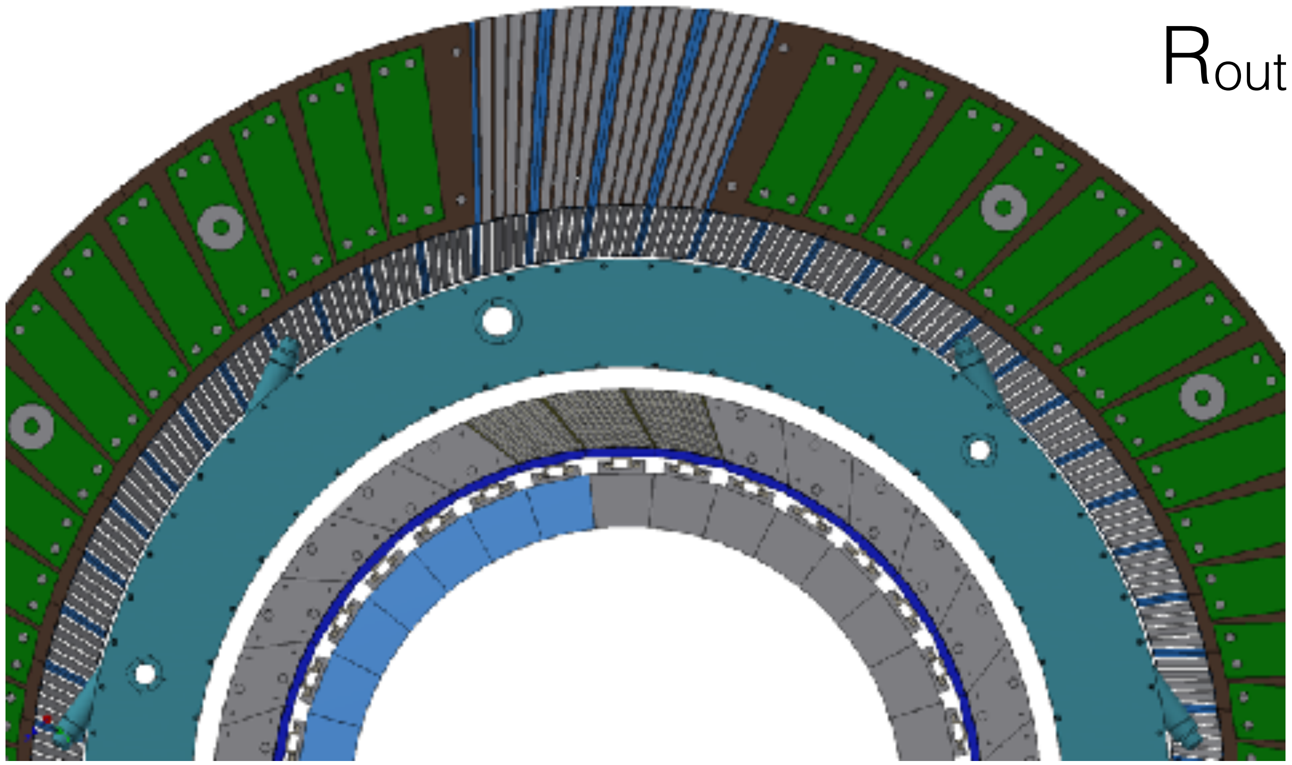
- tungsten powder SciFi SPACAL
- $\phi \times \eta = 2\pi \times 1.1$; $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$
  - → 24576 channels

HCal

- steel / scintillating tile w/ WLS readout
  - plates parallel to beam
  - tilted to avoid channeling
- Inner HCal: inside magnet
- Outer HCal: outside magnet
  - doubles as flux return
- $\phi \times \eta = 2\pi \times 1.1$; $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
  - → 3072



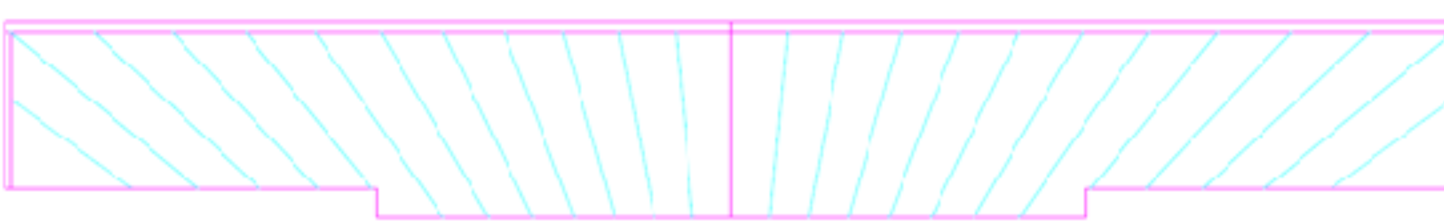
hadronic calorimeter



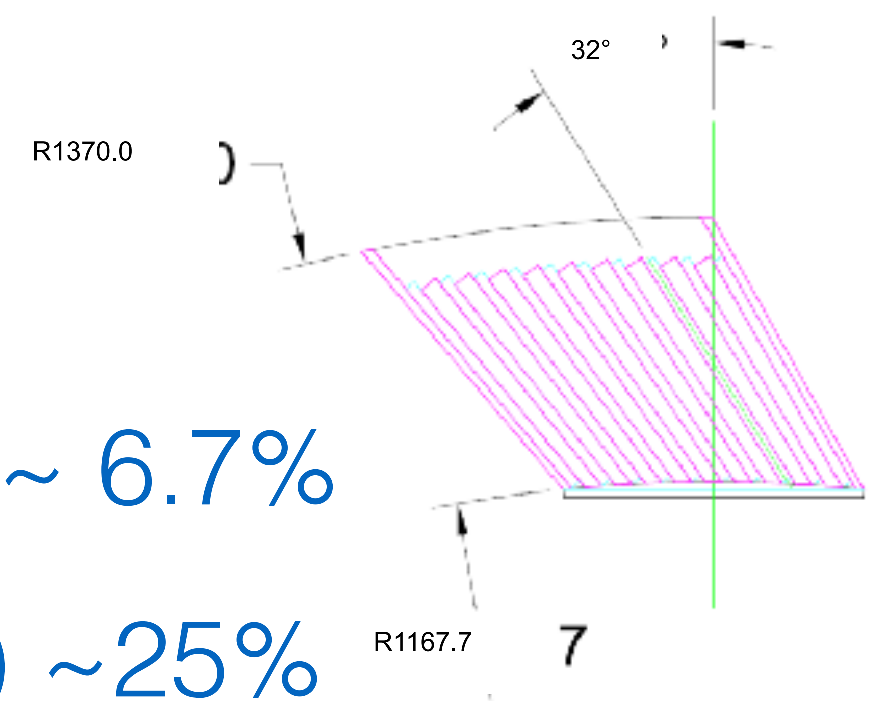
R_{out} = 2.7m

SF ~ 3.5%

⟵ 24 towers in |η| < 1.1 ⟶



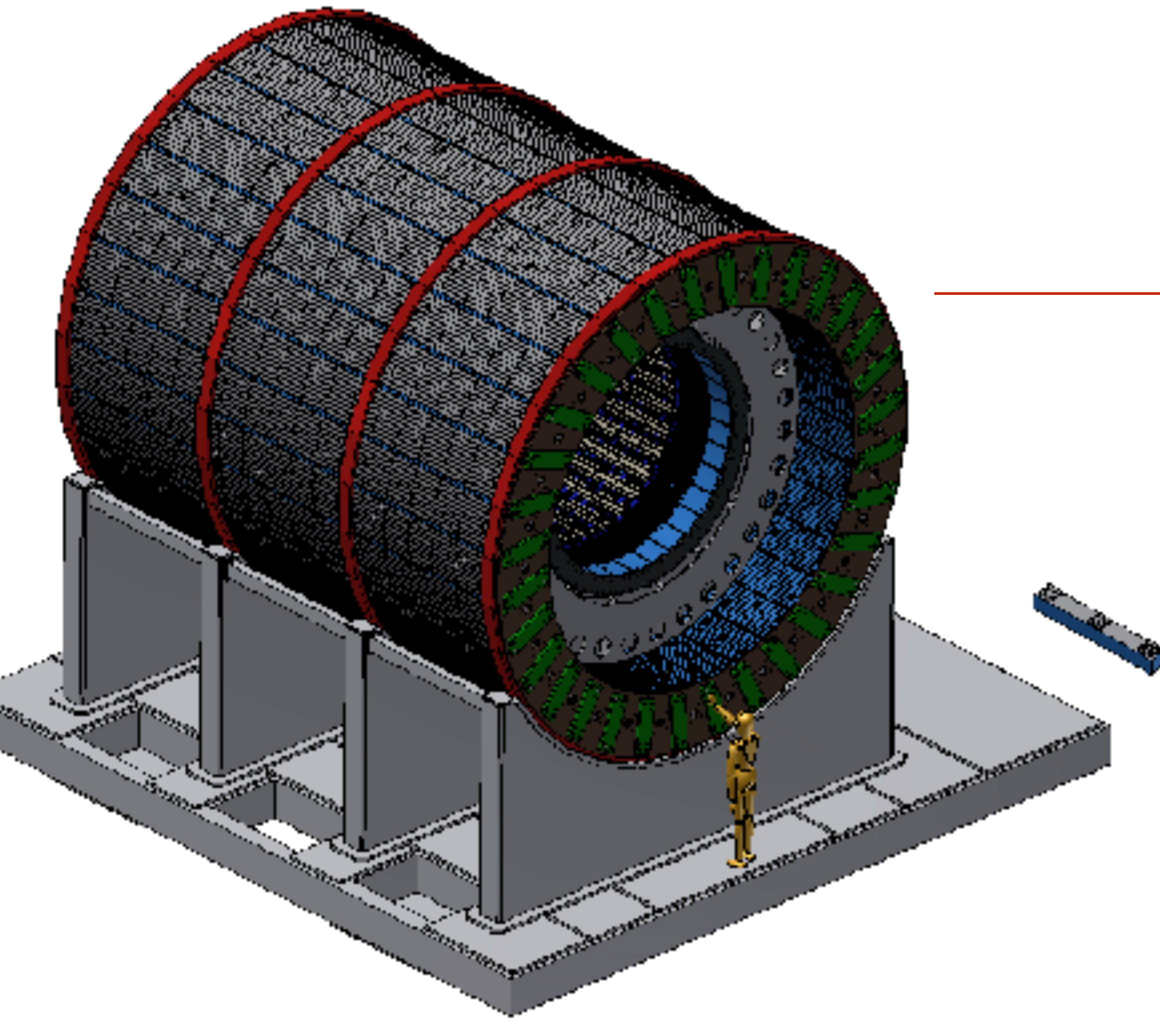
both sections have
SiPM readout

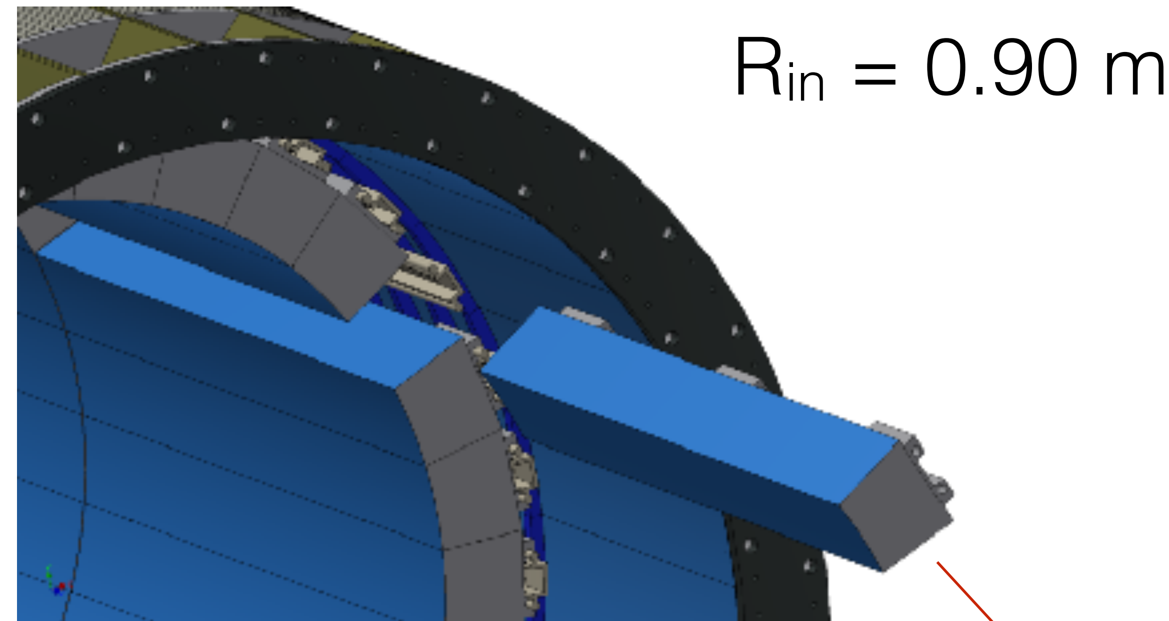


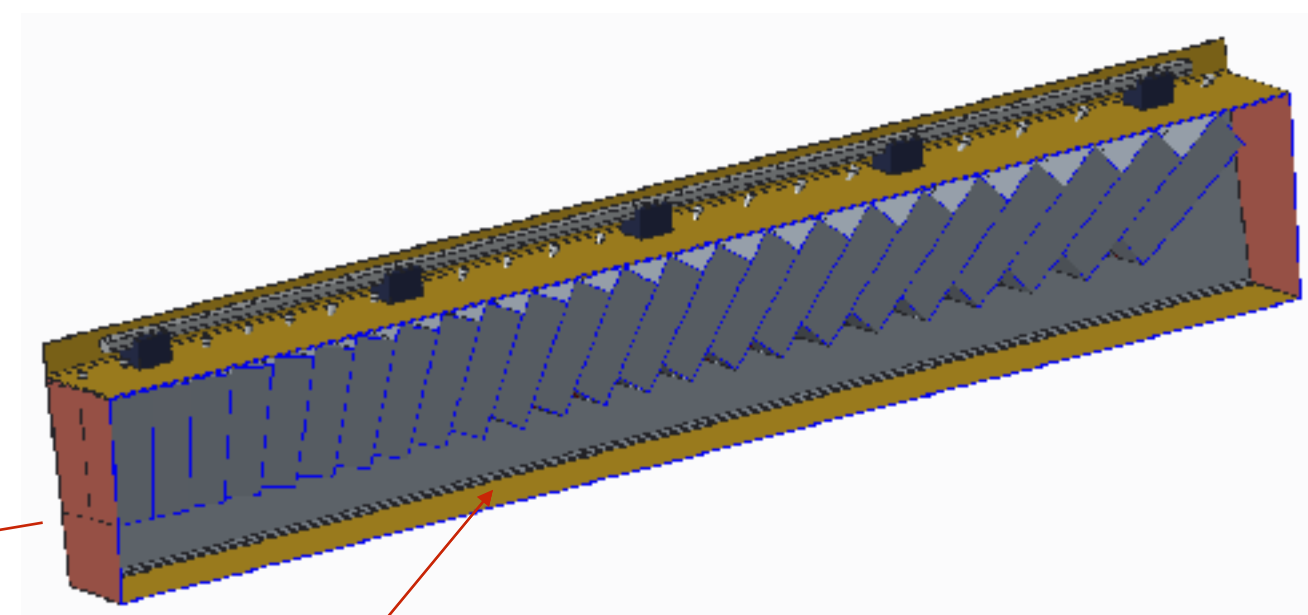
SF ~ 6.7%

ΔSF(R) ~25%

EMCal structure





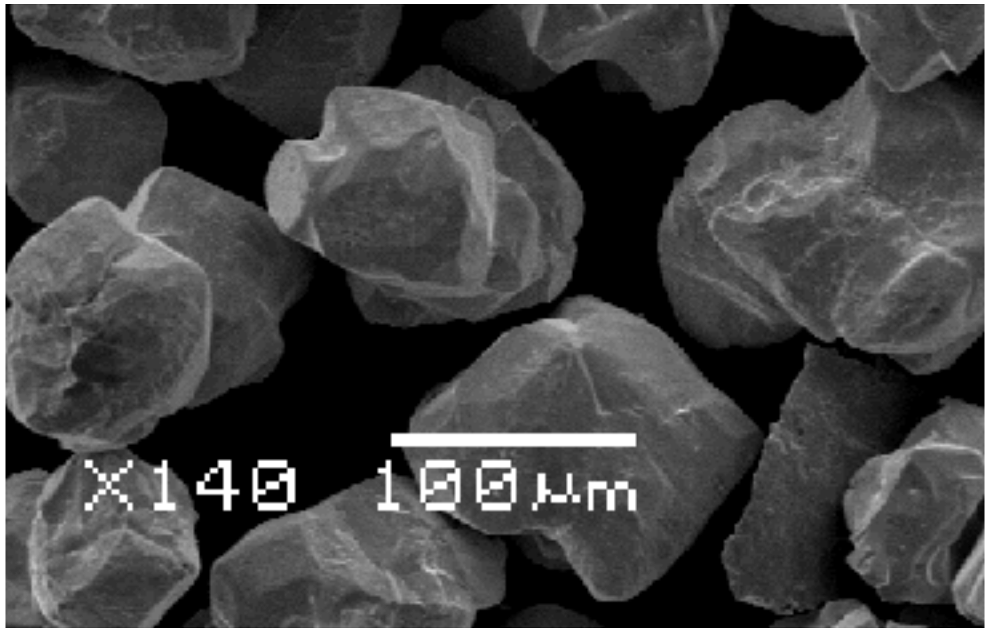


SiPM readout/electronics/cooling

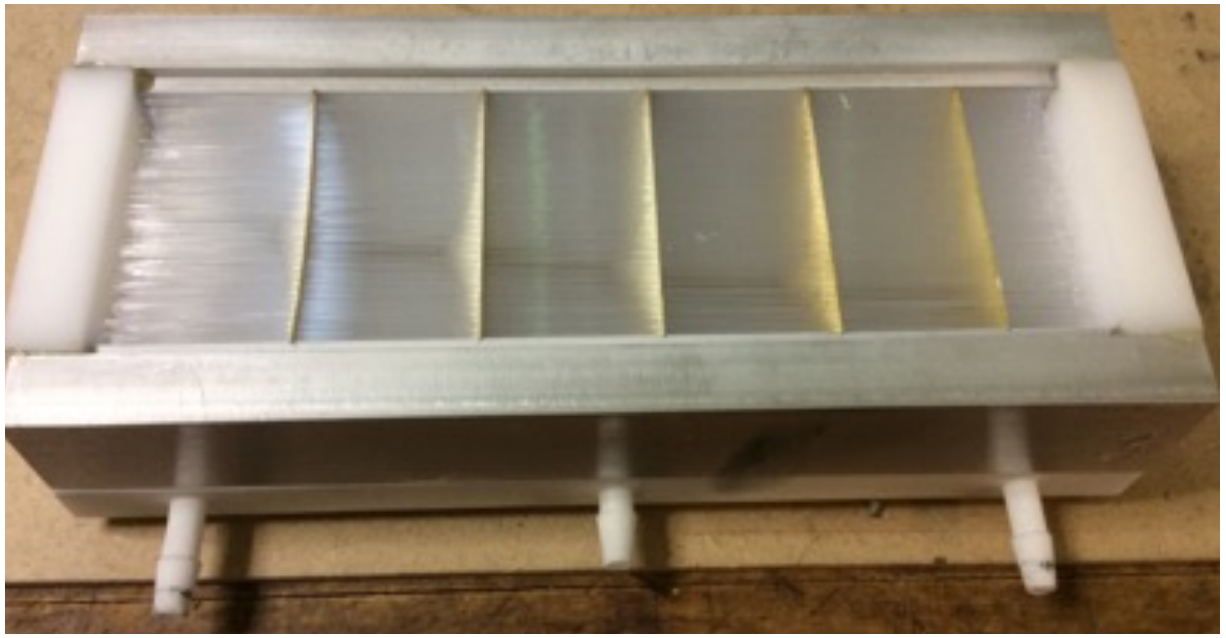
EMCal module construction

- absorber: tungsten powder
- fiber: Kuraray SCSF78 0.47mm
- X0 = 0.7mm
- ρ ~ 10g/cm^3

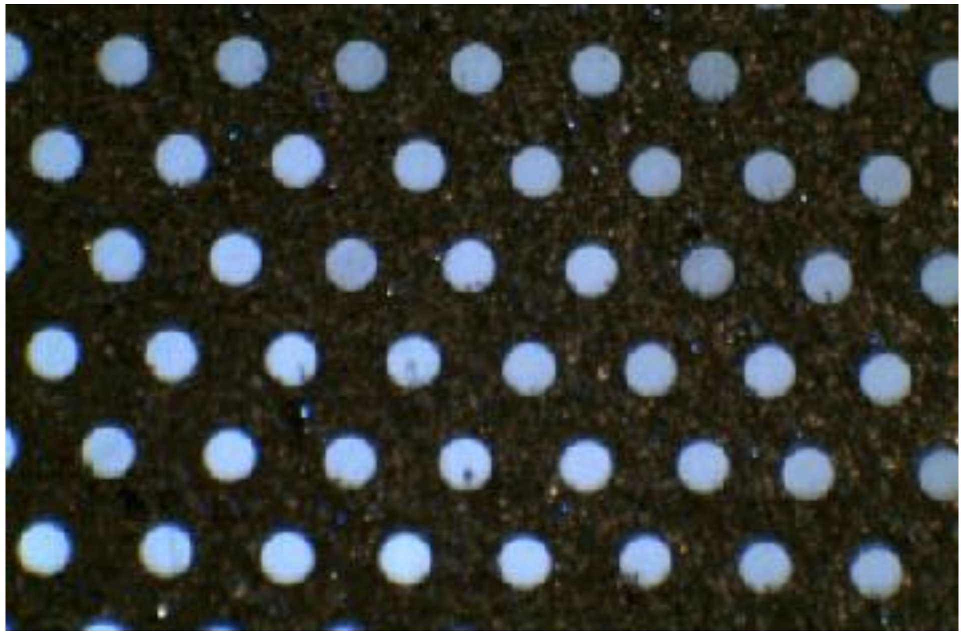
SEM of tungsten powder



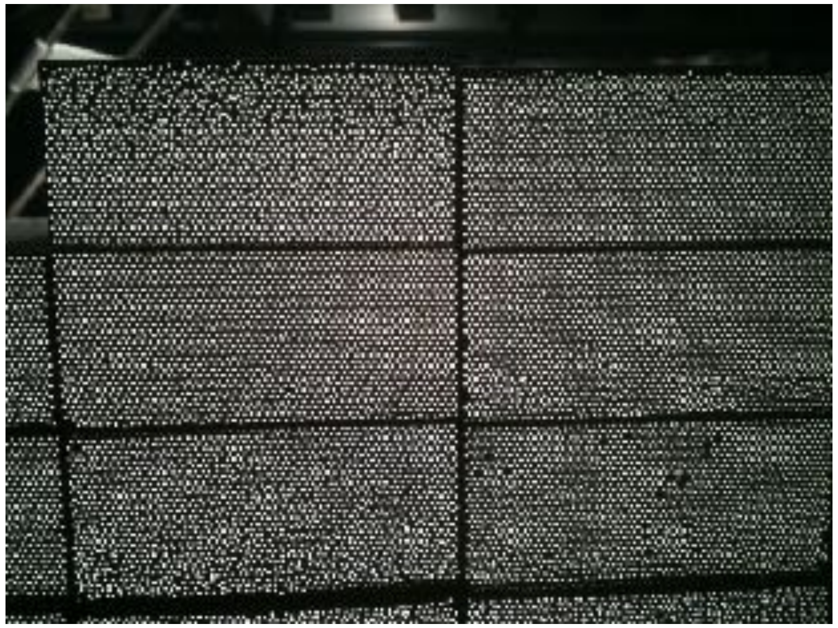
fiber assembly before filling



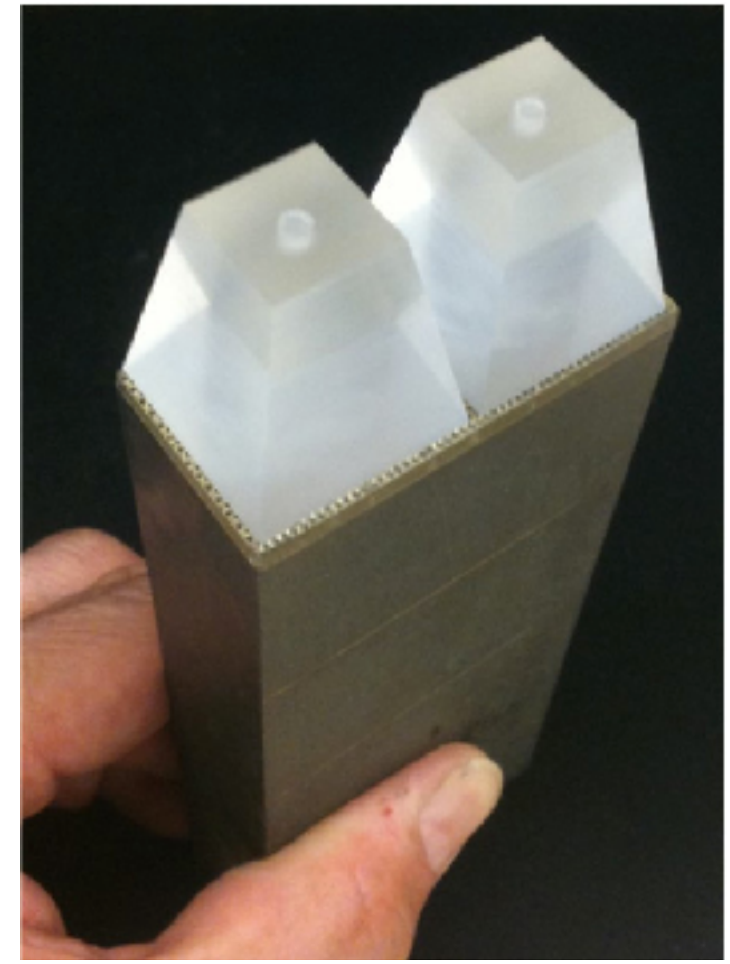
diamond fly cut end



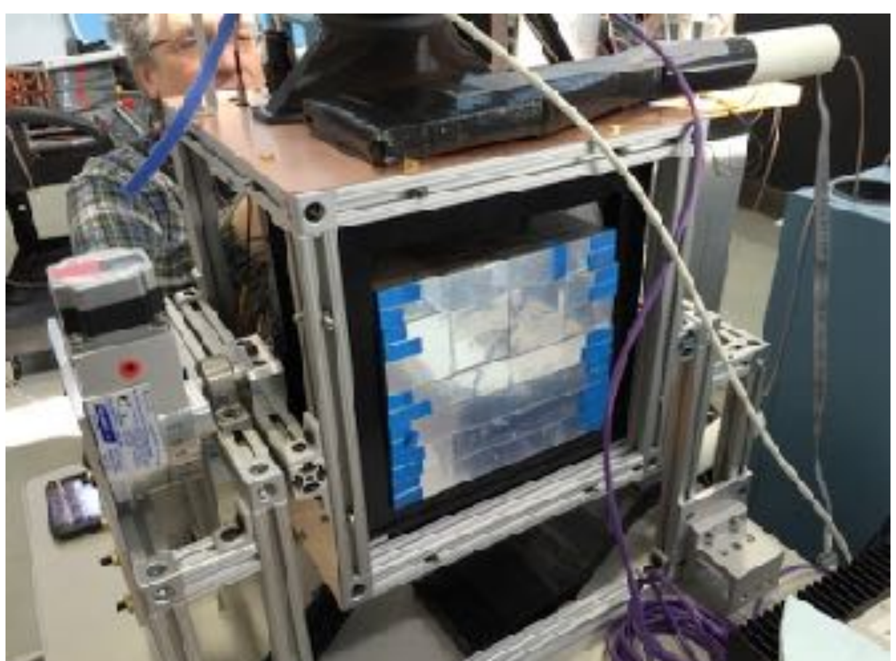
EMCal prototype



1 brick = 2 towers



prototype = 64 towers



industry made

University of Illinois made

THP 10.2	THP 10.5	THP 8.5	THP 8.5	THP 9.0	THP 9.0	THP 9.8	THP 9.8
THP 9.7	THP 9.7	THP 10.0	THP 10.0	THP 10.0	THP 10.0	THP [illegible]	THP [illegible]
THP 9.2	THP 9.2	THP 9.8	THP 9.8	THP [illegible]	THP [illegible]	THP 10.1	THP 10.1
UIUC 9.6	UIUC 9.6	UIUC 9.4	UIUC 9.4	THP 10.1	THP 10.1	THP 9.6	THP 9.6
UIUC 9.5	UIUC 9.5	UIUC 9.5	UIUC 9.5	THP 9.1	THP 9.1	THP 9.1	THP 9.1
UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.6	UIUC 9.6
UIUC 9.2	UIUC 9.2	UIUC 9.5	UIUC 9.6	UIUC 9.3	UIUC 9.3	UIUC 9.3	UIUC 9.3
UIUC 9.5	UIUC 9.5	UIUC 9.6	UIUC 9.6	UIUC 9.3	UIUC 9.3	UIUC 9.2	UIUC 9.2

HCal prototype

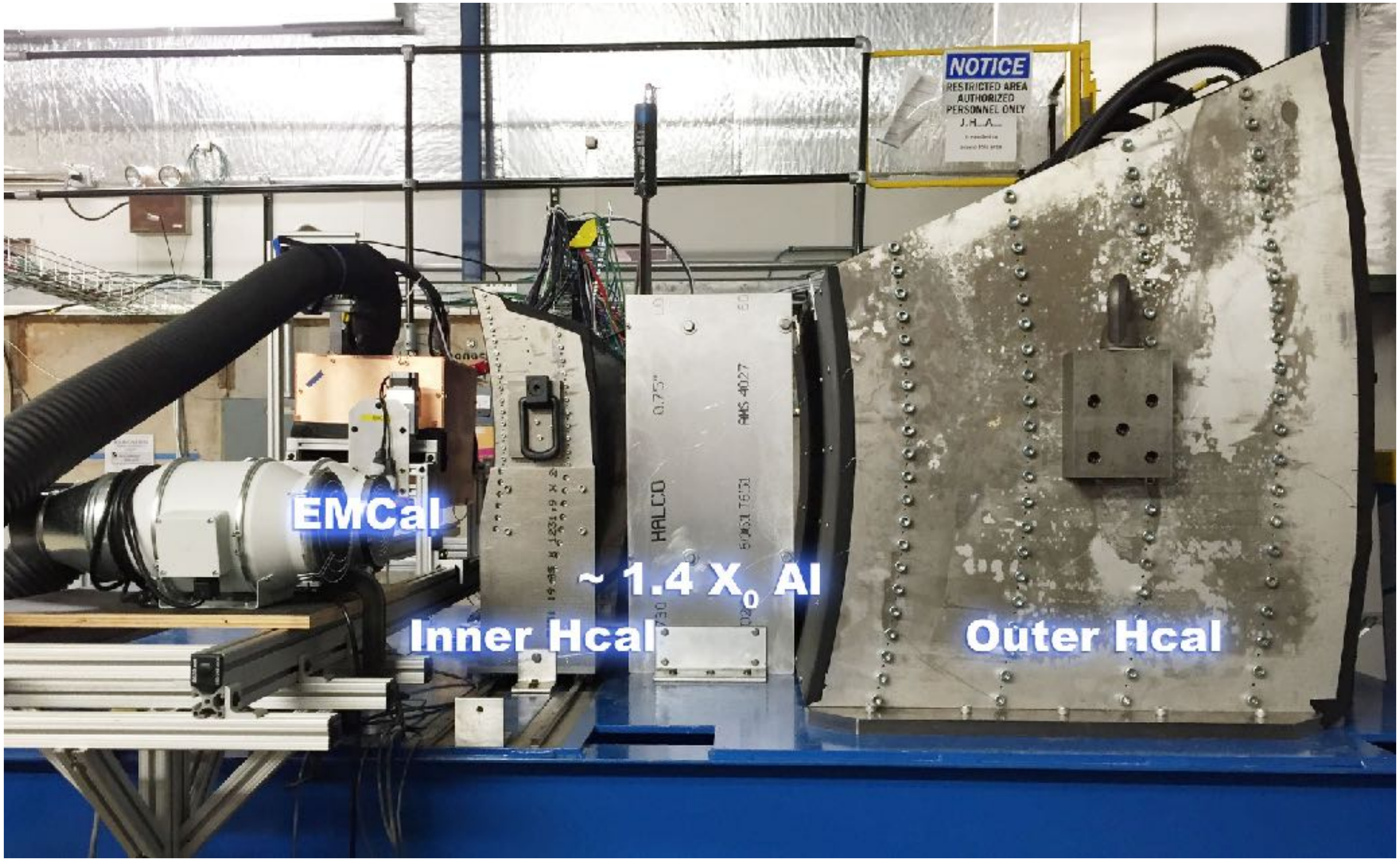
Inner and Outer HCAL prototypes each 4 x 4 towers

- Inner: =56 x 94 cm^2
- Outer: = 74 x 165 cm^2

Outer HCAL prototype with assembled steel plates and readout electronics

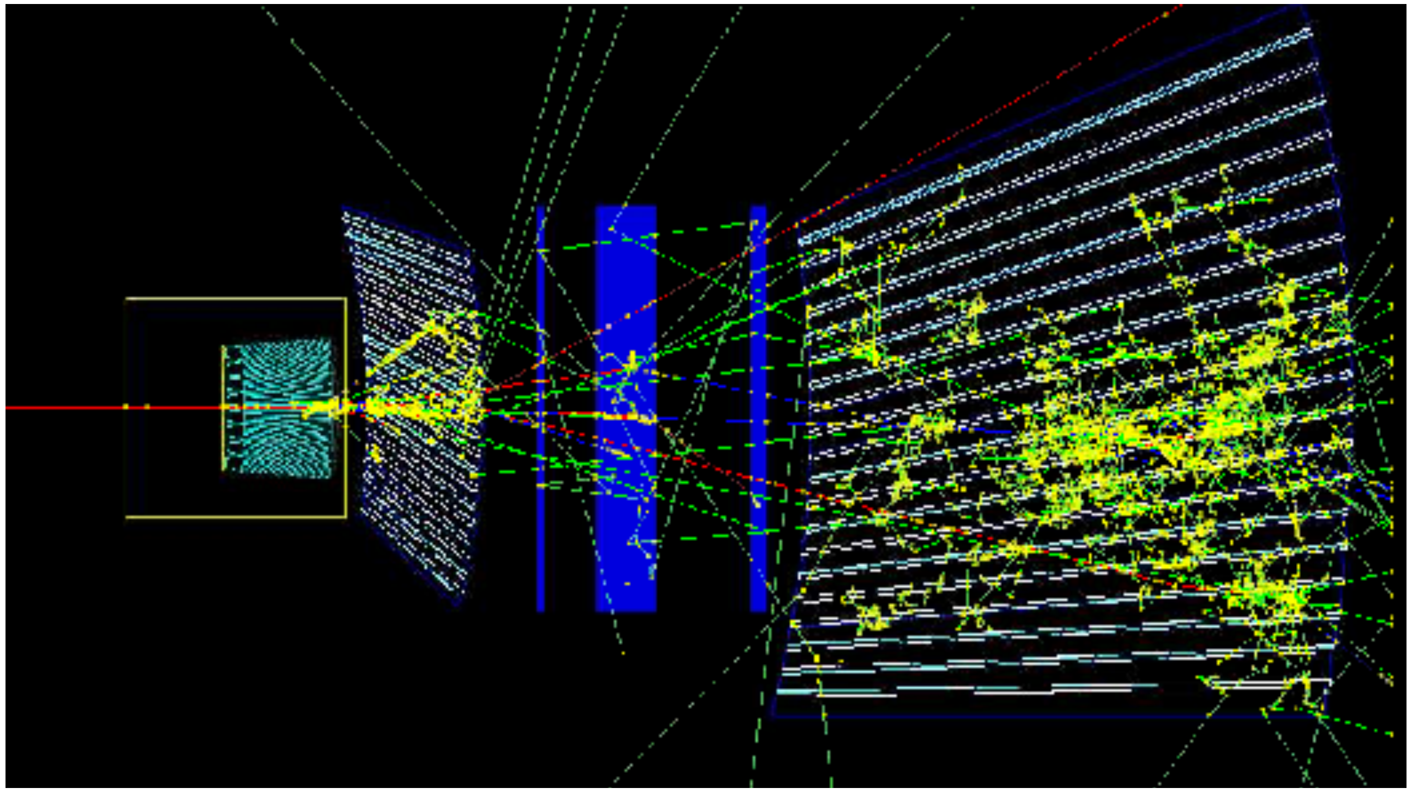
Polystyrene scintillating tiles (7 mm) with WLS fiber (1 mm). One SiPM reads out both ends of fiber. SiPMs from 5 tiles summed into 1 tower

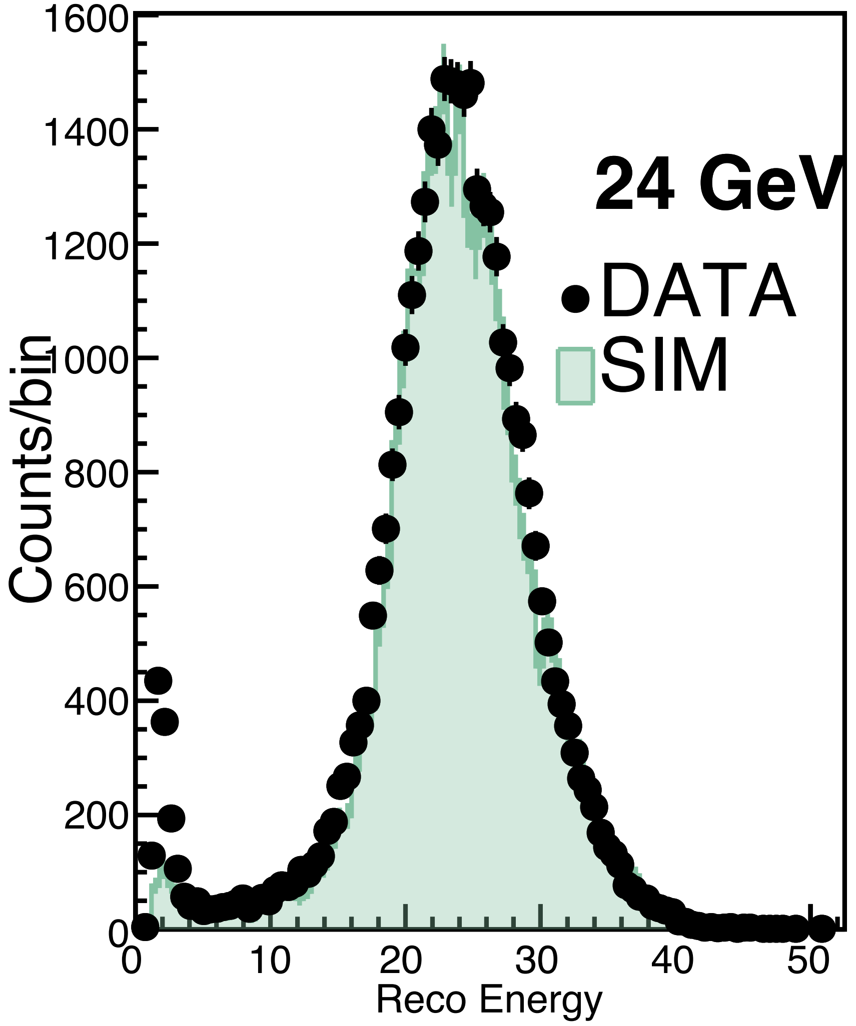
testbeam setup at Fermilab



Geant 4 based simulations

hadron

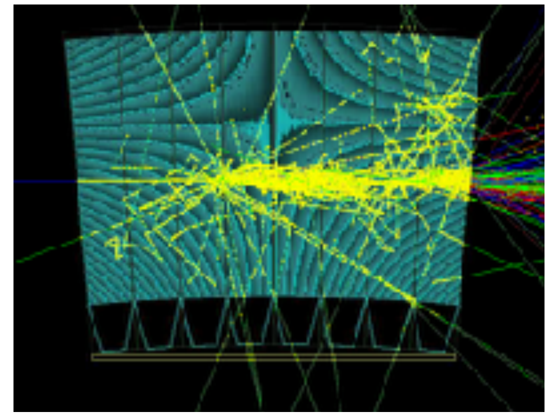




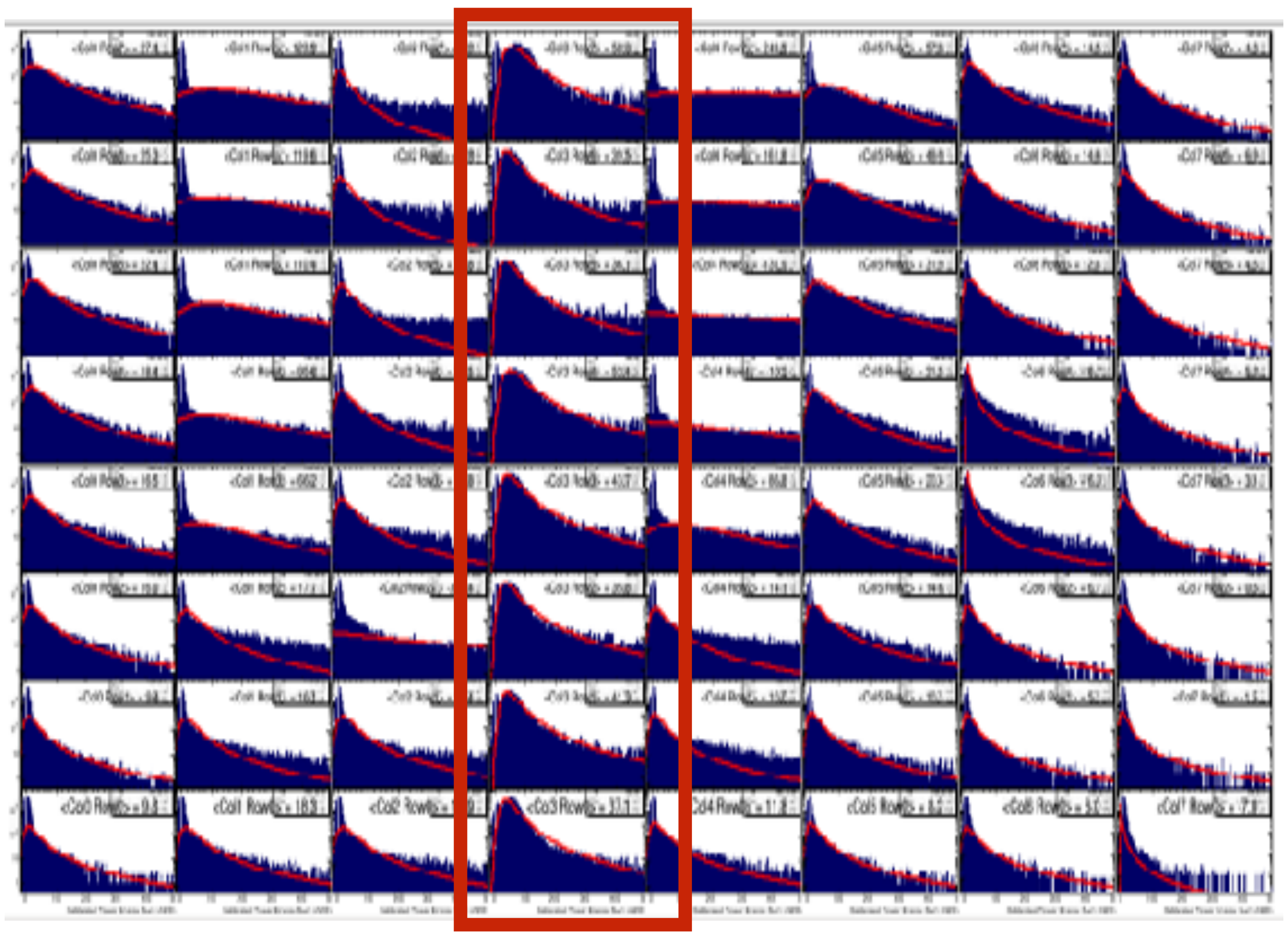
good agreement between data & simulation

EMCal Calibrations

rotated EMCal position
for calibrations



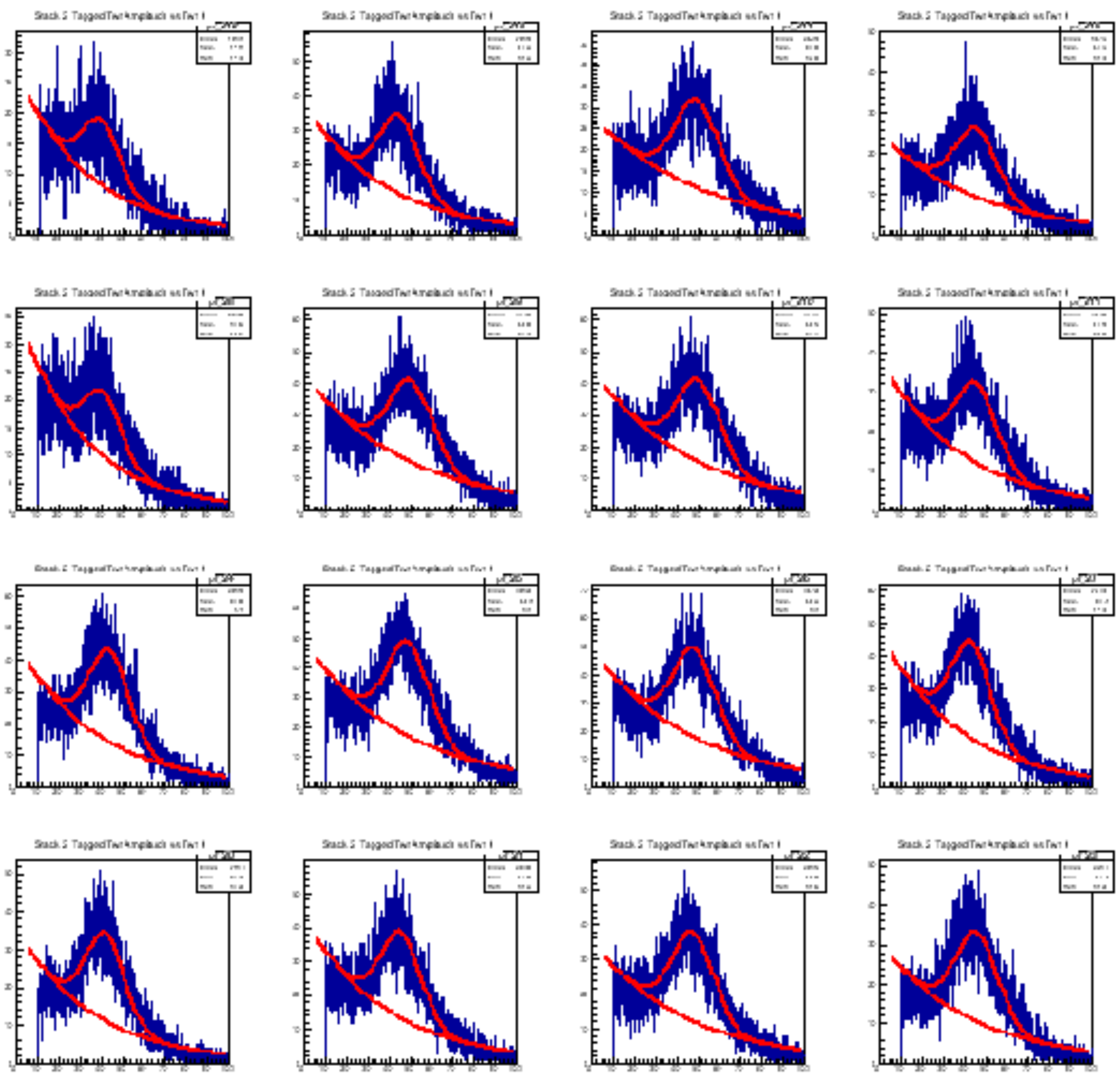
hadron



calibrate w/ 120 GeV
proton beam MIP

beam

HCal Calibrations

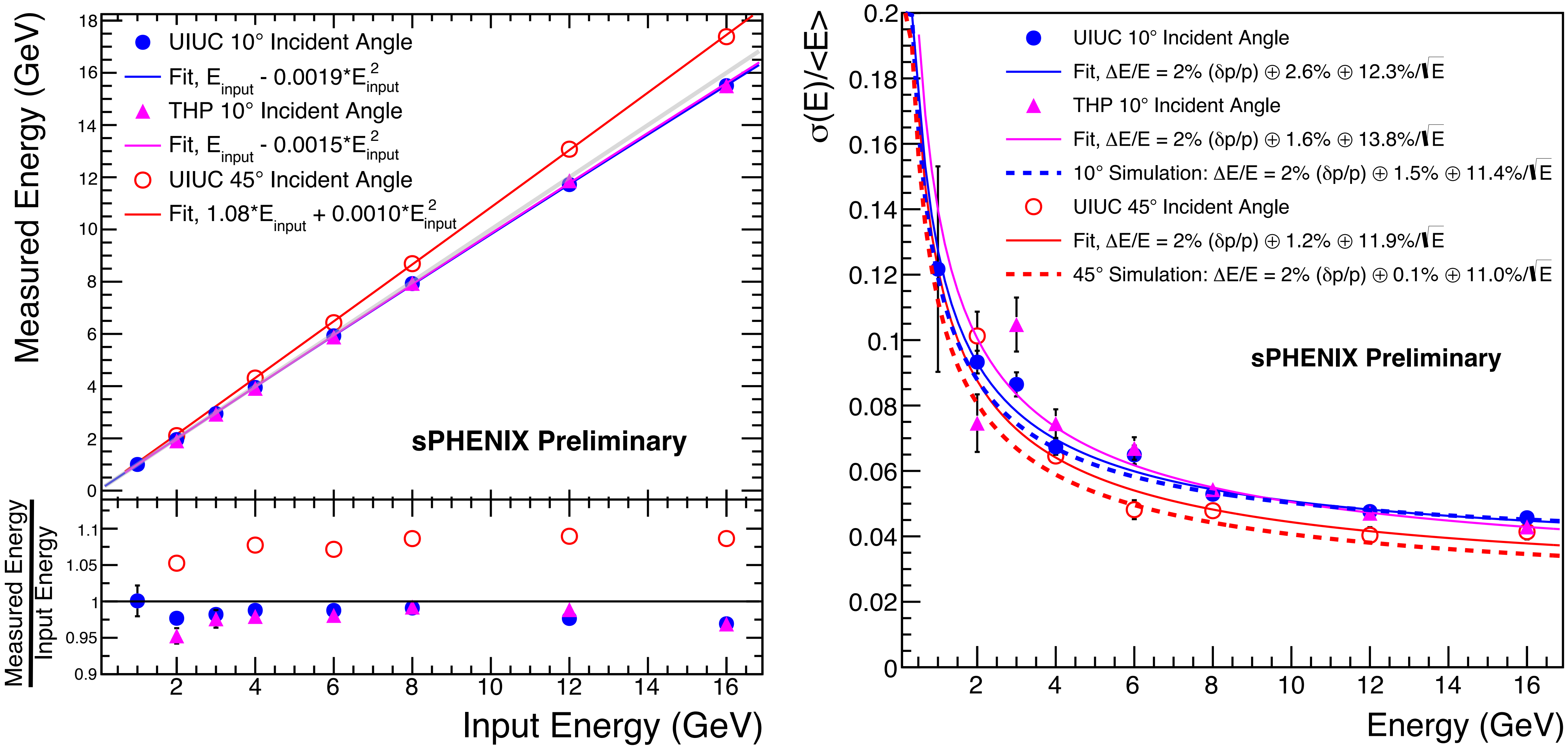


HCAL calibration done with cosmic μ's
E_{dep} ~ 750 MeV (inner)
E_{dep} ~ 1 GeV (outer)

self triggering w/x16 higher gain

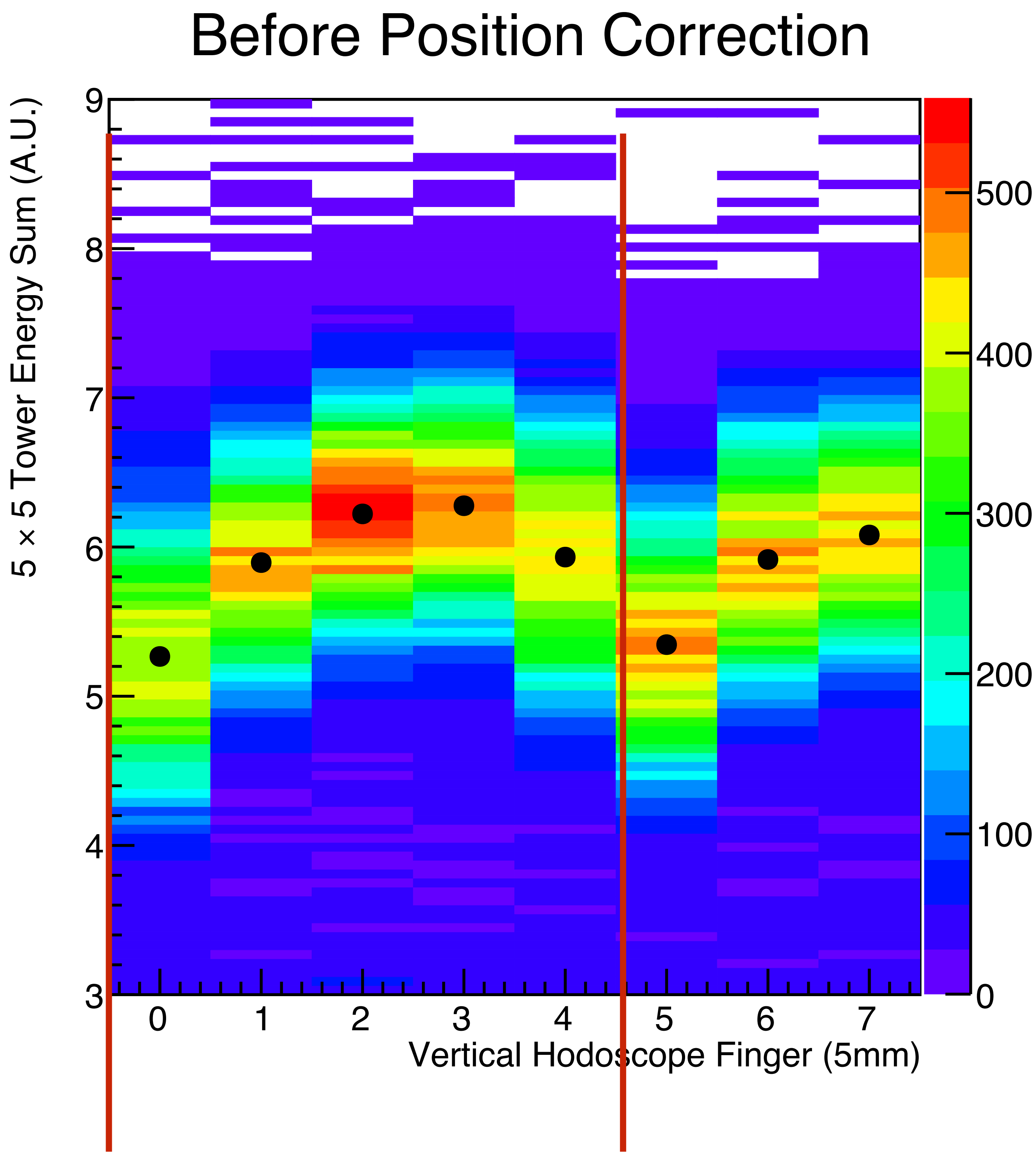
EMCal energy resolution & linearity

center of tower (selected via hodoscope)



- similar performance between **industry** at **Illinois** built blocks
  - resolution better than our requirements
- **larger tilt angles** → shallower showers
- deviations from uniformity in part due to beam energy shifts from nominal values

position dependence of energy scale

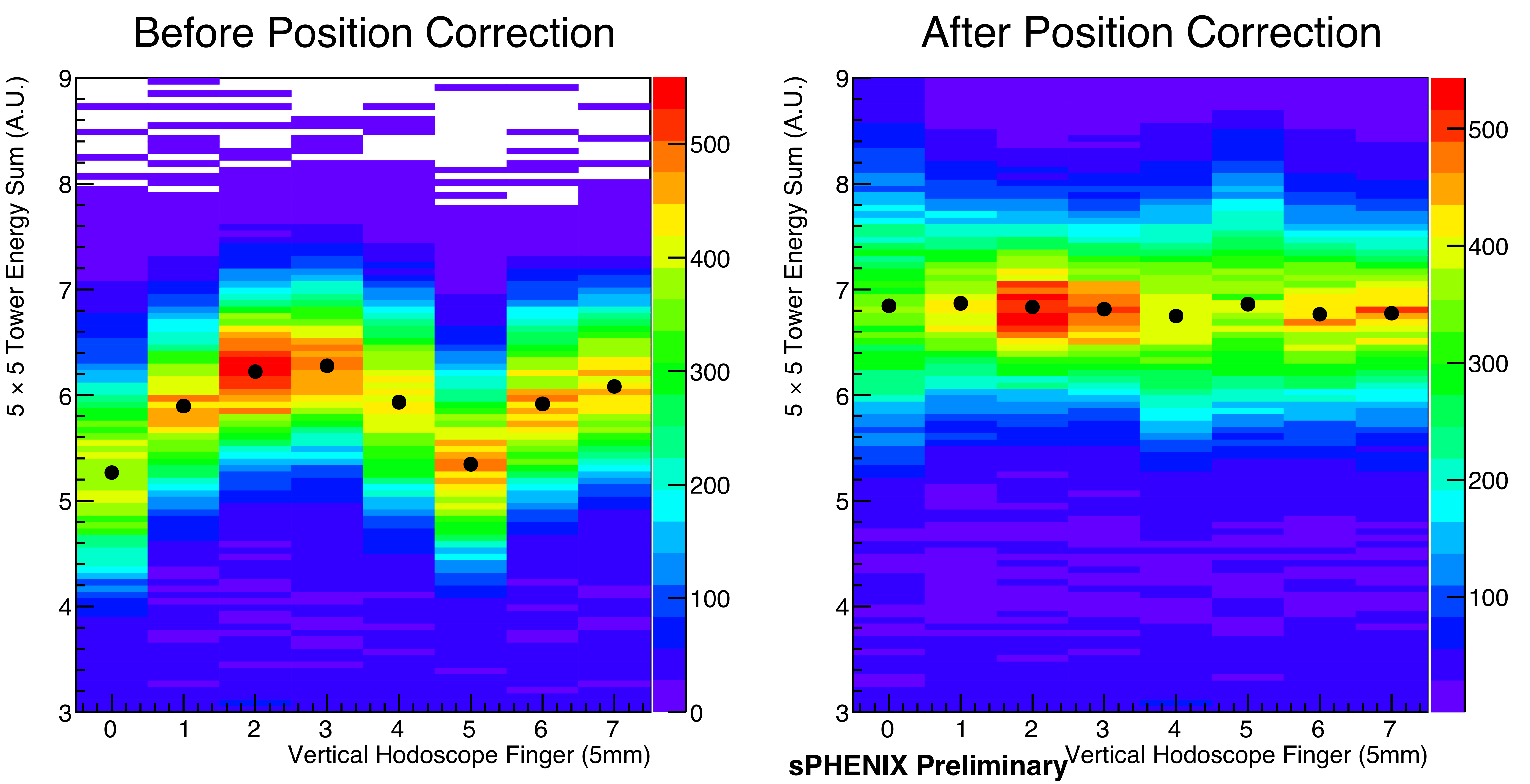


width of tower

- **sources**:
    - lightguide inefficiency near edges
    - gaps in fibers between towers?

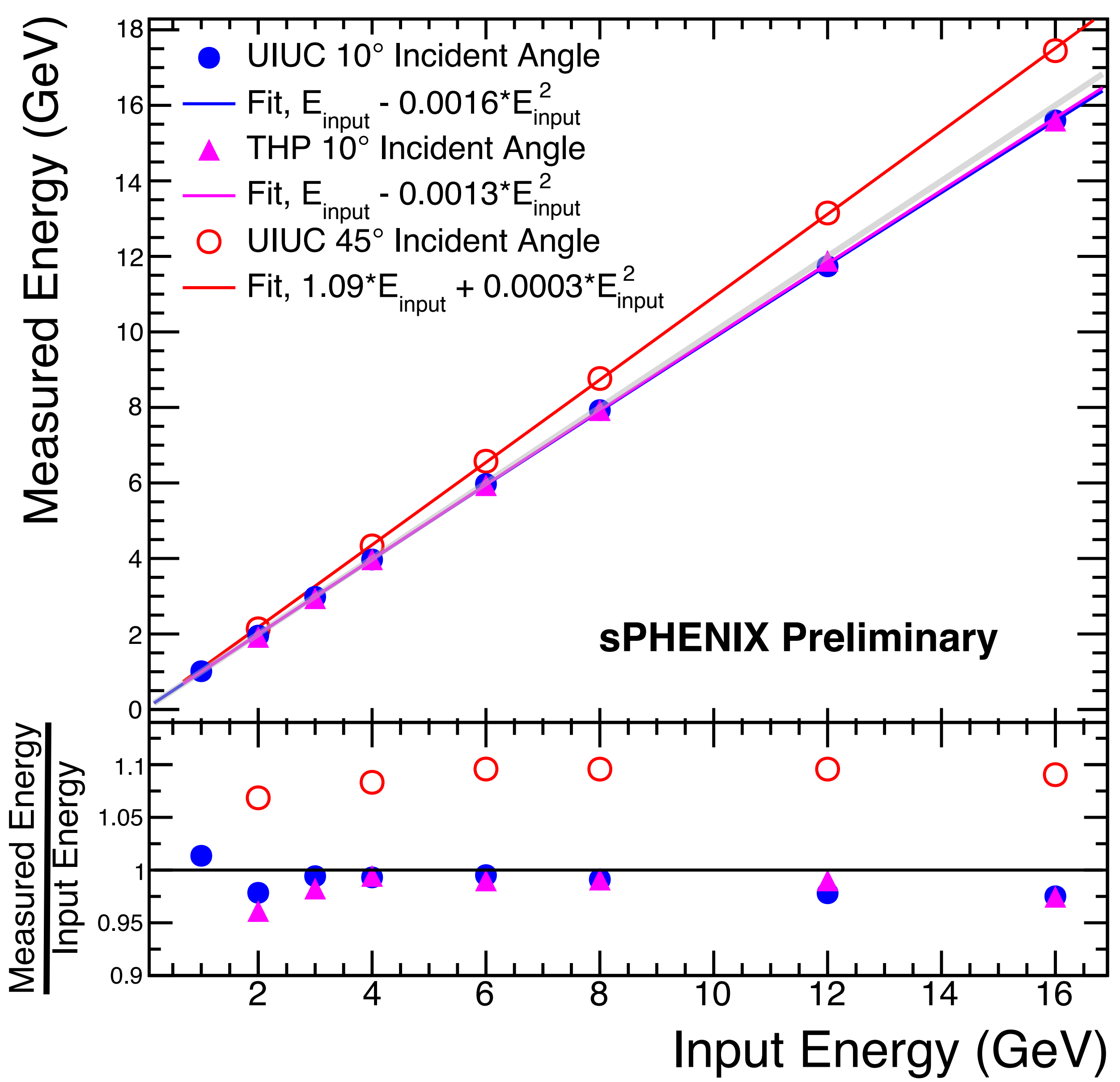
position dependence of energy scale

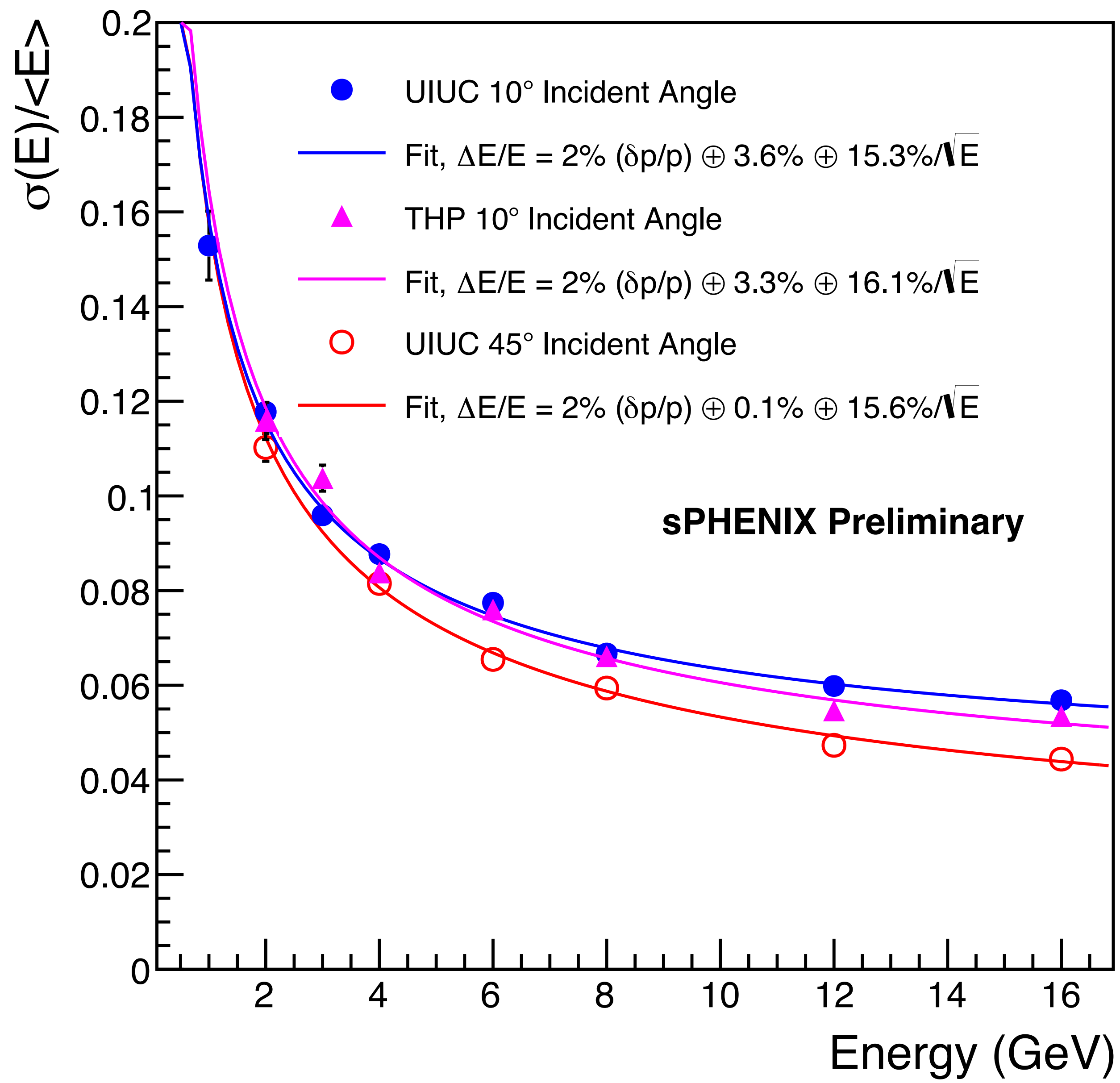
use 2D position correction based on the hodoscope



EMCal energy resolution & linearity

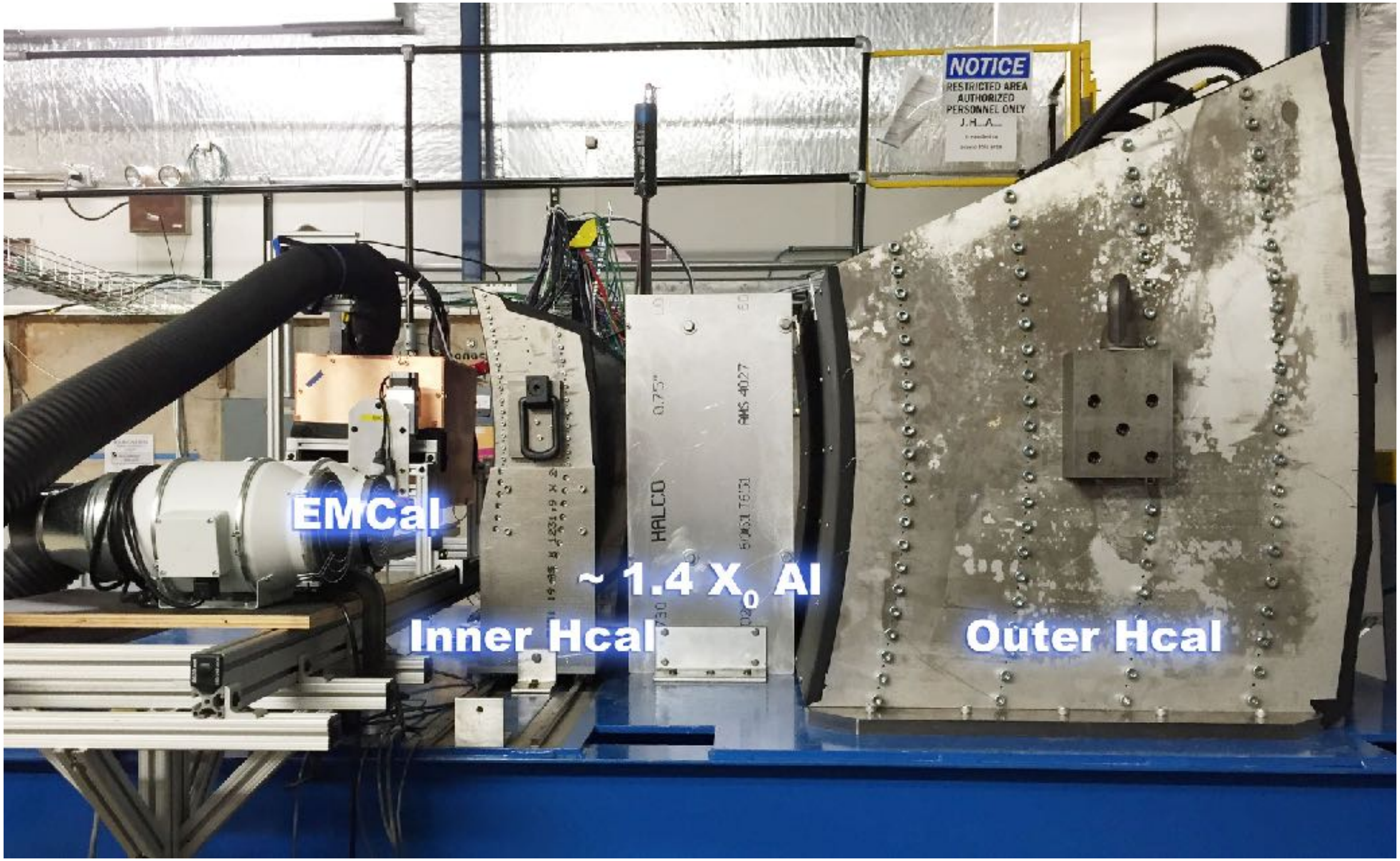
after application of position correction



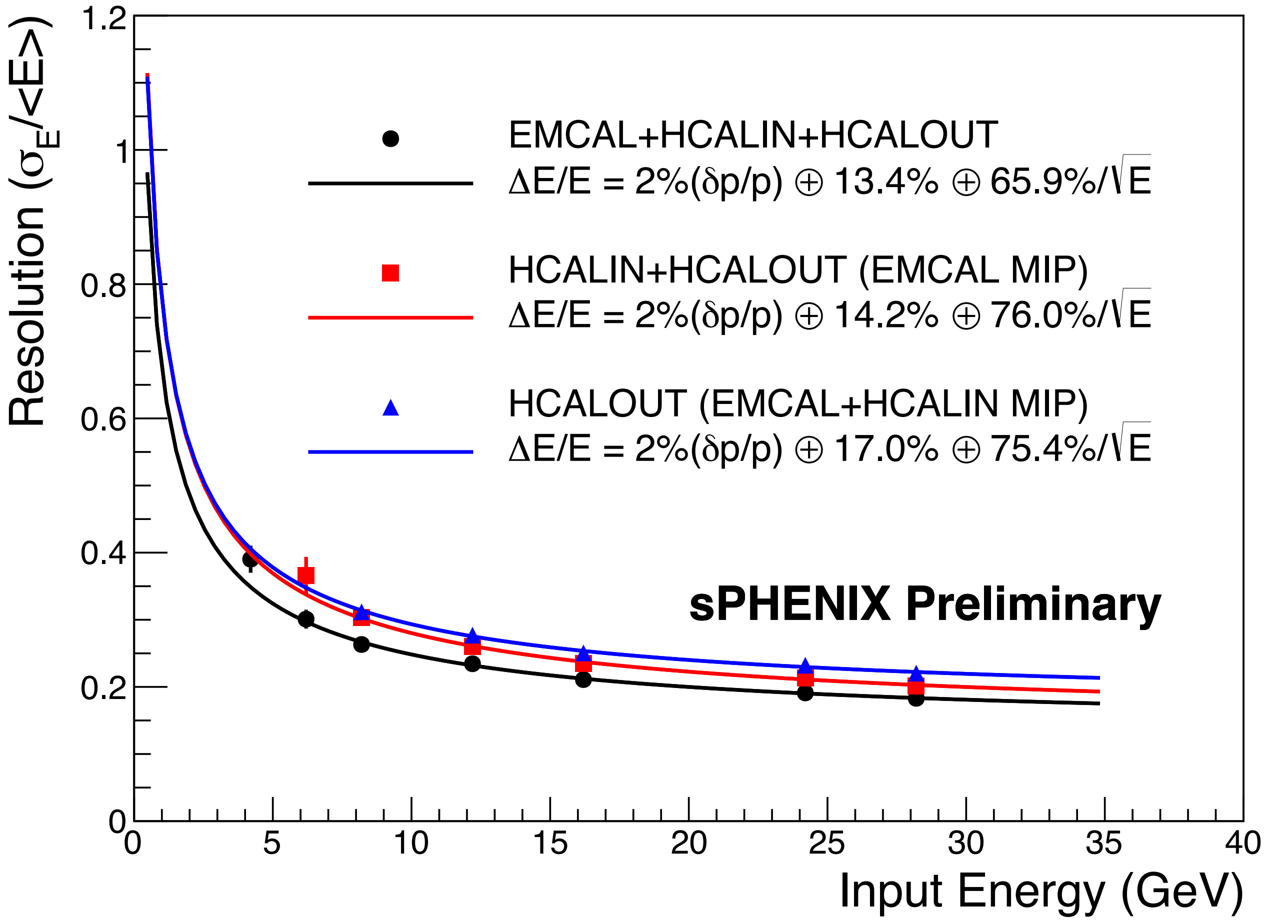


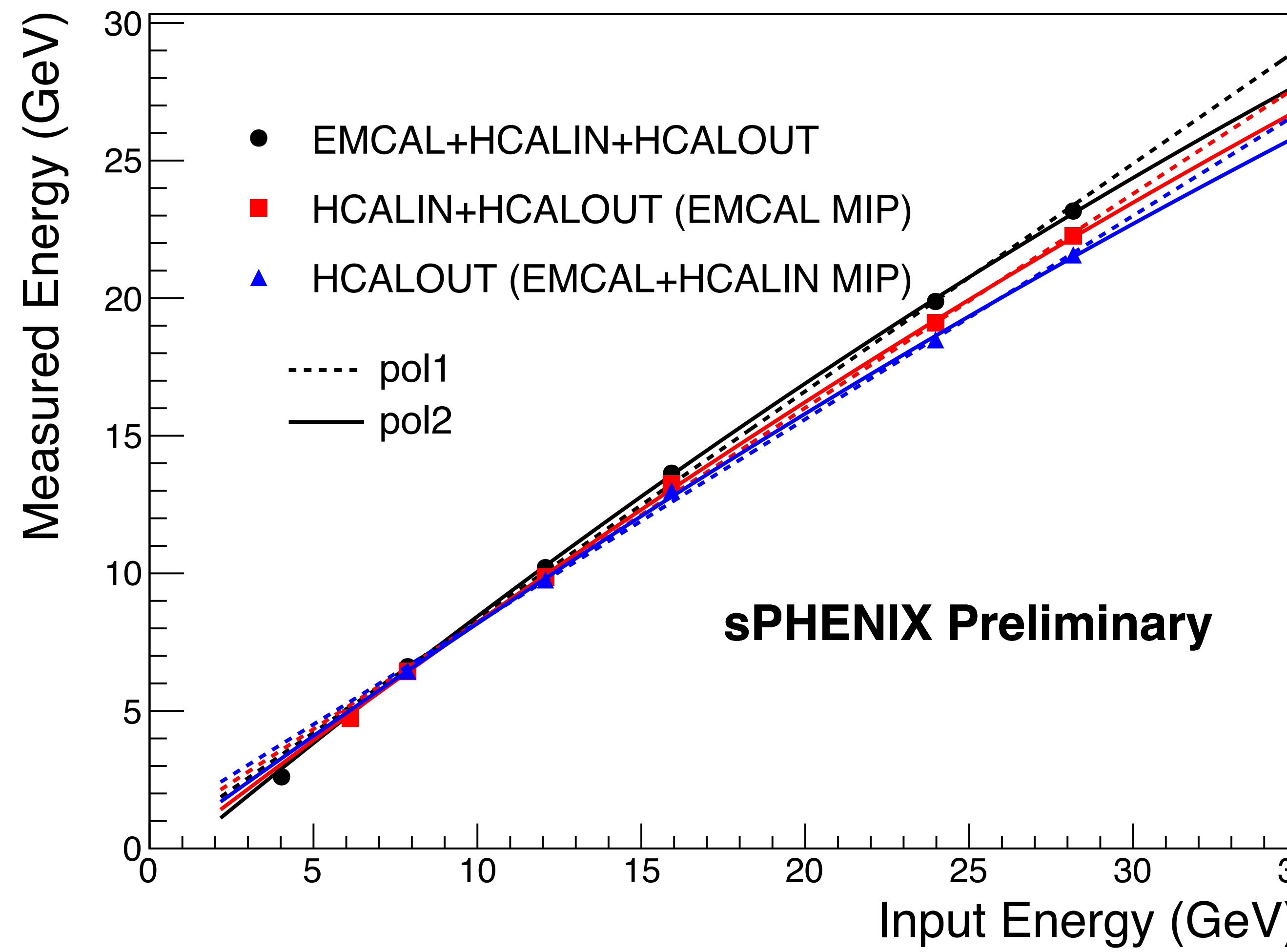
energy resolution ~15% / √E after correction for **Illinois blocks**

combining EMCal & HCal energy



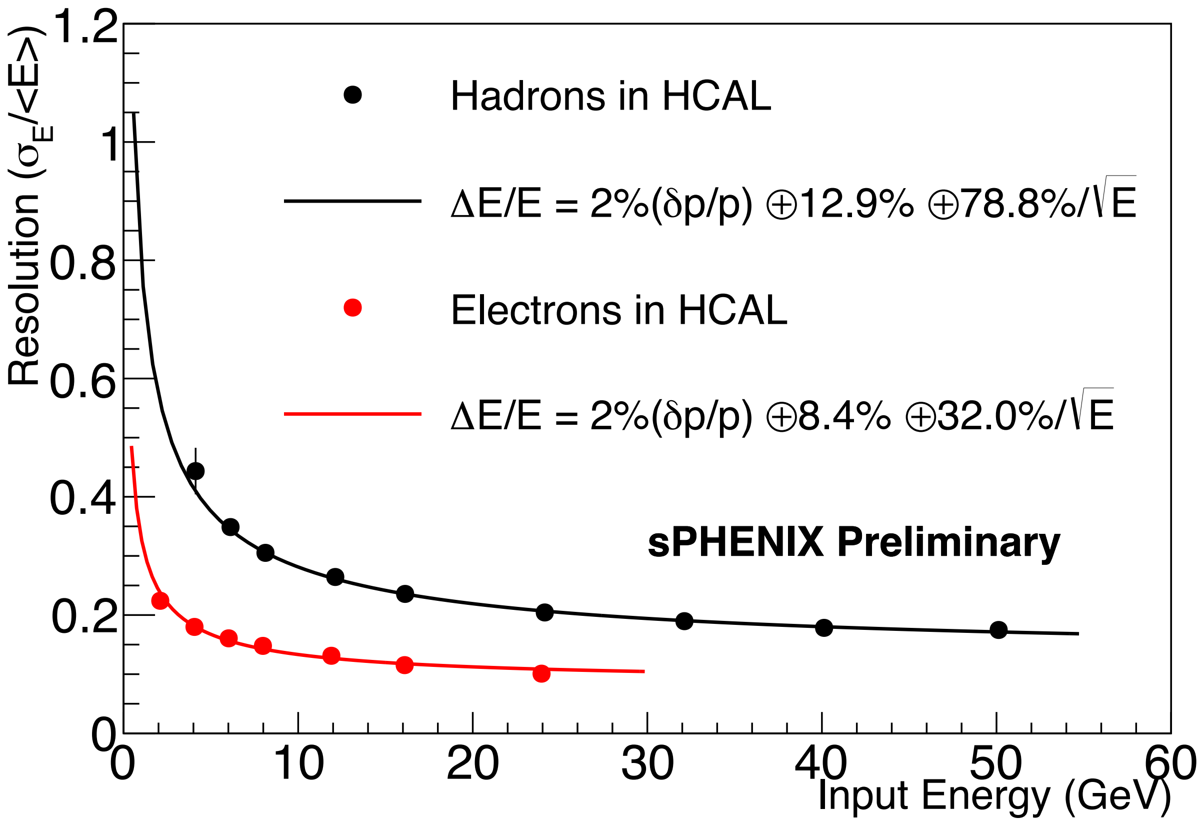
combined resolution

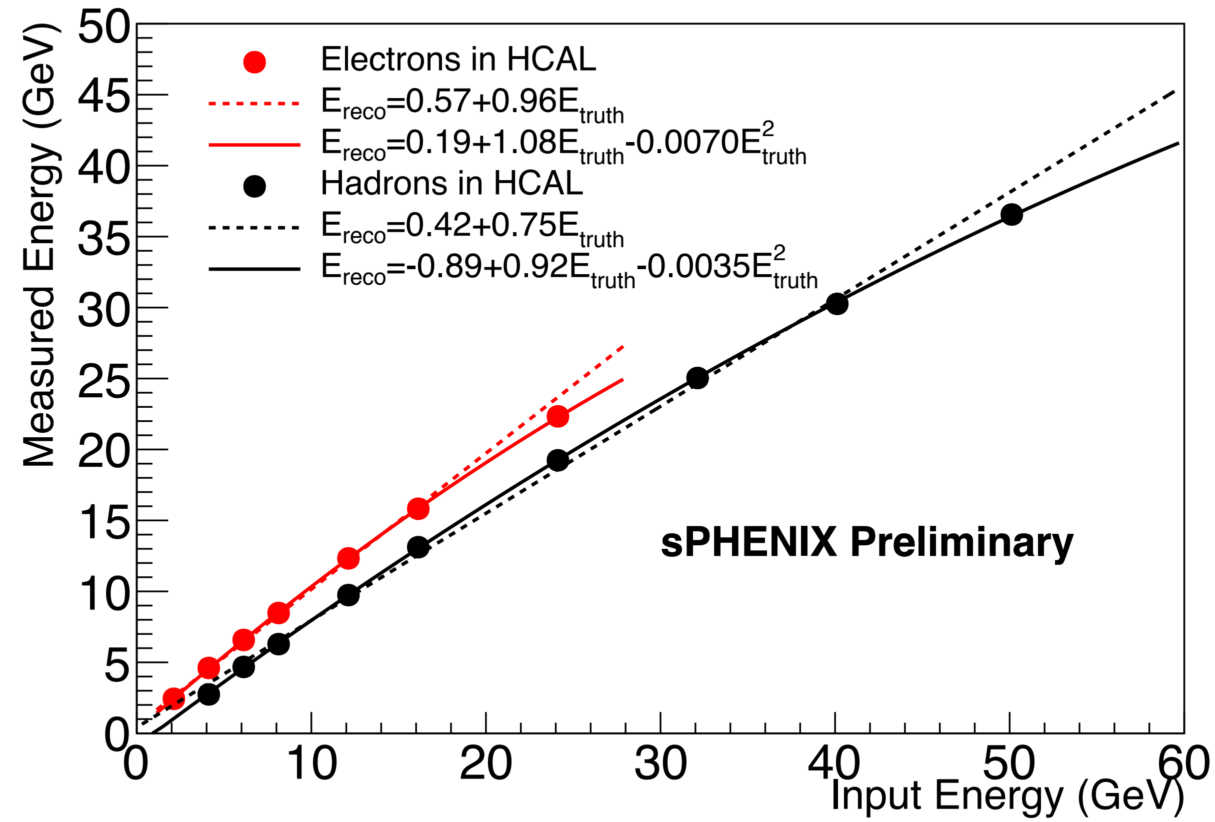




- combined resolution: 13.4% ⊕ 65.9 / √E
    - significantly better than our requirement

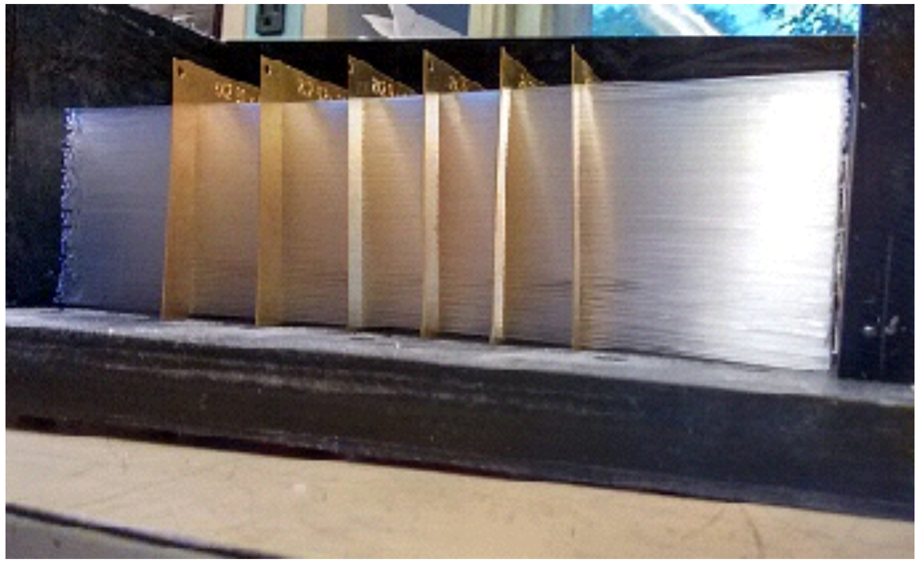
HCal showers alone

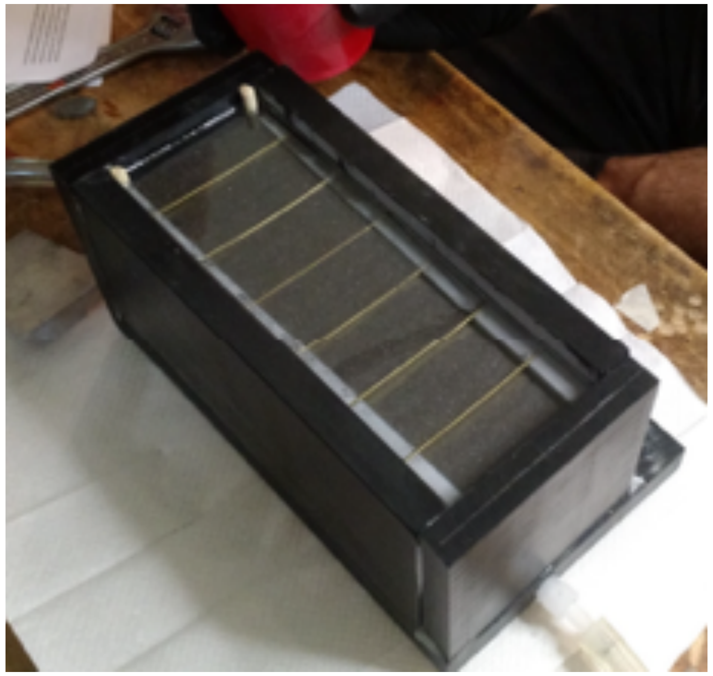


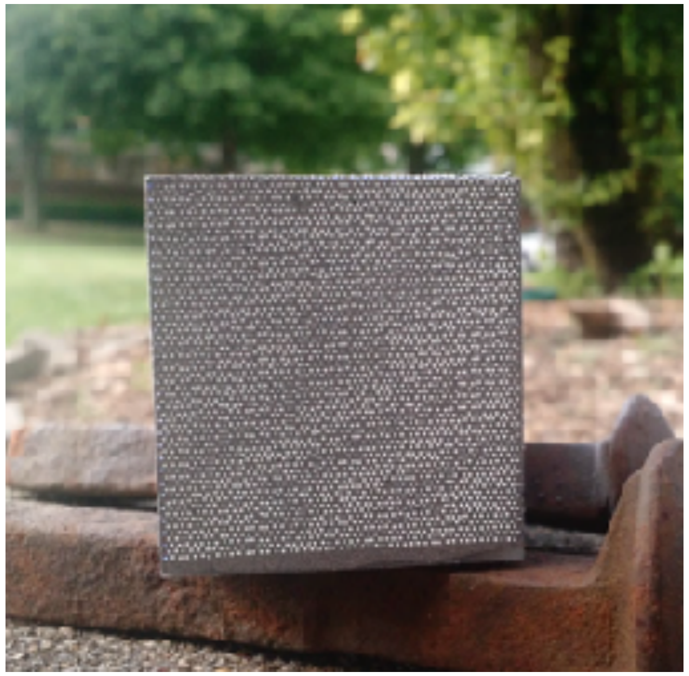


- hadron resolution: $12.9\% \oplus 78.8 / \sqrt{E}$
- some deviations from linearity / saturation at high beam energy

plans for further prototyping







- demonstrate high |η| performance
  - new tiles in HCal corresponding to |η| ~ 0.7
  - improved gain setting
  - 2D projective EMCal modules
    - also 4 towers / brick
    - redesigned lightguides

Fermilab testbeam: January 2017

summary & outlook

- sPHENIX is the planned new detector at RHIC in order to study the QGP with jets, photons, upsilons and heavy flavor
- design and testing of the calorimeters is well underway
- improvements identified, but test beam performance shows that the calorimeters meet the physics requirements
- paper on these results is nearing completion and will be submitted soon!