Simulation and Construction of Shashlyk-Type Ecal for the EIC

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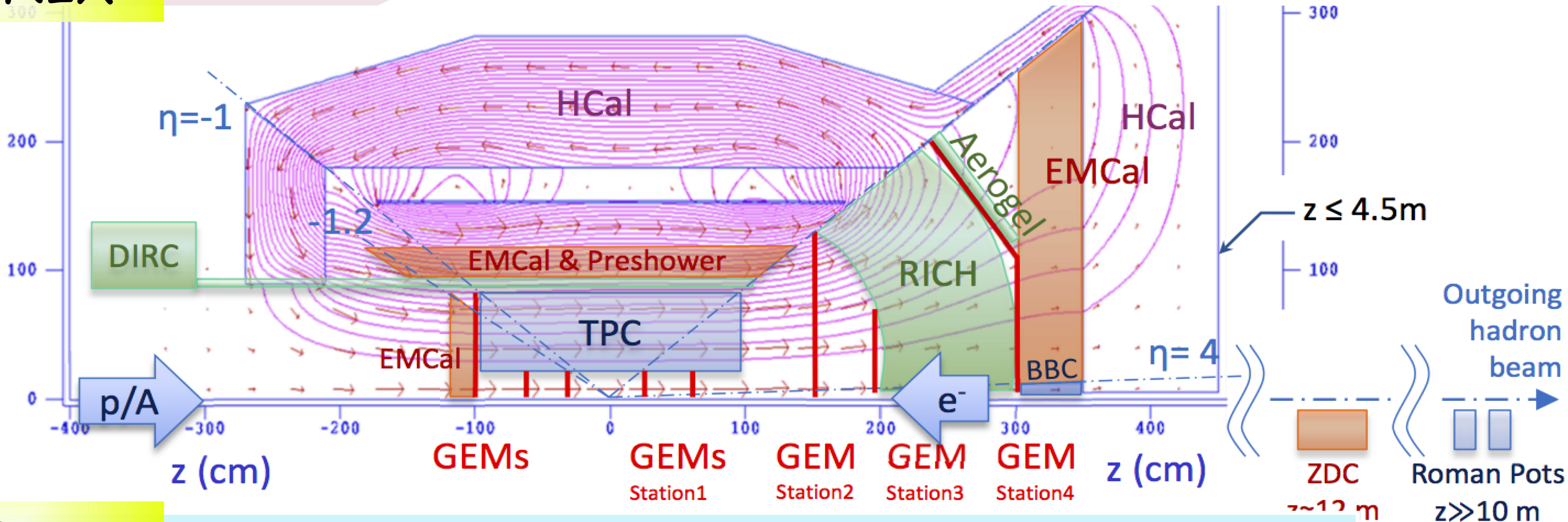
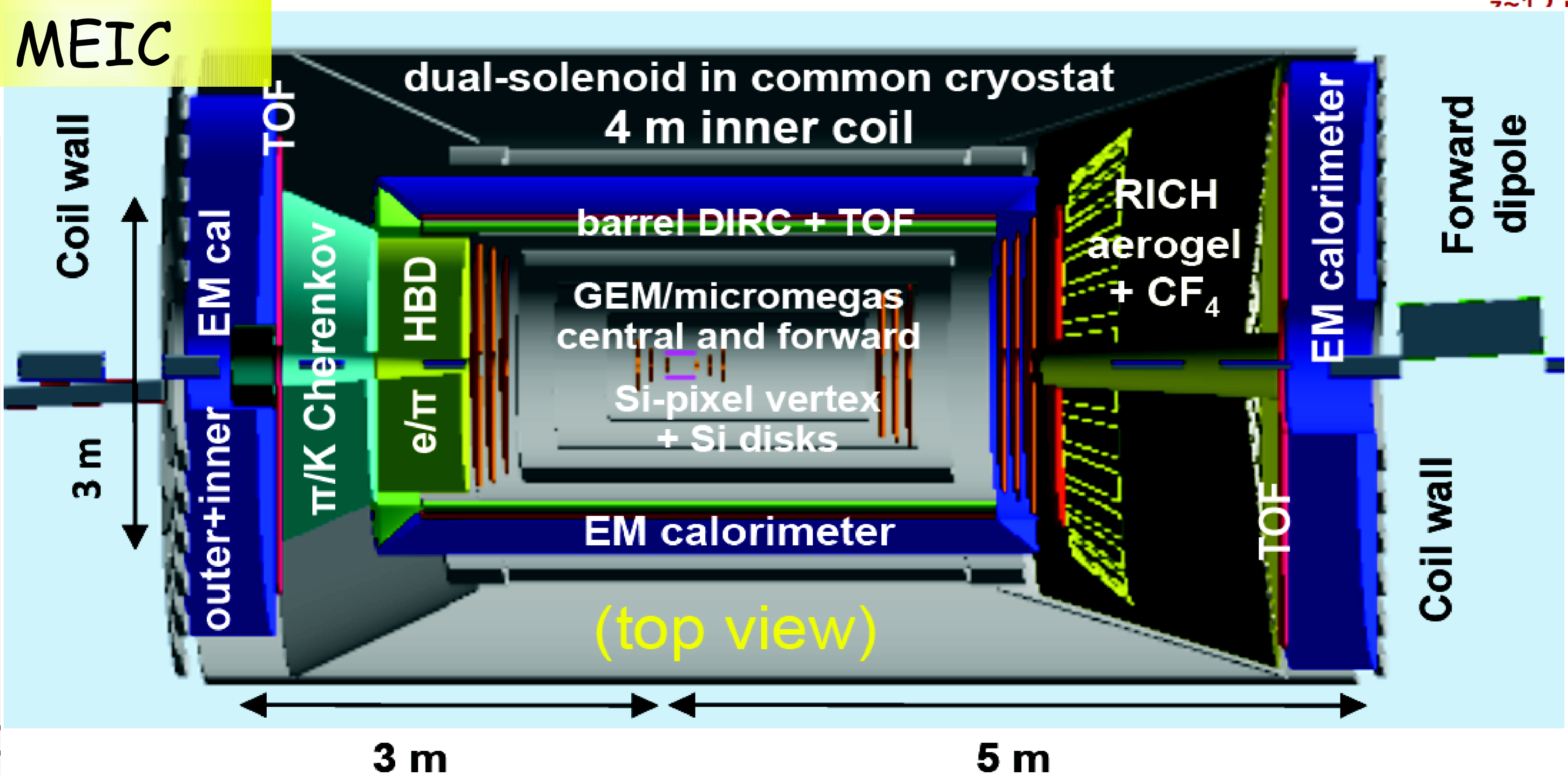
Material	ρ g/cm^3	X_0 cm	R_M cm	λ_I cm	n refrac.	τ ns	peak λ nm	light yield	Npe /GeV	rad	$\delta E/E$
						Crystals					
NaI(Tl)	3.67	2.59	4.5	41.4	1.85	250	410	1.00	10^6	10^2	$1.5\%/E^{1/2}$
CsI	4.53	1.85	3.8	36.5	1.80	30	420	0.05	10^4	10^4	$2.0\%/E^{1/2}$
CsI(Tl)	4.53	1.85	3.8	36.5	1.80	1200	550	0.40	10^6	10^3	$1.5\%/E^{1/2}$
BGO	7.13	1.12	2.4	22.0	2.20	300	480	0.15	10^5	10^3	$2\%/E^{1/2}$
PbWO4	8.28	0.89	2.2	22.4	2.30	15/60%	420	0.013	10^4	10^6	$2.0\%/E^{1/2}$
LSO	7.40	1.14	2.3		1.81	40	440	0.7	10^6	10^6	$1.5\%/E^{1/2}$
PbF2	7.77	0.93	2.2		1.82	Cher	Cher	0.001	10^3	10^6	$3.5\%/E^{1/2}$
						Lead glass					
TF1	3.86	2.74	4.7		1.65	Cher	Cher	0.001	10^3	10^3	$5.0\%/E^{1/2}$
SF-5	4.08	2.54	4.3	21.4	1.73	Cher	Cher	0.001	10^3	10^3	$5.0\%/E^{1/2}$
SF-57	5.51	1.54	2.6		1.89	Cher	Cher	0.001	10^3	10^3	$5.0\%/E^{1/2}$
						Sampling: lead/scintillator					
SPACAL	5.0	1.6				5	425	0.3	2×10^4	10^6	$6.0\%/E^{1/2}$
Shashlyk	5.0	1.6				5	425	0.3	10^3	10^6	$10\%/E^{1/2}$
Shashlyk(K)	2.8	3.5	6.0			5	425	0.3	4×10^5	10^5	$3.5\%/E^{1/2}$

Ecal Needs for EIC

ePHENIX



MEIC



Ecal Needs for EIC

1. Central Ecal: need 12%/sqrt(E), need to be radially compact (25cm), current top choice is W-scifi, does not need to be projective for EIC but have to be projective for heavy ion physics at sPHENIX;
2. Electron-direction Ecal: need (1-2)%/sqrt(E) for inner radial region, top choice is crystal; (5-6)%/sqrt(E) for outer radial region.
3. Hadron-direction Ecal: need (12-15)%/sqrt(E) for ePHENIX or (5-6)%/sqrt(E) for MEIC

Possible Use of Shashlyk Ecal for EIC

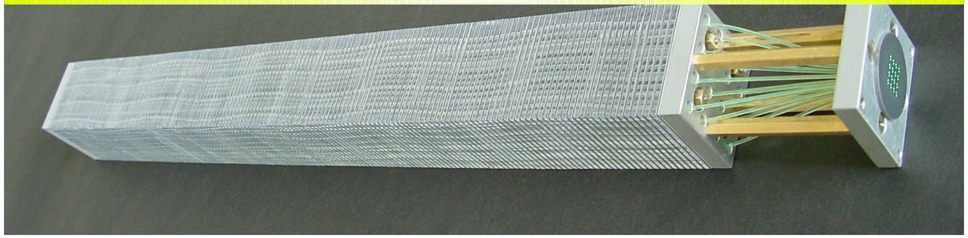
1. Central Ecal: need 12%/sqrt(E), need to be radially compact (25cm), current top choice is W-scifi, does not need to be projective for EIC but have to be projective for heavy ion physics at sPHENIX; (– need to study if shashlyk is possible?)

2. Electron-direction Ecal: need (1-2)%/sqrt(E) for inner radial region, top choice is crystal; (5-6)%/sqrt(E) for outer radial region – shashlyk may be the best choice.

3. Hadron-direction Ecal: need (12-15)%/sqrt(E) for ePHENIX or (5-6)%/sqrt(E) for MEIC – shashlyk may be the best choice.

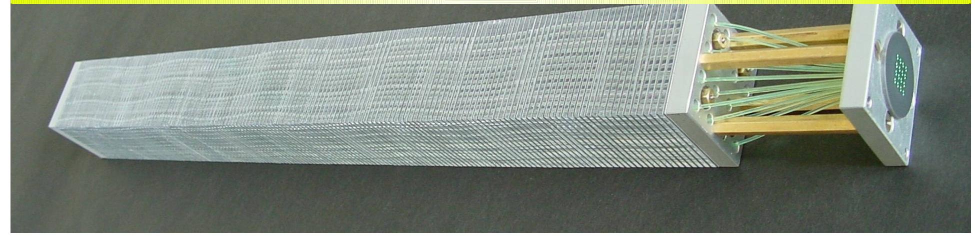
for electron- and hadron-direction Ecals, projective shape is not required, but will help with performance.

IHEP, COMPASS Shashlik, 2010



Our Focus for the first year

IHEP, COMPASS Shashlik, 2010



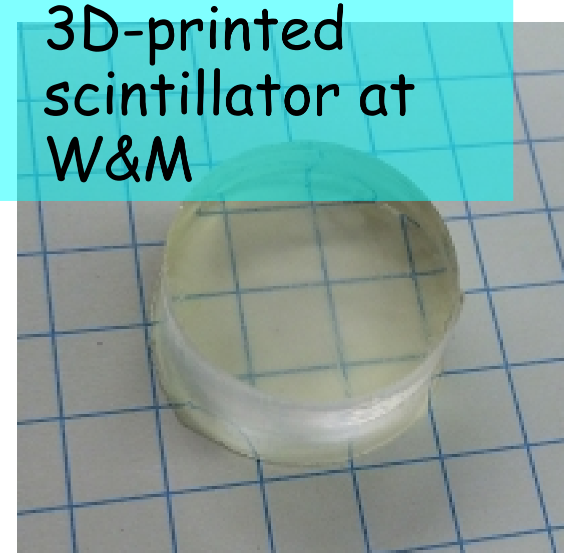
- Study preliminary design of shashlyk Ecals for EIC's outer electron and hadron Ecals, look into central Ecals.
- Look into possible re-use of existing or planned Shashlyk modules for EIC
- To gain knowledge and hands-on experience with testing shashlyk module components, with potentially innovative components

Snapshots of shashlyk technology:

- Technology relatively mature, but construction expertise is dominated by IHEP&ITEP (Russia). Only a couple of US groups have constructed Shashlyk modules before (e.g. ALICE — Wayne State U., U. of Iowa)
- scintillator parts by injection molding and lead sheets by stamping, mold and tooling cost ~$45k, dominate prototyping cost
- difficult to construct projective-shape modules
- requires intensive manual labor during assembling process

The "New" Component — 3D Printing

- Three existing 3D printing methods:
  - Fused Deposition Modeling or FDM (common, low cost), using plastic filaments
  - Resin-printing ("Polyjets", less common, higher cost), print with int/compound/resin then cured to solid by UV light or laser
  - metal printing ("binder-jet" or sintering with laser/beam, rare, expensive)
- Polyjet-printing scintillators has already been experimented by several groups: G. Ron (Hebrew U.), W. Deconinck (W&M)
  - Published results show plausible light yield, but need more study
  - Also need data on optical transparency, mechanical strength, stability, radiation hardness
- Potentials of 3D printing:
  - fast and cost-effective prototyping;
  - "easy" construction of projective shape modules;
  - possible simplification of assembly process.



3D-printed scintillator at W&M

Test Plan for the First Year

- Obtain 3D-printed scintillator samples from Stratasys(Isarel), or made in-house at W&M
- Study light yield, transparency, mechanical properties (compressive strength, shear strength, Young's modulus, shear modulus), radiation hardness → revise compound and iterate
- *[Many of these studies are valuable for shashlyk module construction (quality screening of parts) regardless of whether 3D-printed sci works]*
- Will also study 3D-printed light guides using t-glase (a commercially available "optical quality" material)

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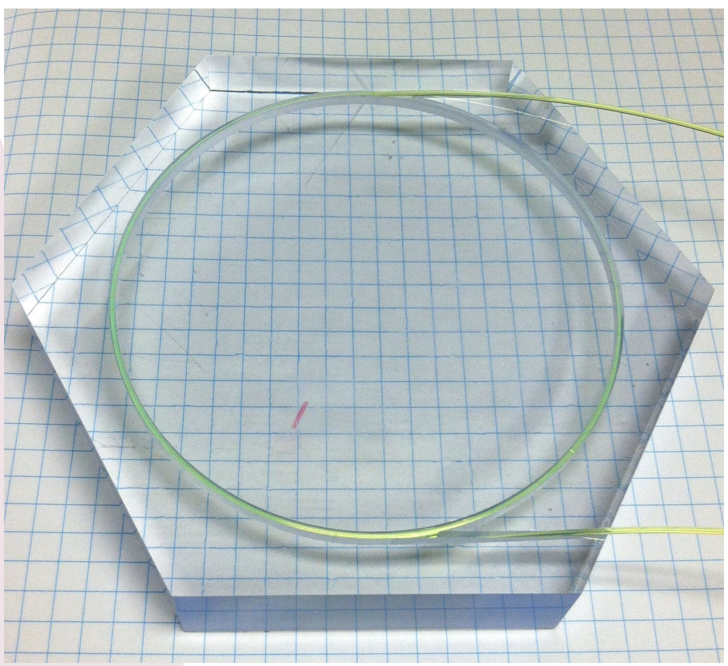
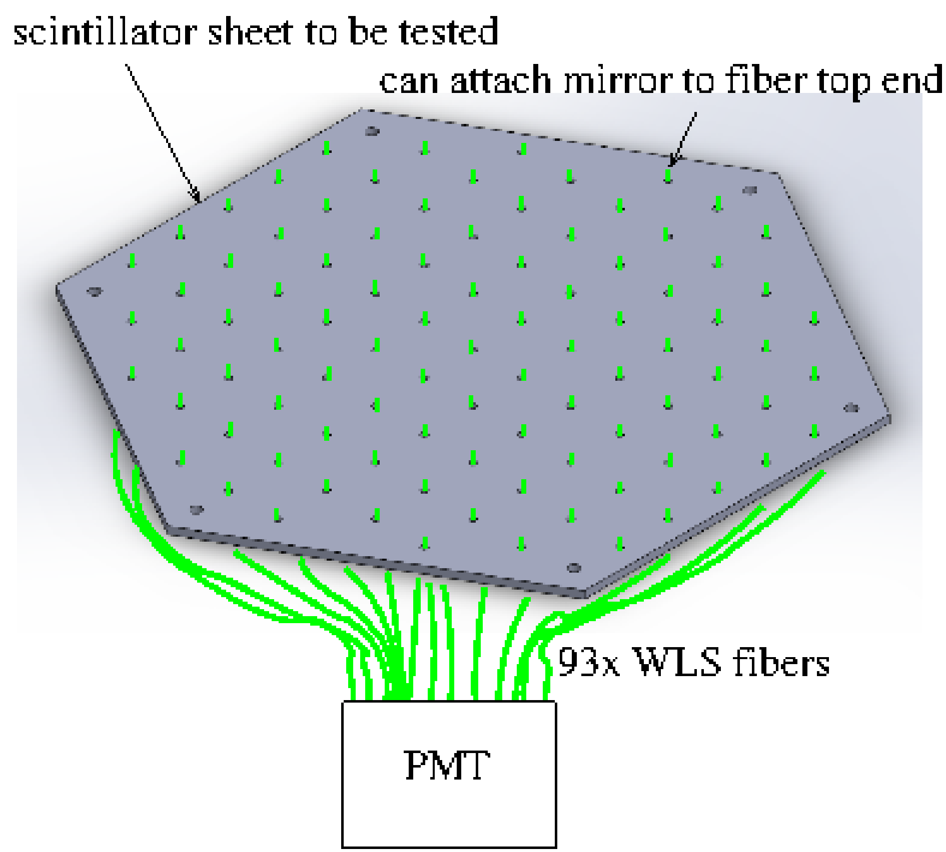
Test Plan for the First Year

- For mechanical testing: simple shape first, then shashylk components

- SoLID Preshower samples 20-mm (regular scintillator) tested at UVa, 2 vendors/bases – polysterene, phenylethene; will also test PVT-based



- Shashlyk components (1.5mm)



Budget

Item	cost
5 Eljen EJ-205 shashlyk sheets	\$1,570
5 Beijing HE-Kedi shashlyk sheets	\$1,000*
10 lead layers (Kolgashield) for the combined mechanical test	\$800
Simple-shape scintillators as references (Eljen)	\$1,000*
Light guides as references (Eljen)	\$1,000*
Two scintillator bars (Eljen) for triggering the cosmic test	\$1,400
Readout PMTs for the cosmic test (2 R11102)	\$800
Other material and supply	\$2,000
Travel	\$1,000
One quarter postdoc support (incl. 28% F.B.)	\$17,910
Graduate student, one-half A.Y. stipend	\$19,158/2=\$9,579
Total Request (direct only)	\$38,059
Total Request (including 58% UVa F&A cost)	\$60,133

- The postdoc will focus on simulation/design, lead the radiation hardness test, and guide the graduate student;
- From other UVa resource: FDM/t-glase for printing light guides; make Tungsten-filled FDM filament for printing absorber sheets.

Future Plan

- Prototyping for EIC's Shashlyk Ecal and test its performance, but whether 3D printing can be used will depend on results from the first year.