ePIC Forward ECal: Status and Plan

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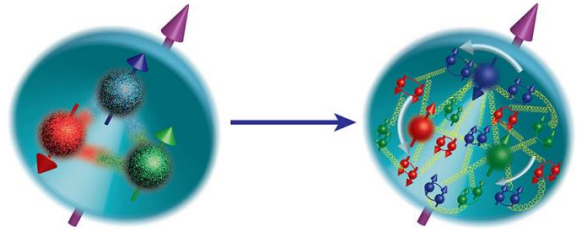
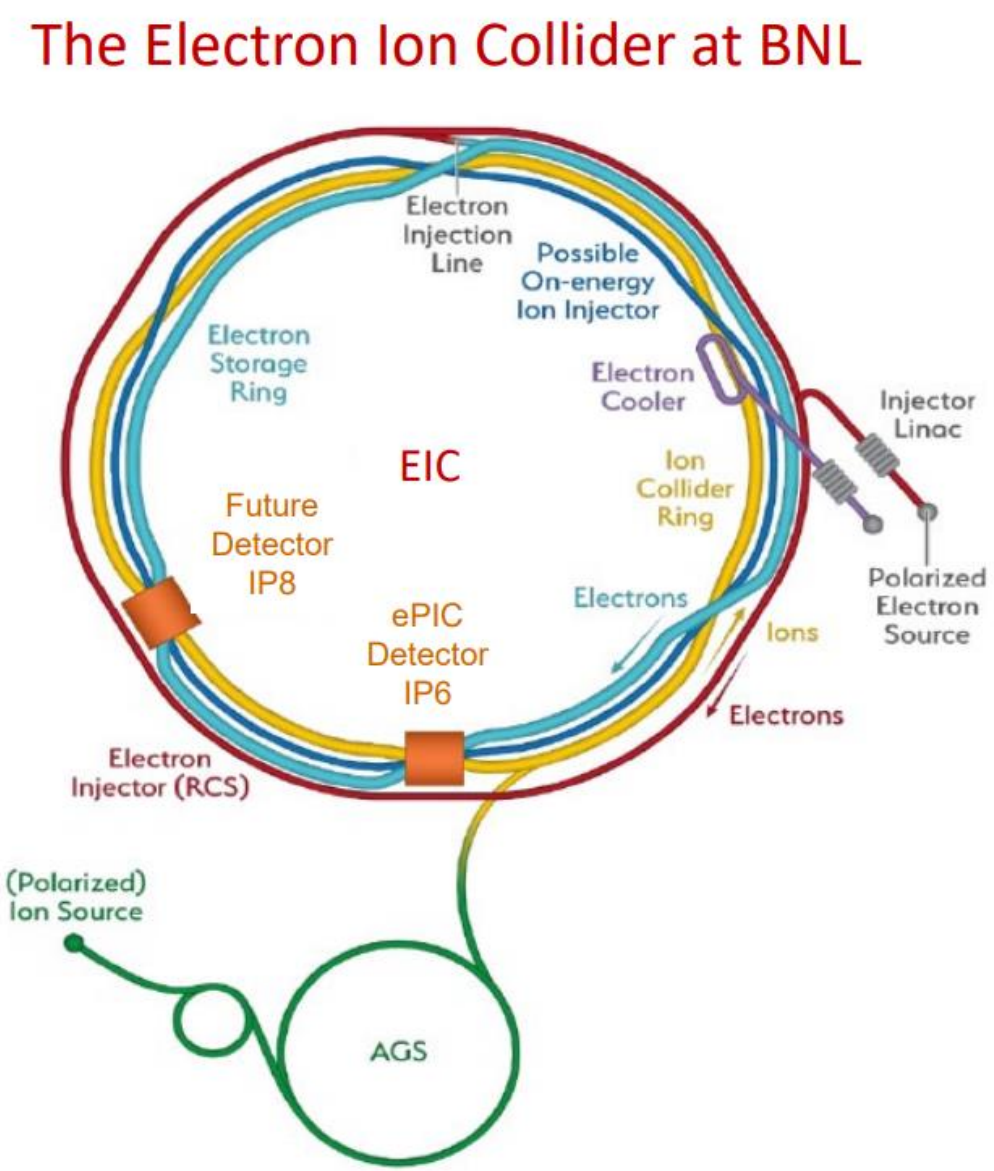
For the ePIC fECal Team
July 28, 2023

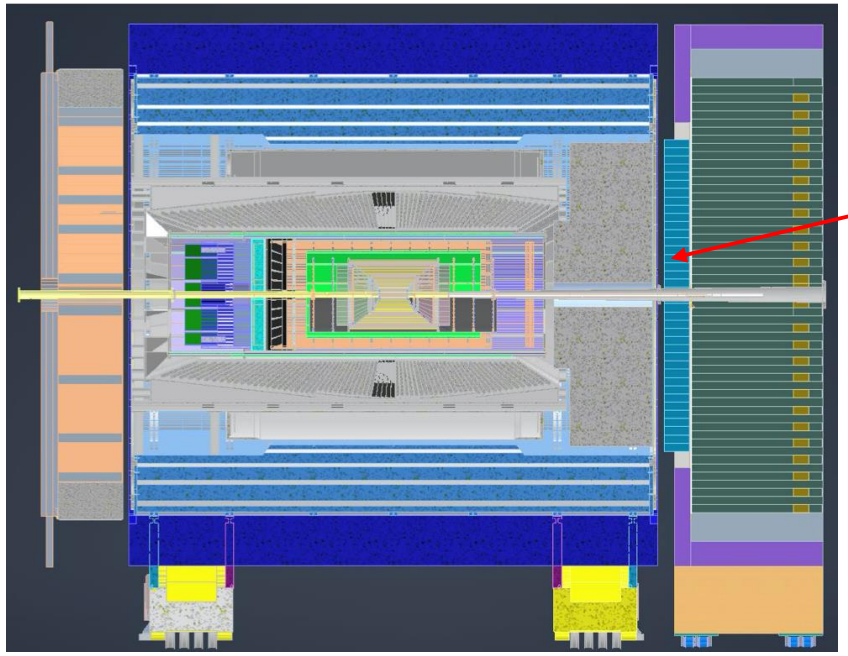
Outline

- ✓ High Level Summary of Scope
- ✓ High Level Input
- ✓ Choice of Technology
- ✓ Current Status
- ✓ fECal Consortia Structure, WBS
- ✓ Plans for Future
- ✓ Summary

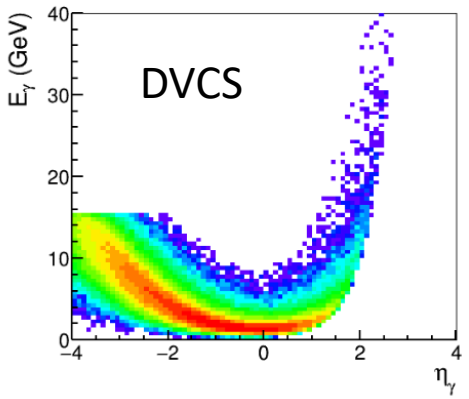


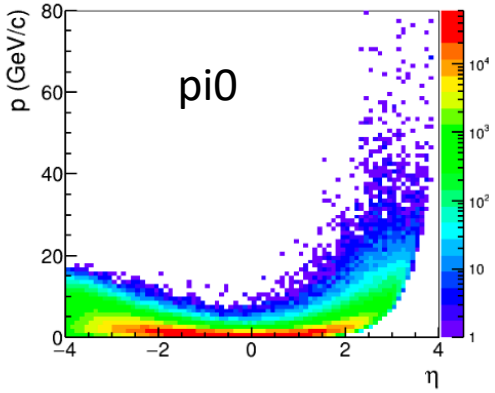


High Level Summary of Scope



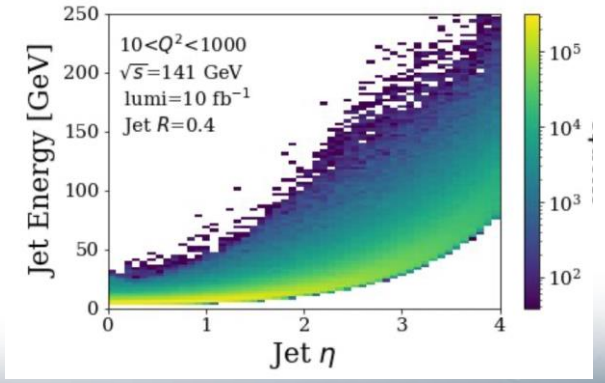
- Forward ECal is part of a Hadron Endcap
- Covers pseudo rapidity range ~1 to 4 (R_{in} 30 cm, R_{out} 173 cm)*
- Integration length along Z - 30 cm
- Total weight ~ 20 tons
- Number of readout channels ~15k





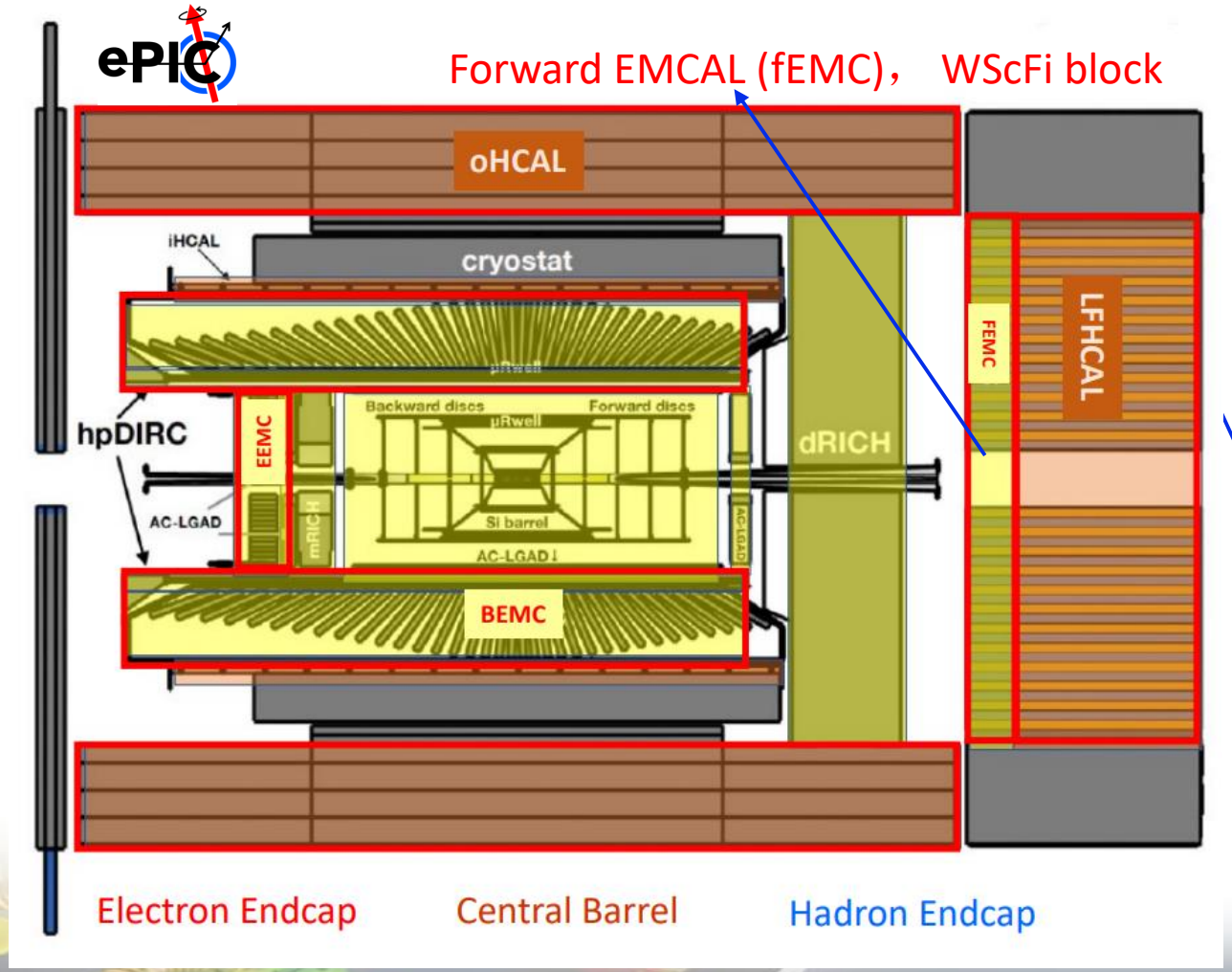
High Level Input

- Yellow Report – desired energy resolution 10%-12%/√(E) ⊕ 2%
- Yellow Report – good pi0/gamma discrimination up to ~ 50 GeV
- Optimal reconstruction of jets (ECal +Hcal (+ tracker))
- Readout must work in magnetic field, neutron fluxes up to 10^{12} n/cm^2.
- ECal must fit in limited space. (Small X_0)

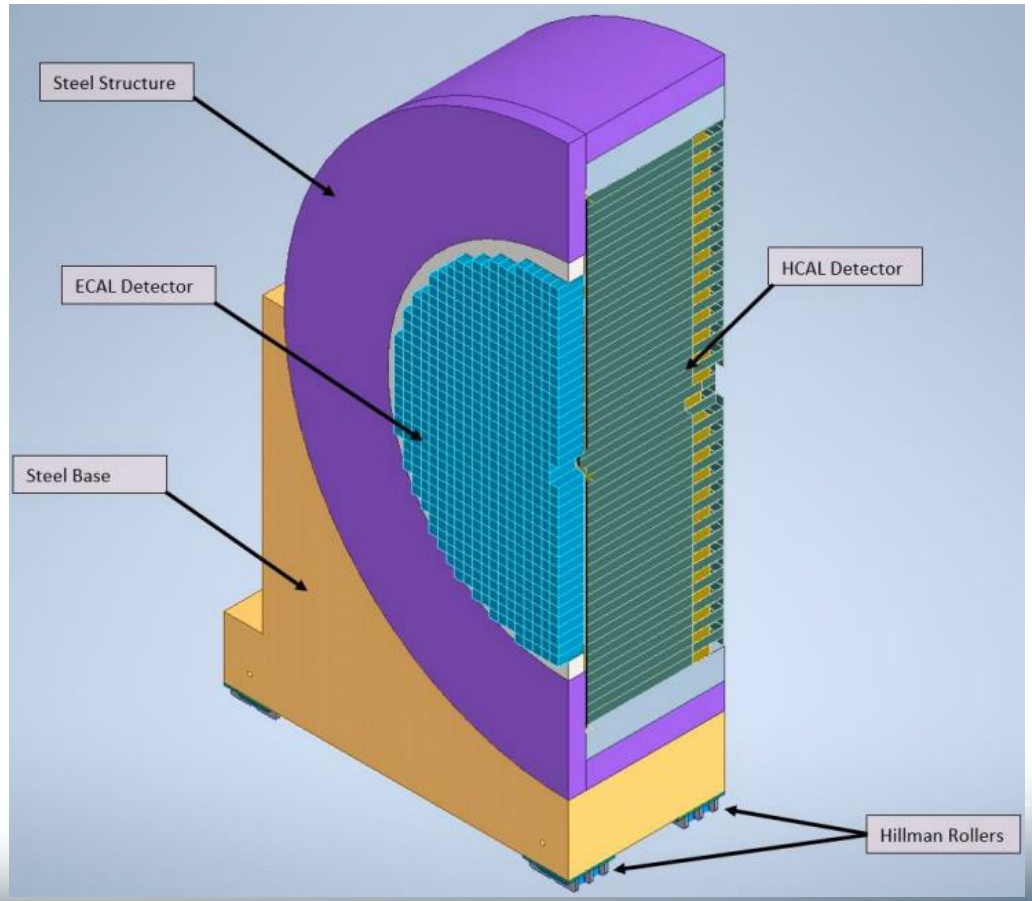


Choice of Technology

fECal is based on technology developed during generic EIC R&D and then used in the construction of sPHENIX EMCal.



pi0/photons etc. detection



ePIC R&D Plans for FY23

- Our plan is to build 4 installation blocks (4 x 4 towers) with improved light collection uniformity and test these at FNAL.
- Continue to work on mechanical integration of ECal into ePIC.
- Perform structural tests (sheer and compressions).
- Make comparison of ‘EIC specs’ Saint Gobain and Kuraray fibers.
- Perform optical/mechanical/electrical integration of readout (with eRD109)

Current Status

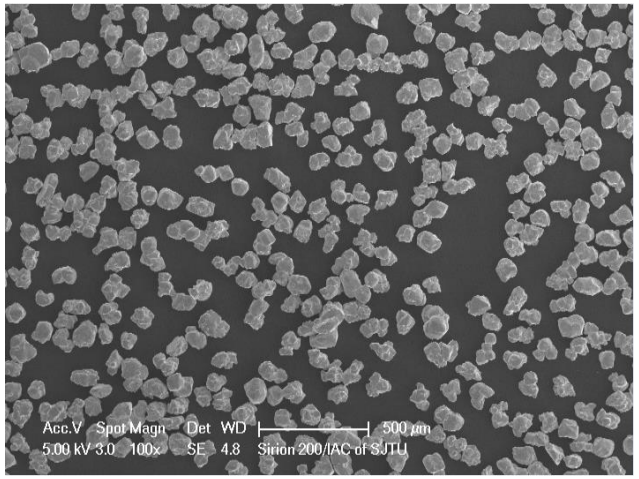
Original schedule presented in October 2022 at DAC meeting. In red shown task that were accomplished or in advanced stage at this moment. Delay in funding and setting of contracts shifted schedule by ~ 6 months.

FY 22 Detailed Schedule

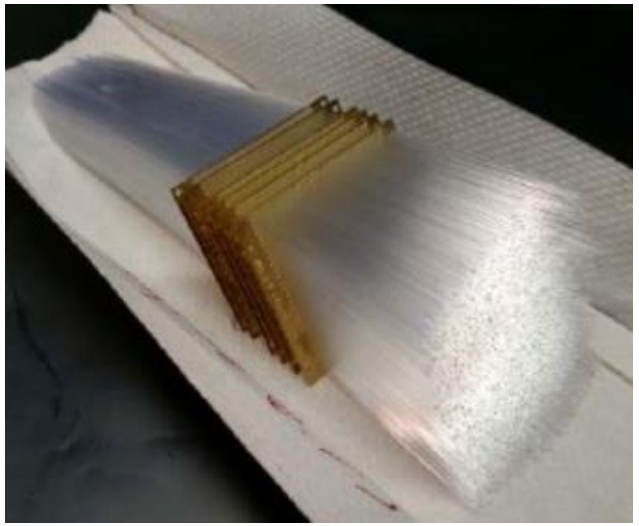
1. Discussion with Fudan group personal to agree on the new production mold/methods and tooling. 12/31/22
2. Comparison of new Bicron BCF-12 Fibers with Kuraray SCSF-78. 1/15/23
3. Assembly of one production block in China from leftover materials 1/31/23.
4. Shear tests complete 3/30/23
5. Acquire Sc. Fibers (all fibers delivered to Fudan) 02/27/23
6. Acquire W Powder (all powder delivered to Fudan) 02/27/23
7. Acquire production meshes and tooling (all meshes and some tooling in Fudan) 02/27/23
8. Iteration on production methods and molding forms finished 03/30/23
9. Start production of blocks for test beam prototype 04/01/23
10. Deliver two production blocks to US for inspections 05/01/23
11. QA first production blocks 05/15/23
12. Perform UV scan to check uniformity LY 05/30/23
13. Deliver all production blocks to US 06/30/23
14. QA Production all blocks done 07/15/23
15. Compression tests complete 7/30/23
16. Mechanical/optical/electrical integration with readout complete 8/15/23
17. Light guides for prototype produced 8/30/23
18. 64 channel prototype ready for integrating readout. 09/30/23
19. Readout electronics for test run, software, MC complete 10/30/23
20. Test Run at FNAL complete 12/15/23.

ePIC-fECal block: key Materials

Tungsten Powder:
Tap density: > 11.2 g/ cm^3
Purity: >99.9%, Fe, Co, Ni <0.1%
Size: 90~110μm
EMCal block desity: ~9.6 g/cm^3



Scintillation Fibers:
Diameter: 0.47±0.01 mm
Emission peak: 430~460 nm
Decay time: 2.5~3.5 ns
Attenuation length:>4m



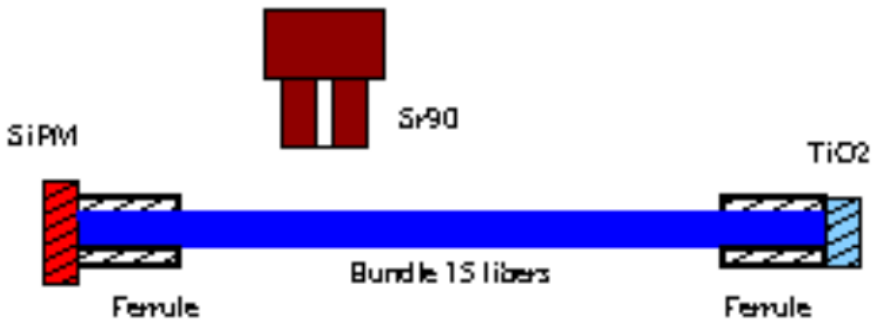
Epoxy
Long term stability
High shear strength
Safe
Cheap

- ✓ De Neef Denepox I-40
- ✓ BONDHUAJU

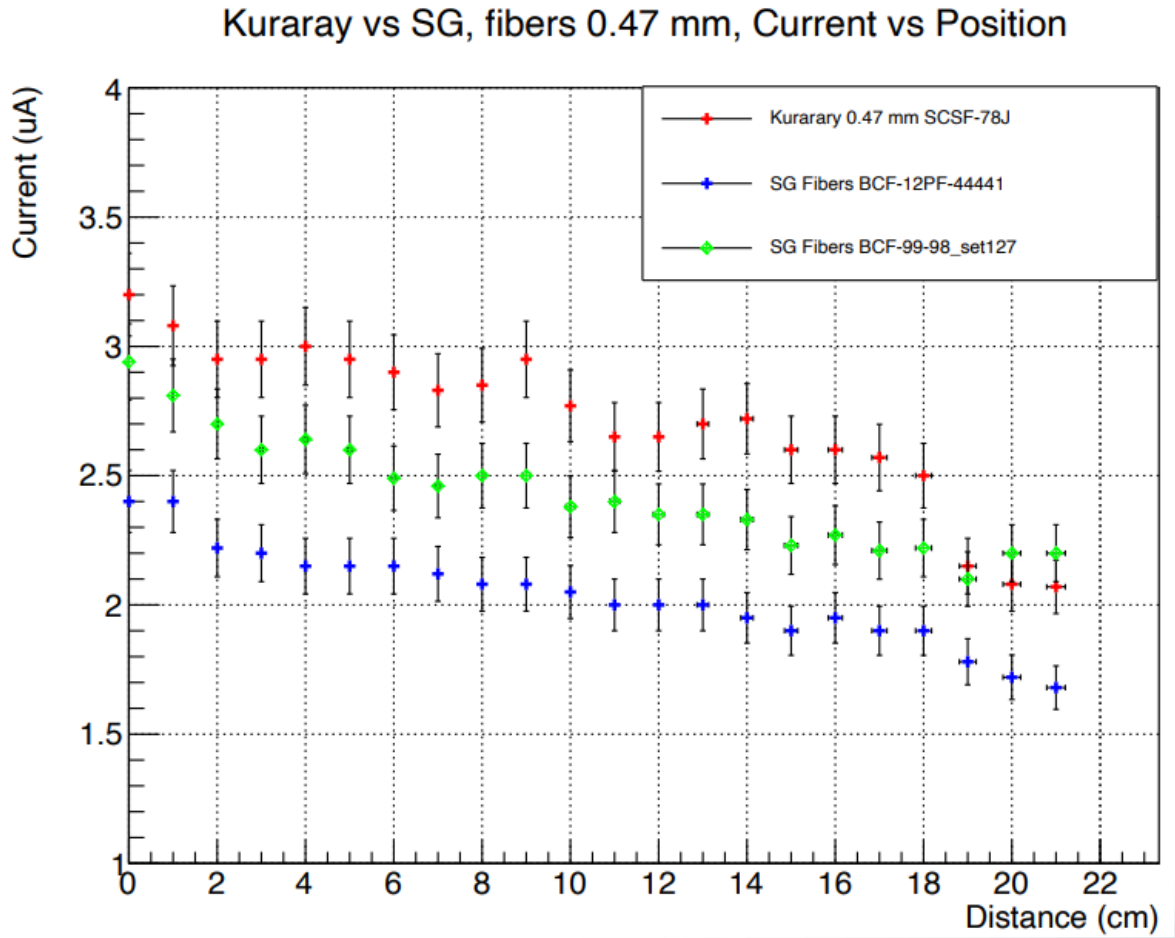
ePIC-fECal block: Scint. Fibers Testing

In the middle of July 2023 we are expecting third and final batch of fibers from Luxium (former Bicron, St.Gobain)
We are expecting Luxium fibers will meet our requirements. Kuraray already there.

Measurements at UCLA of LY for Luxium and Kuraray fibers

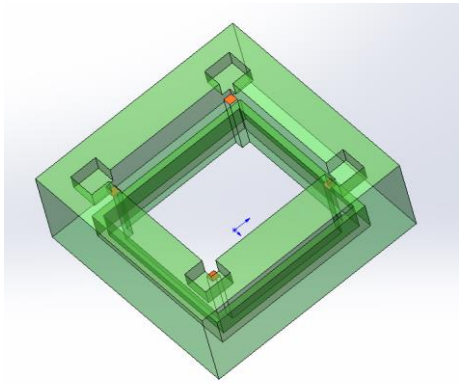


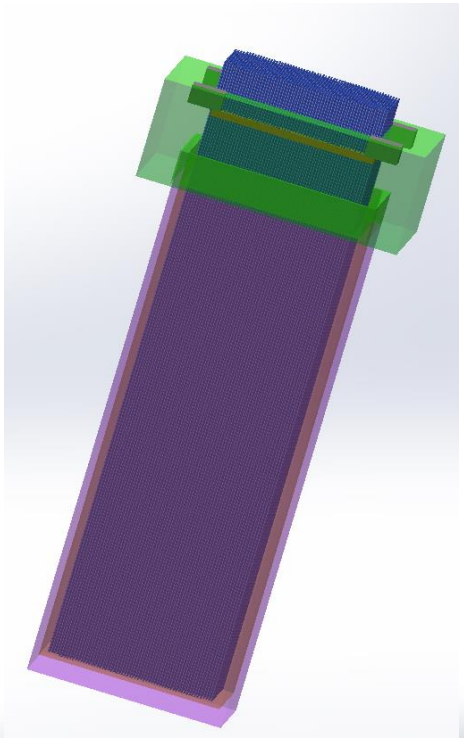
Bundle of fibers readout by same SiPMs, far end with TiO2 diffuser, activated with Sr 90 source



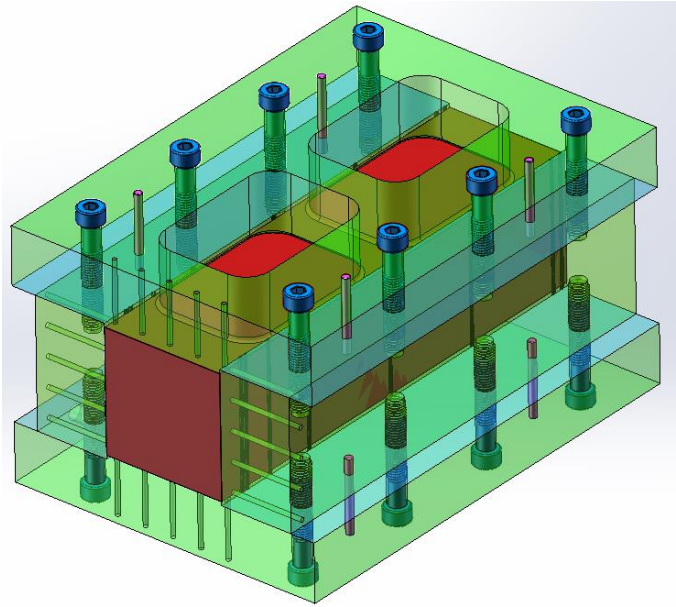
ePIC-fECal block: Fiber filling

- Tools for fiber filling are ready.
- It works well both for meshes and filling.
- 30 min. filling time for the first try.

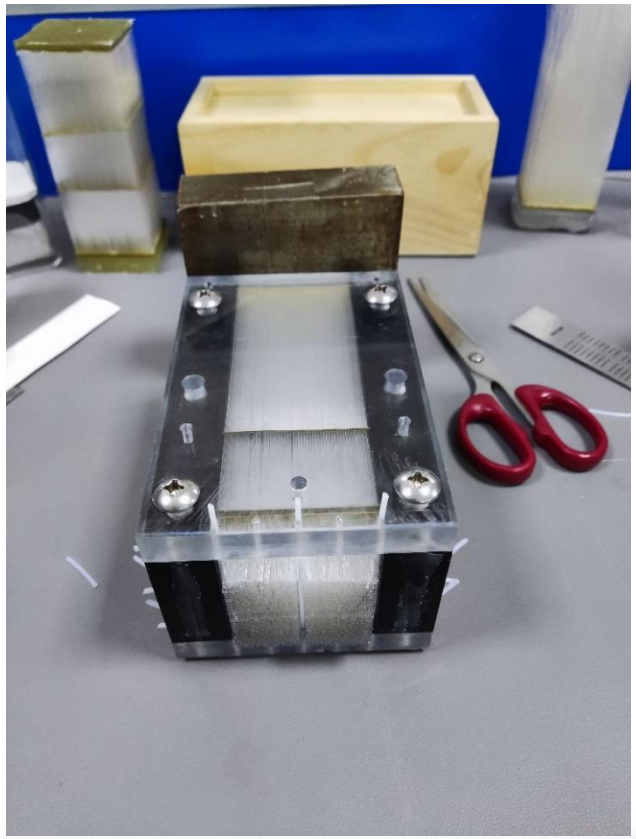


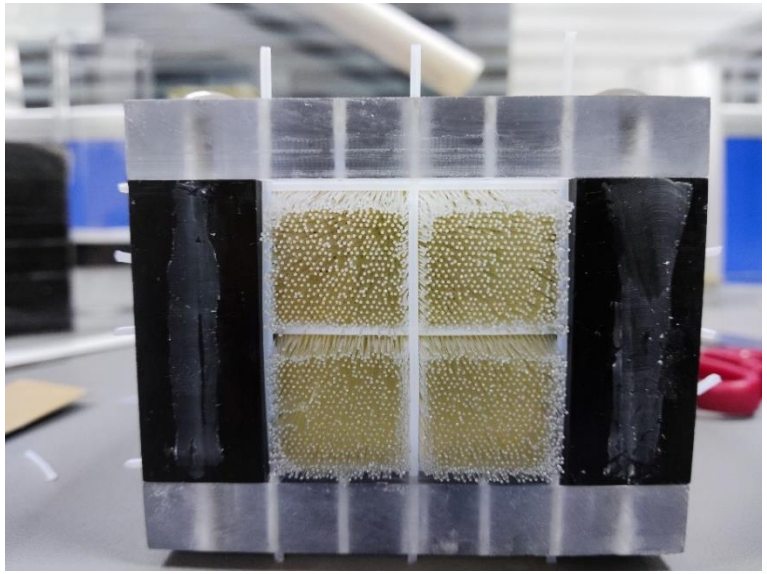


ePIC-fECal block: Mold

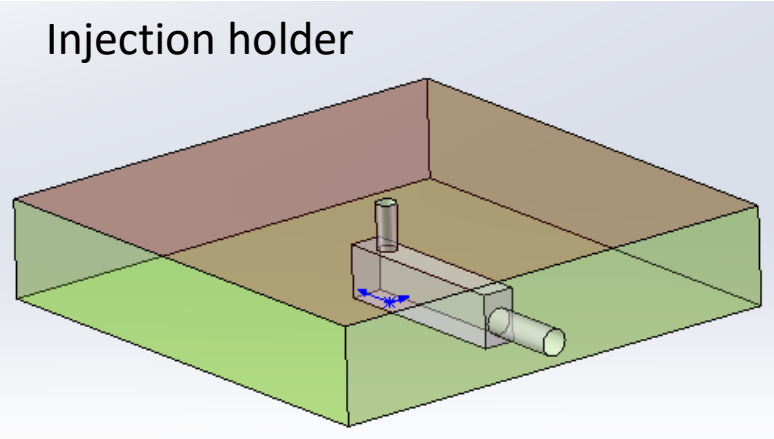


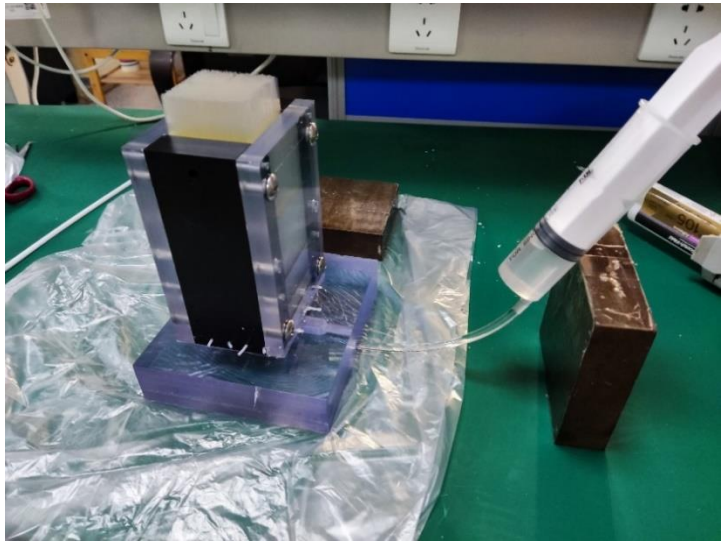
- Tools (screws, dowels, capillary tube, etc) for mold assembly are ready at Fudan.
- It works well for putting the fiber set in the mold.
- New molds are ready.



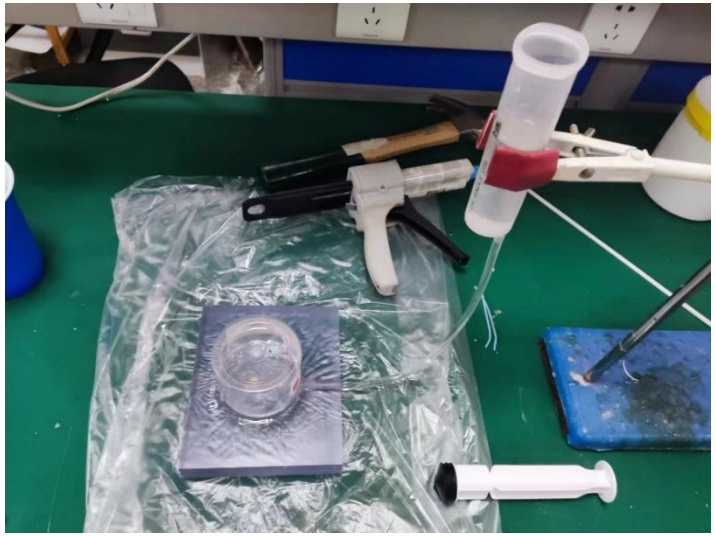


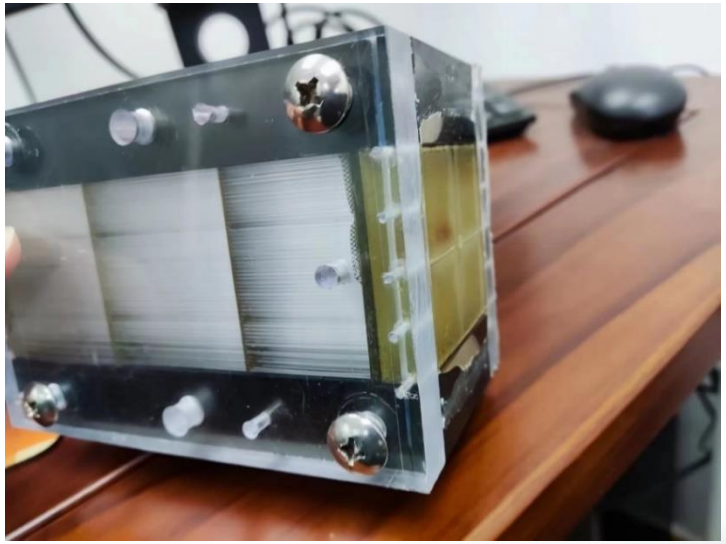
ePIC-fECal block: Epoxy flow test at Fudan





Get rid of bubbles:
Warm and flow slowly

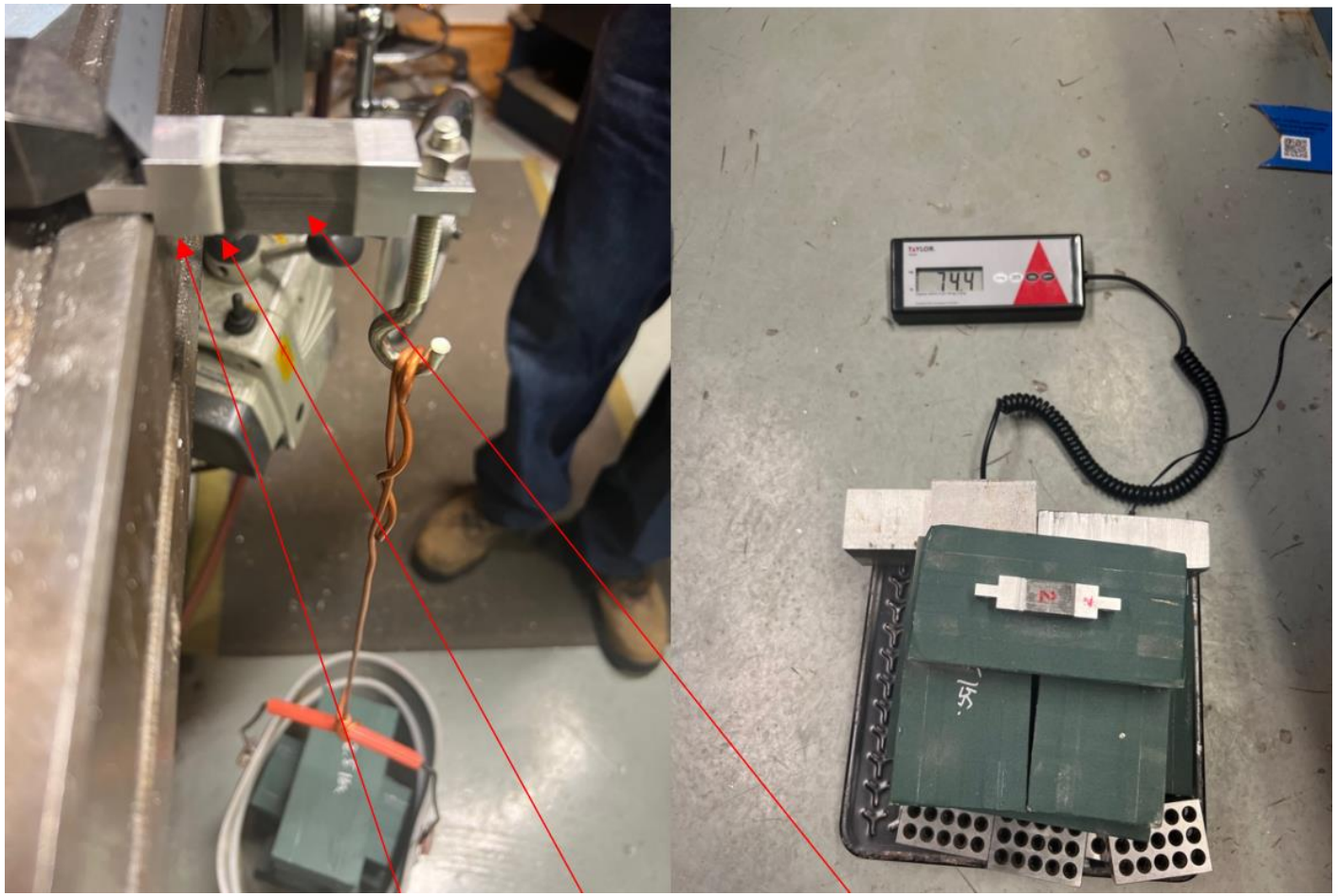




ePIC-fECal block: Shear Tests

Shear tests performed at BNL

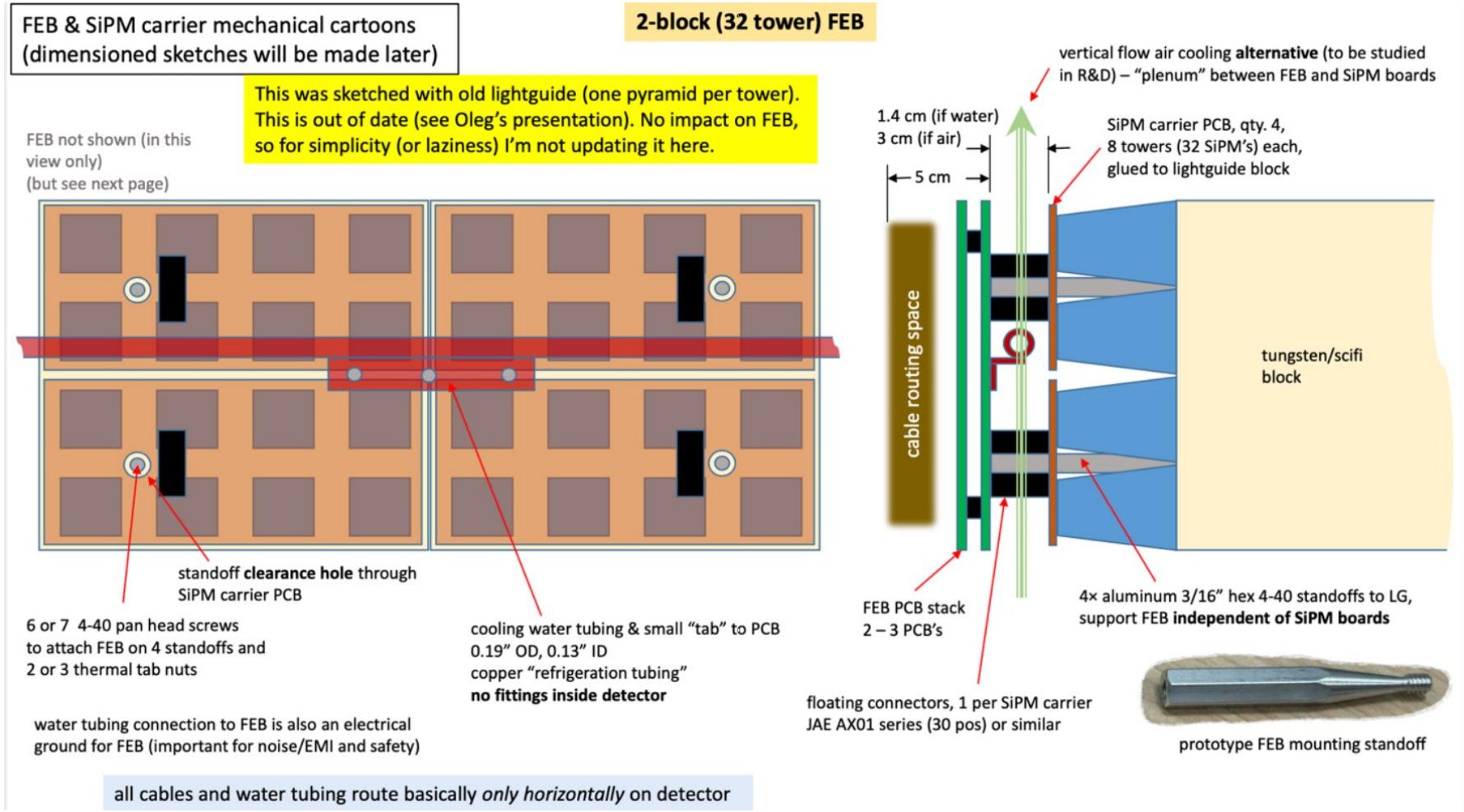
- The purpose of these tests is to measure safety factor for proposed mounting scheme of fECal at the ePIC configuration.
- With the tests performed, a very simple mounting scheme for fECal has been validated. Safety factor is larger than 75.
- Additional tests are being discussed (long term stability).



Al strong back, TiO_2 layer 2 mm thick, WScFi body.

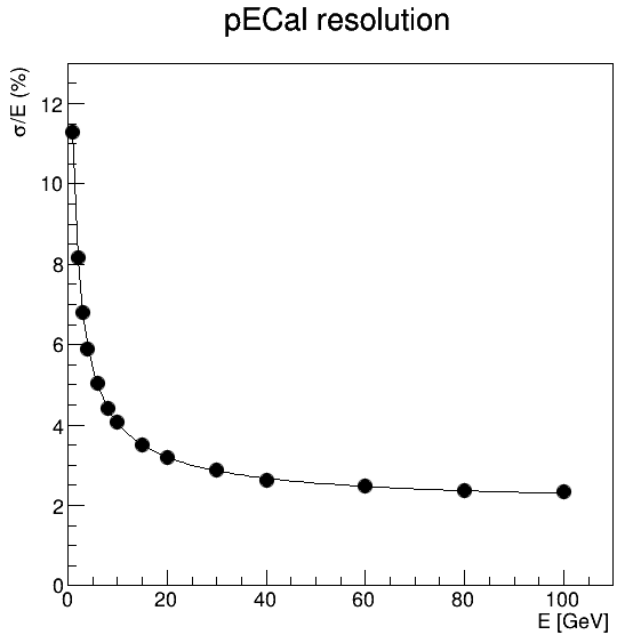
ePIC-fECal: Readout

A mechanical/optical/electrical integration of readout is part of this proposal. This activity is closely coordinated with eRD109 project. Latest integration concept developed by G. Visser (Indiana)



It includes redesigned light guides, FEB, SiPM boards and cooling as well as mounting of readout electronics to fECal installation blocks.

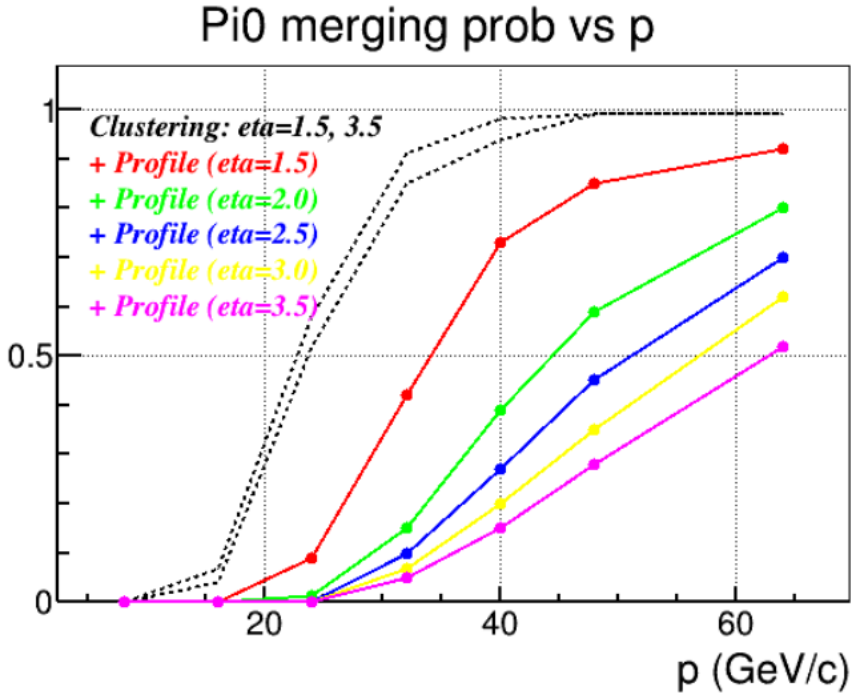
ePIC-fECal: Simulations



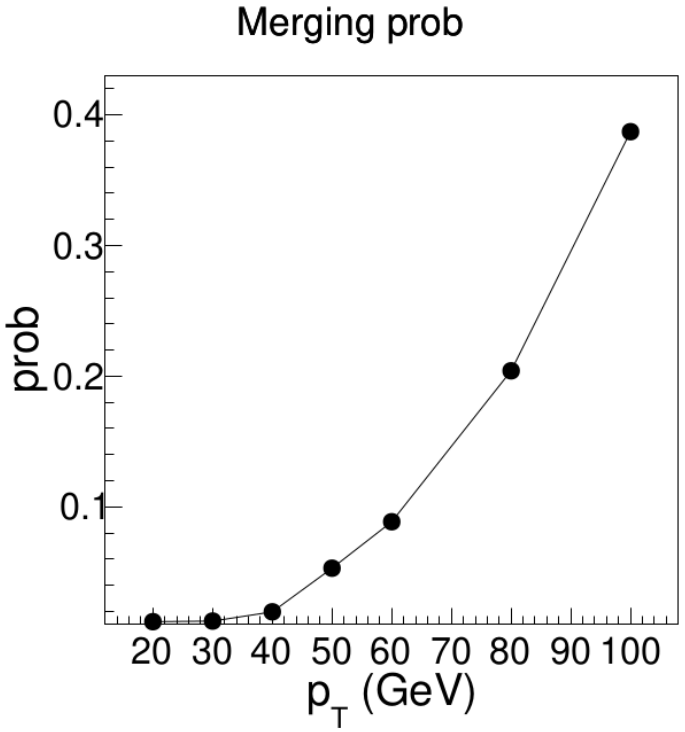
pECal energy resolution for single photon input:

$$\frac{11.2\%}{\sqrt{E(GeV)}} \oplus 2.0\%$$

Pi0 merging rate by shower profile
Figure from EIC YR Fig. 11.46

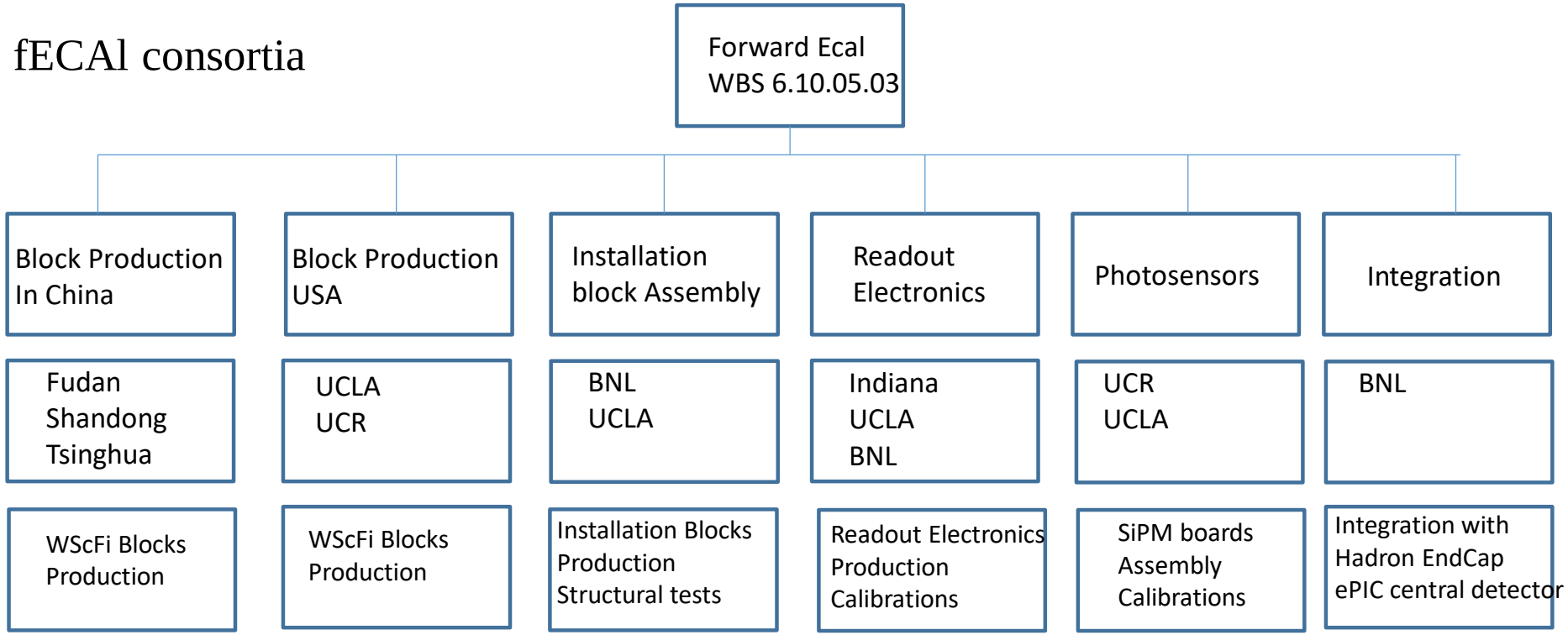


Pi0 merging rate from neural network at η = 2: Comparing with the green curve in the middle



fECal consortia structure, WBS

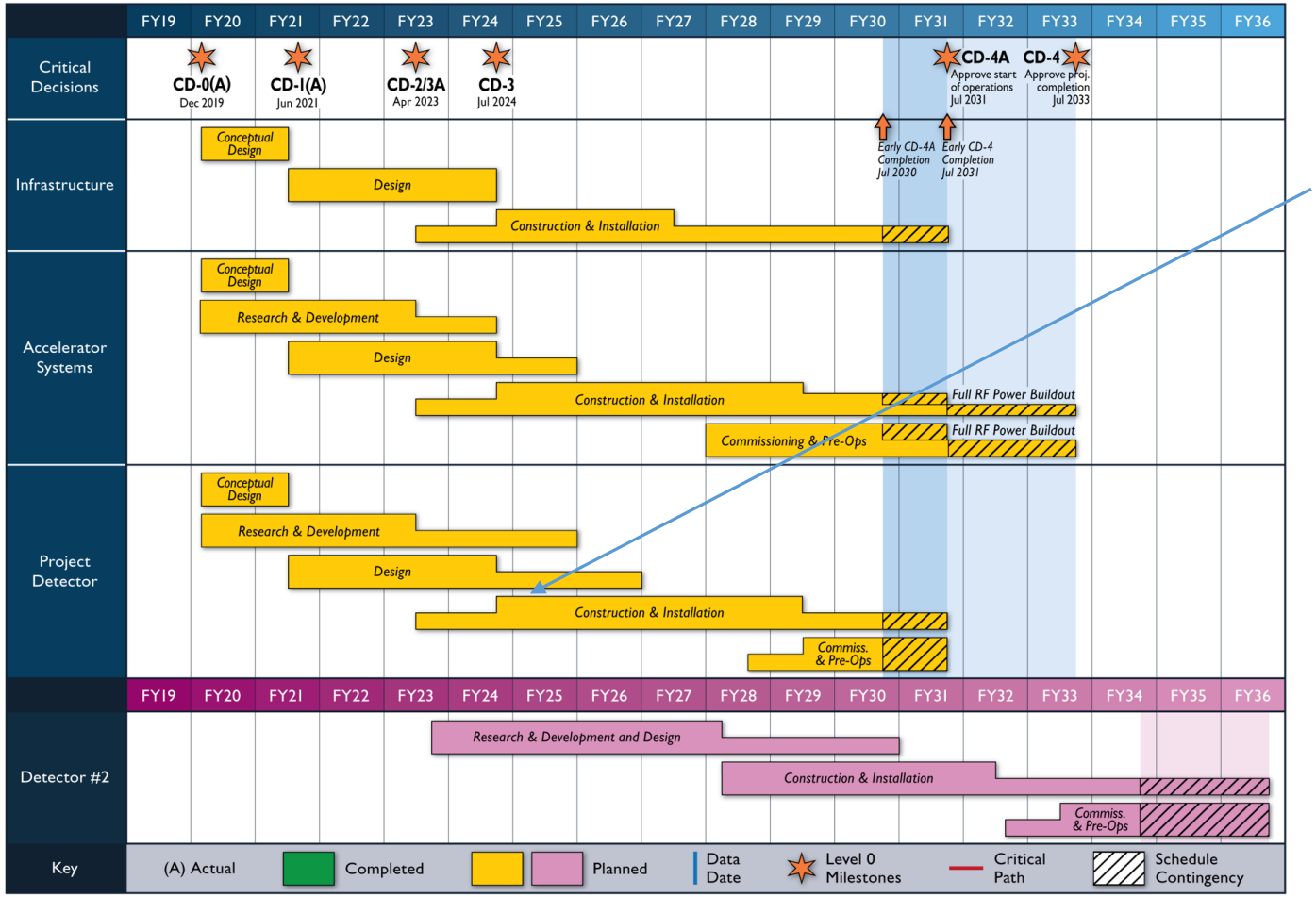
ePIC fECAl consortia



- Chinese fECal Consortium (Fudan University, Shandong University, Tsinghua University)
- University of California EIC Consortium (UCLA, UCR)
- Indian University
- BNL

Groups have extensive expertise and capabilities in executing large scale projects in high energy and nuclear physics experiments around the world. (RHIC, JLab, CERN, Super KEKB).

Production Plan



Post R&D

- Rump up production – 6 month
- Production – 3 years
- Installation 6 months

Enough schedule float.

Assumed, Production sites:

- China – 2/3 production blocks (backup plan is production of all blocks in the US)
- UC EIC (UCLA, UCR) – 1/3 production
- BNL – gluing 2/3 installation blocks and light guides.

Summary

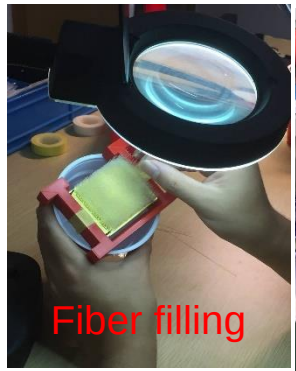
- The structure and plans for fECal are well defined.
- R&D program for two remaining questions is well defined.
- Design of the forward ECal is based on mature technology and is well advanced.
- All participating institutions are committed and are making progress toward prototype production and preparation for full production.
- Workforce is experienced in executing large scale projects (including recently built forward calorimetry systems for STAR and participating in sPHENIX WScFi barrel Ecal construction).
- Participating institutions have extensive capabilities to carry out large scale construction projects.
- Risks understood. Mitigation is part of the project plan.

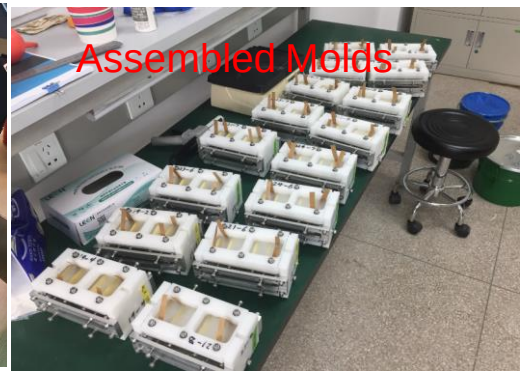
Thanks!

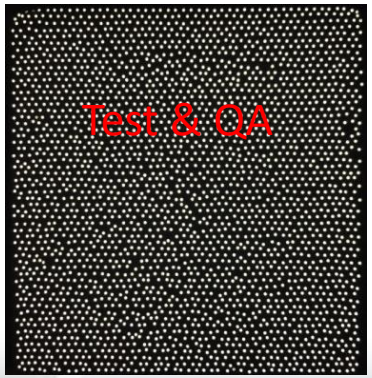
W-powder/ScFi EMCal mass of production at Fudan

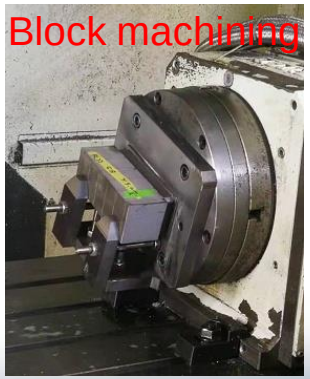
Fudan University has established the infrastructure for the construction of such W-powder/ScFi ECal blocks, including raw material procurement and testing, block production and processing, testing and QA, etc.

sPHENIX EMCal blocks production flow at Fudan:



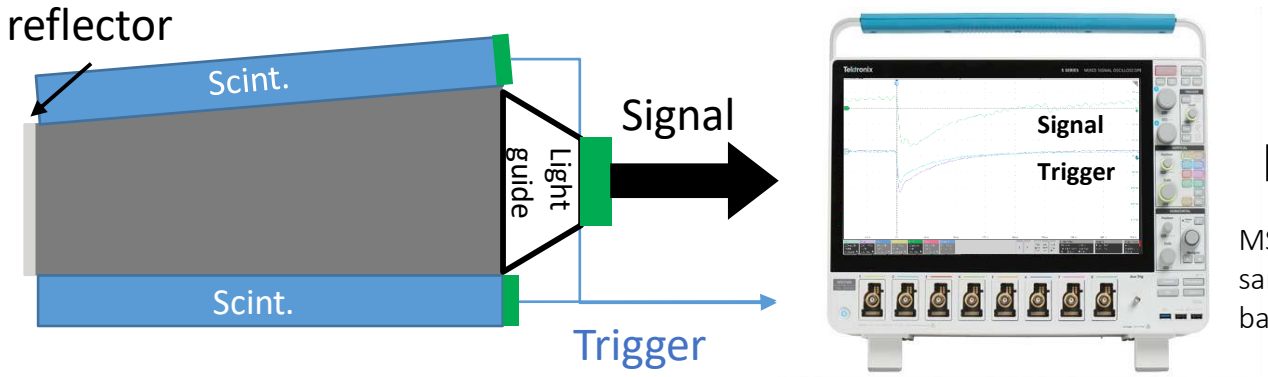


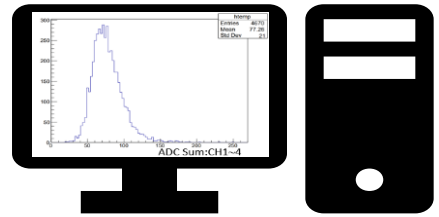




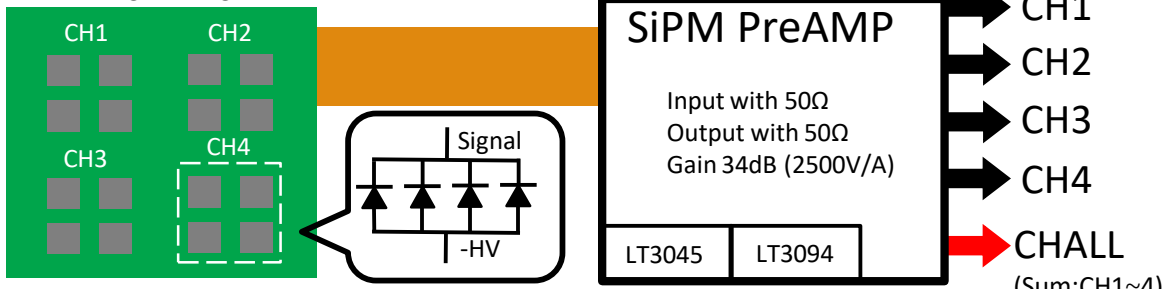
EMCal block Scintillation and Cosmic ray test at Fudan

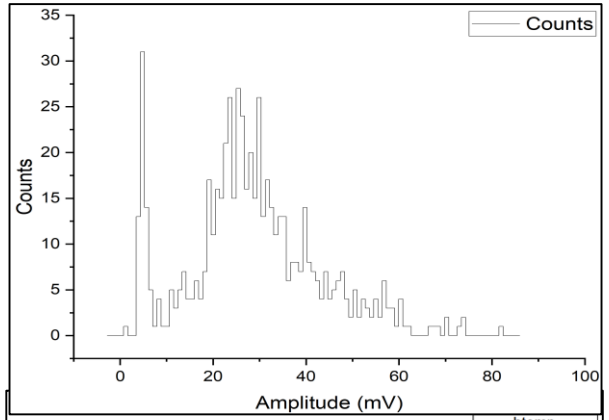
Xiyang Wang

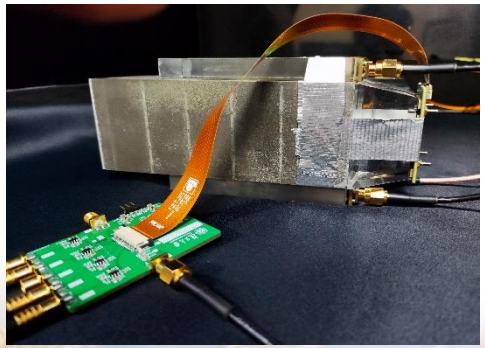


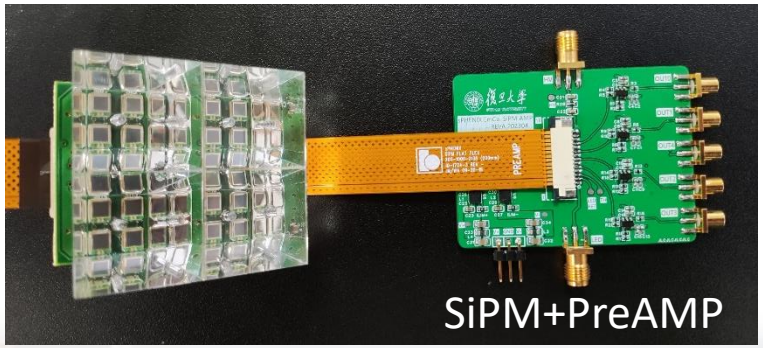


SiPM: S12572 (Hamamatsu)
4 × 4: 3mm×3mm



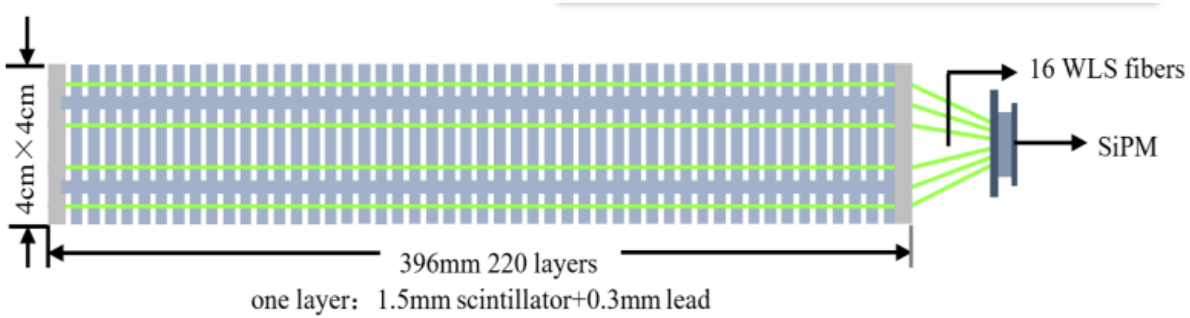


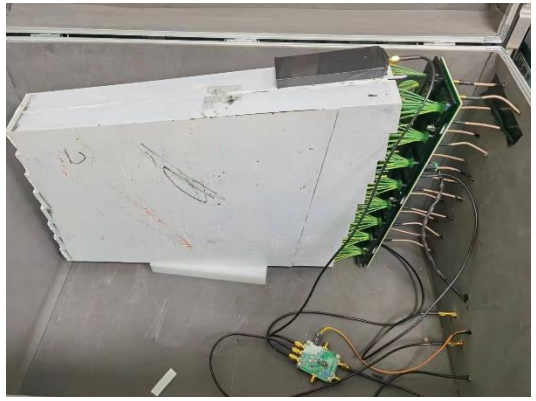


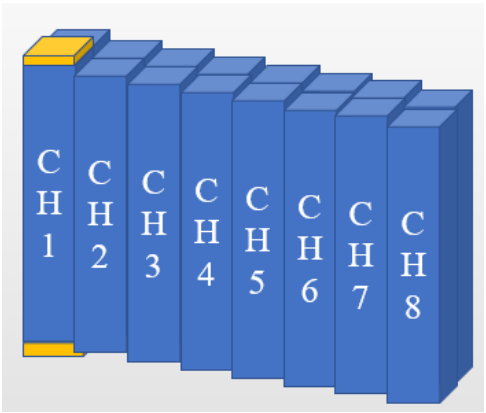


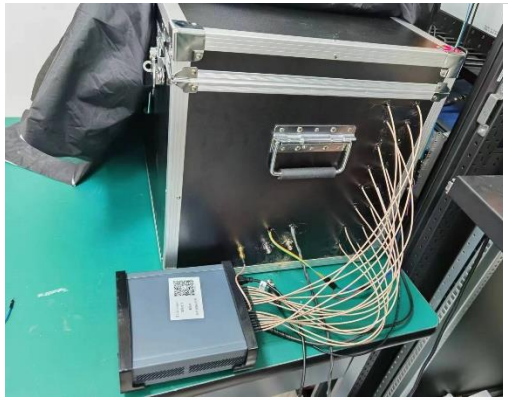
Pb/Sc Shashlyk EMCal modules production at Fudan

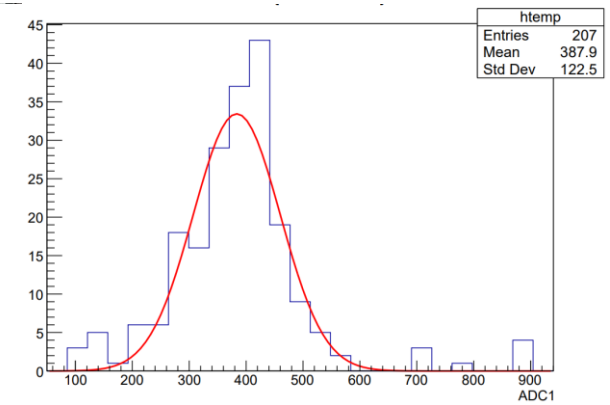
Fudan group has also experienced in producing and testing Pb/Sc Shashlyk EMCal modules with advanced standards and complete facilities.











Nuclear physics Group at Shandong University

- The SDU group is currently working with RHIC-STAR experiment, and has been focusing on the nucleon spin structure and the heavy ion physics.
- We made the MWPC modules the inner TPC (iTPC) upgrade at STAR, also produced the small-strip Thin Gap Chamber(sTGC) for the forward tracking upgrade at STAR. We are a key part of EMCal R&D program for SOLID at Jlab.
- Pb/Sc Shashlyk EMCal modules production.

Shashlyk prototyping

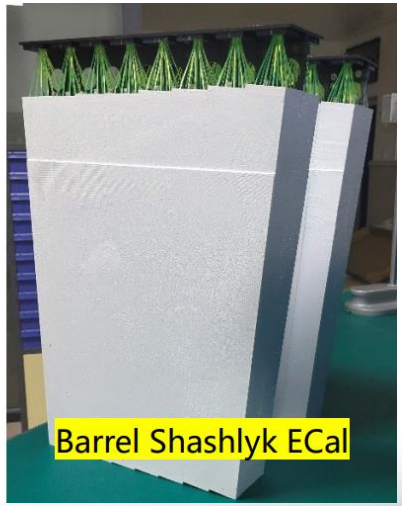
Front End Board for SiPM-based Ecal

CNC center

Nuclear physics Group at Tsinghua University

- The Tsinghua group is currently working on multiple experimental projects at Jefferson Lab (Hall-A, B, C, SoLID) and RHIC-STAR experiment. Our major physics interests are on the hadronic structure of nucleons, e.g., spin, PDF, TMD, GPD, as well as the nuclear structure of nuclei, e.g. SRC & EMC effect, asymmetric energy, equation of states, critical points etc
- Tsinghua has extensive experience in developing the Shashlyk Ecal and the highresolution sealed MRPC. We constructed MRPCs for RICH-STAR, GSI-CBM and CSRCEE. We are leading or heavily involving in the R&D efforts for SoLID and US-EIC.

SoLID Shashlyk Ecal Beam Test at JLab



Barrel Shashlyk ECal