EEEMCal CUA R&D Activities

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Current collaboration with: A.I. Alikhanyan National Science Laboratory/Yerevan, IJCLab Orsay/France, INFN/Italy, Jefferson Laboratory, MIT, Brookhaven National Laboratory, Caltech

Plans for FY21 and beyond

From EIC eRD1 presentation July 2020

FY21 Focus Areas

- ❑ Crystal/glass characterization and a prototype beam test program to establish ~20 X_0 glass performance and iterate formulation/fabrication as needed
- ❑ Simulations in support of the prototype tests and configuration of the electron endcap calorimeter - exploration of glass for the barrel EMCal and HCals

FY21 Milestones

- ➢ Fabricate additional ~10X_0 glass bars and demonstrate ~20 X_0 glass bar
- ➢ Further develop and commission readout software and simulations
- ➢ Construct a 3x3 glass/crystal prototype (~10 X_0 and/or ~20 X_0)
- ➢ Carry out a prototype beam test program
- ➢ Evaluate optimal reflector choice for the calorimeter
- ➢ Evaluate impact of mechanical structure, e.g. carbon fibre on resolution

- ➢ SBIR/STTR proposals for glass development and large scale production
  - Phase 2 for scintillating glass for EM calorimeters
  - New Phase 1: glass for hadronic calorimeters

Overall goal: reach a level for crystals/glass to be considered as active material for EIC electromagnetic calorimeters

What was achieved so far

- ❑ Continue working with vendors on crystal/glass
  - ➢ **Characterized additional Crytur crystals (expect total 900-1100 crystals)**

- ❑ Produce larger glass samples – fabrication method
  - ➢ **Initial scale-up completed successfully**
  - ➢ **Can reliably produce several 2cm x 2cm x ~10X_0 glass blocks per week**
  - ➢ **Fabricated first block of 2cm x 2cm x ~10-20X_0**

- ❑ Prototype beam test program - validation
  - ➢ **Results from initial tests in 2020**
  - ➢ **Planning prototype tests including SRO in summer/fall 2021 in Hall D at JLab**

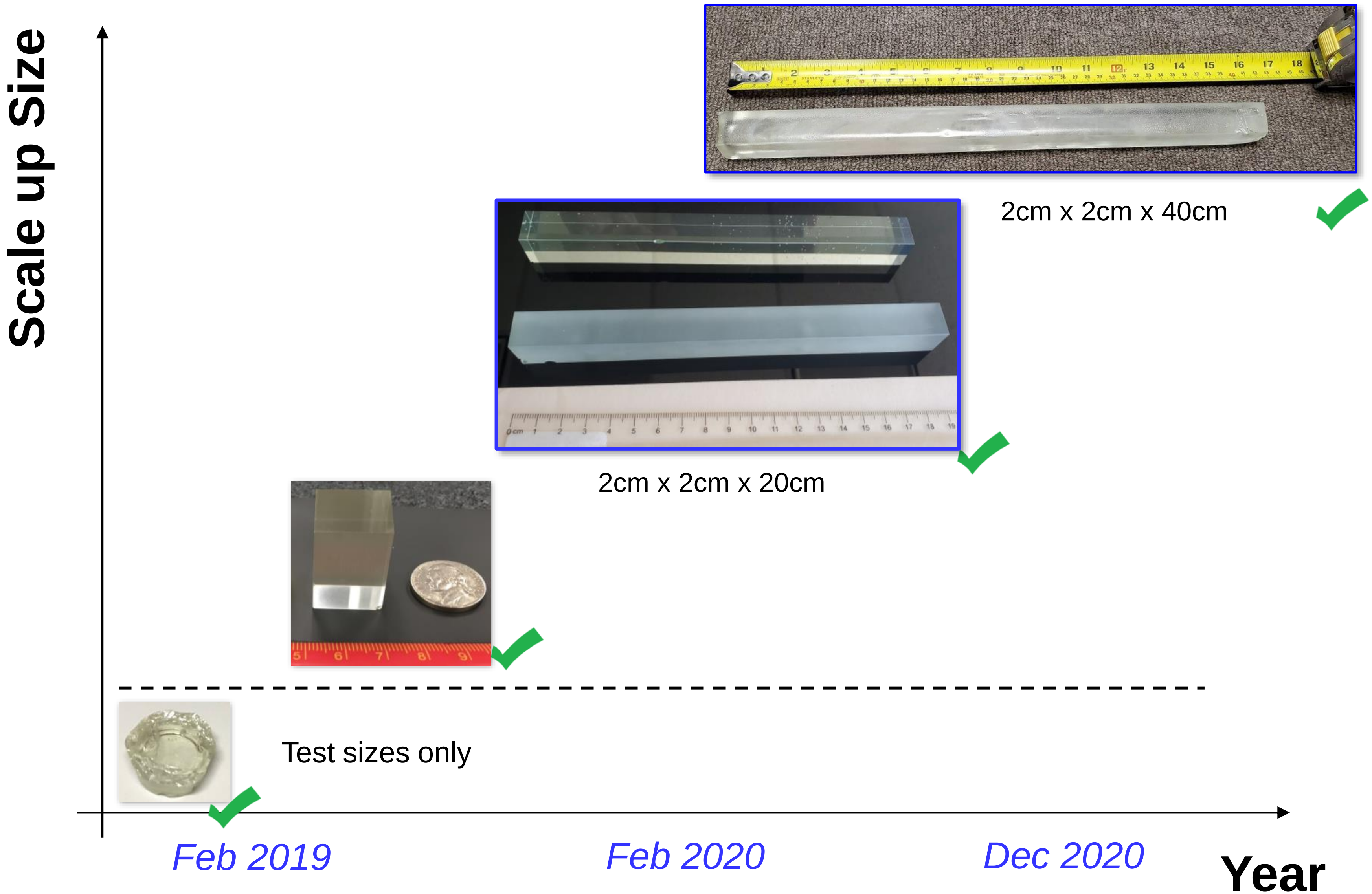
- ❑ GEANT4 simulations for optimization and extension to other regions

- ❑ Submitted SBIR/STTR Phase 2 SciGlass and Phase 1 CSGlass proposals

SCINTILEX

Glass Scintillator Scale-Up 2020

SCINTILEX



Energy Resolution – simulation and initial beam test 2020

20cm long SciGlass (~7X0)

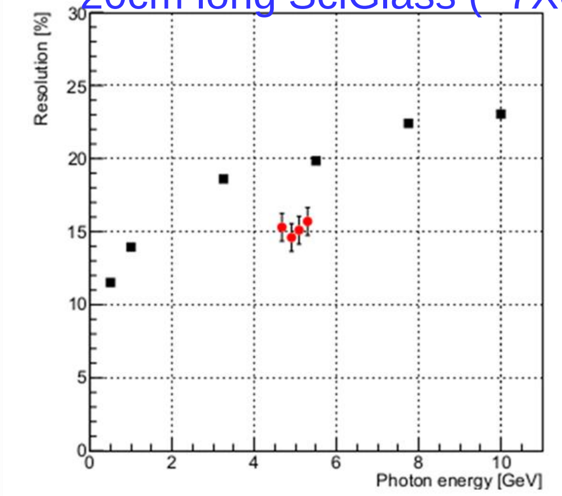


Figure 11: Preliminary energy resolution results from the beam test (red squares) and simulation projections (black)

SciGlass (~15-20X0)

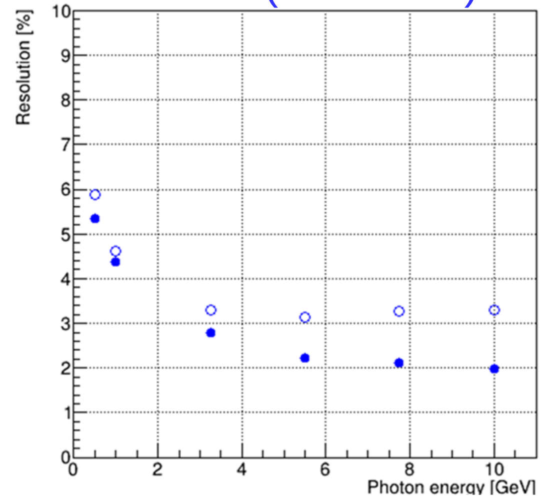
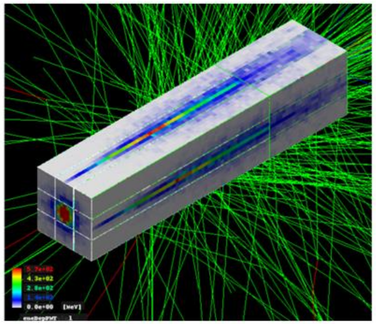
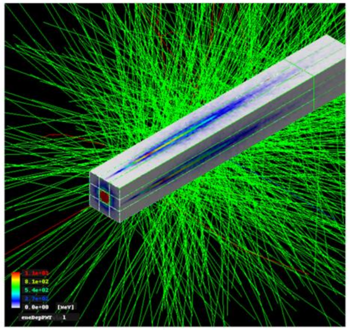


Figure 14: Simulation results for energy resolution of SciGlass blocks of 40cm and 50cm lengths.

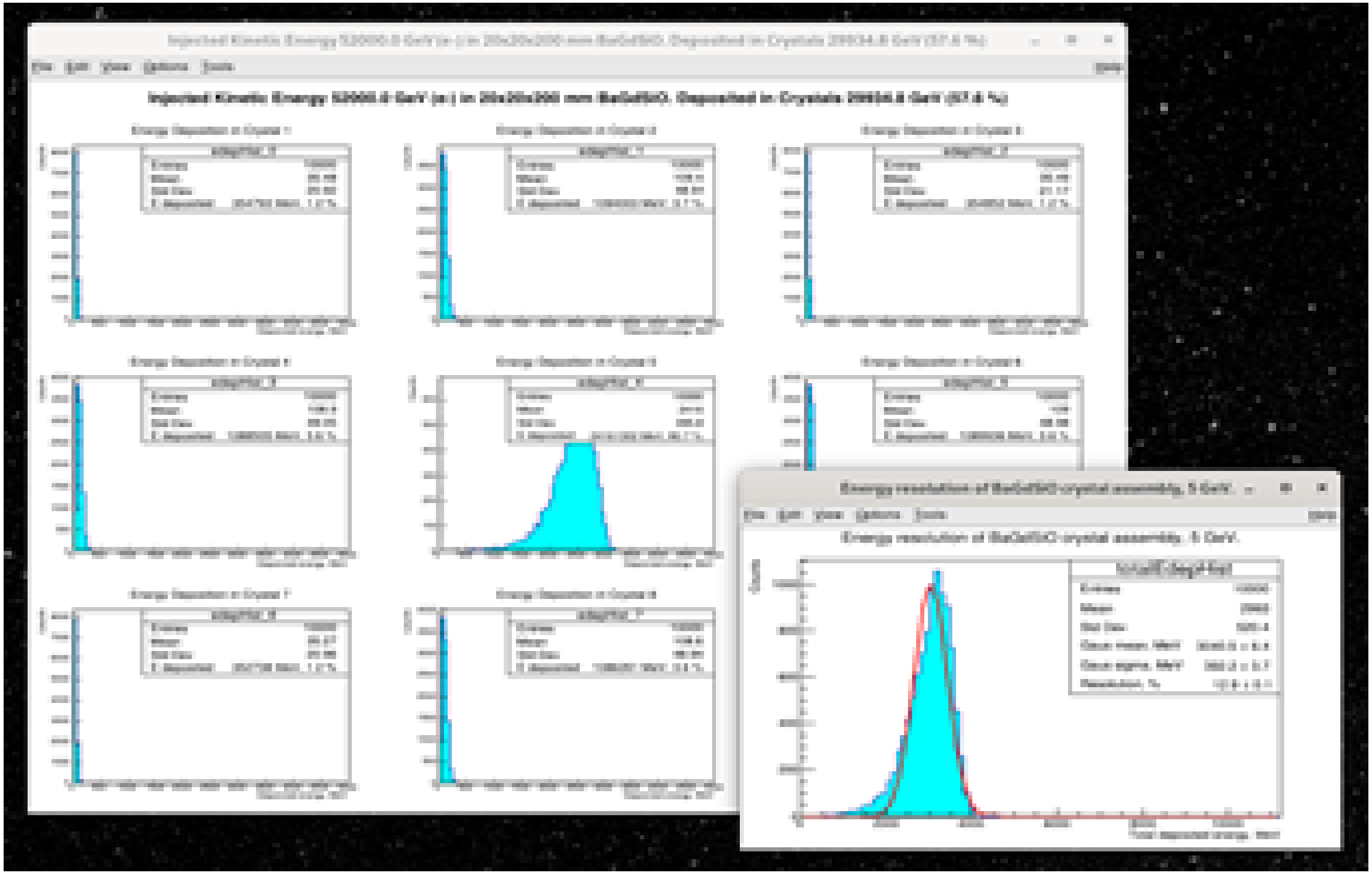


~59% of shower contained



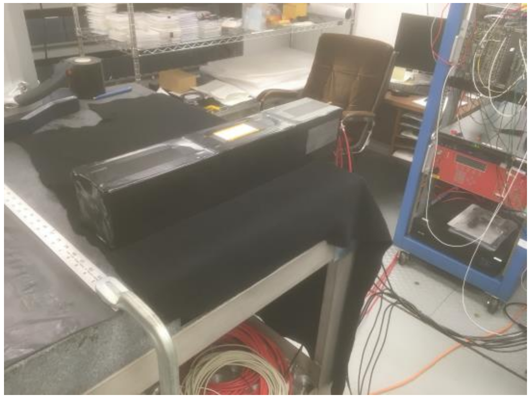
>85% of shower contained

Energy Resolution – simulation and initial beam test 2020



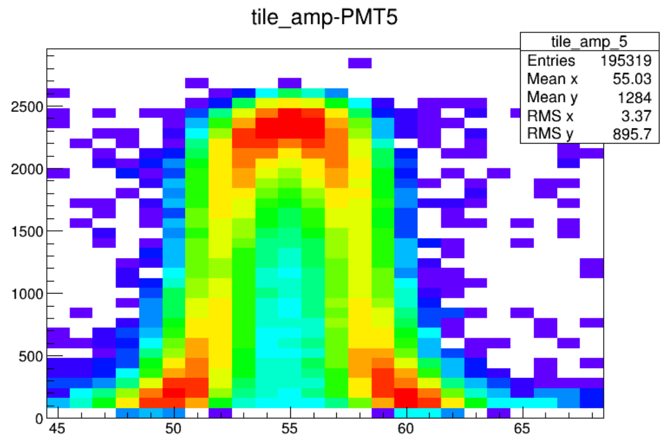
~80% deposited in central module – 5x5 contains lateral showers

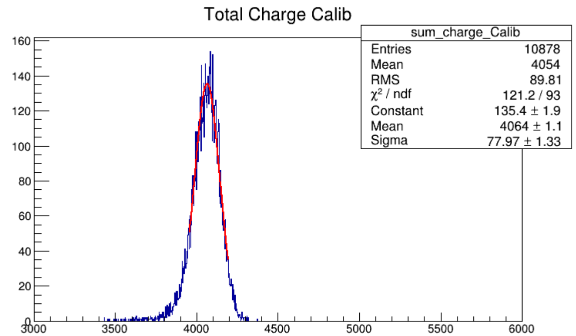
Prototype test 2021 – preparations (1)



EMCal key parameter tests

- Instrument two 3x3 (5x5) SiPM and PMT based prototypes to test scintillator materials and test/optimize the entire readout: preamps, fADC and streaming DAQ system
- Establish baseline performance with PMT based PWO prototype and standard RO
- Tests in Hall D with 10 production configurations





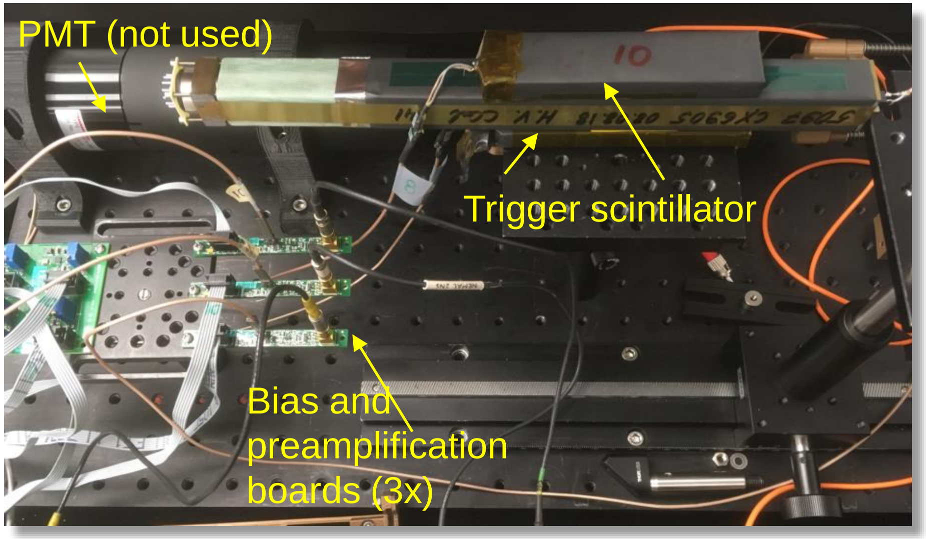
Energy resolution ~1.9% for ~4GeV lepton

Prototype test 2021 – preparations (2)

SCINTILEX

Streaming Readout Tests

- Instrumenting 9 channels (to begin with) to test and optimize the entire readout chain: SiPM, preamps, fADC, and Streaming DAQ system
- Tests in Hall-D with TRIDAS will have 4 configs:
    1. (proto-PMT+VTP+fADC 250)
    2. (proto-PMT+WB)
    3. (protoSIPM+VTP+fADC 250)
    4. (proto-SIPM+WB).
- Configs 1-2-4 are ready, config 3 requires preamps+bias boards



JLab planned Beam Tests in 2021

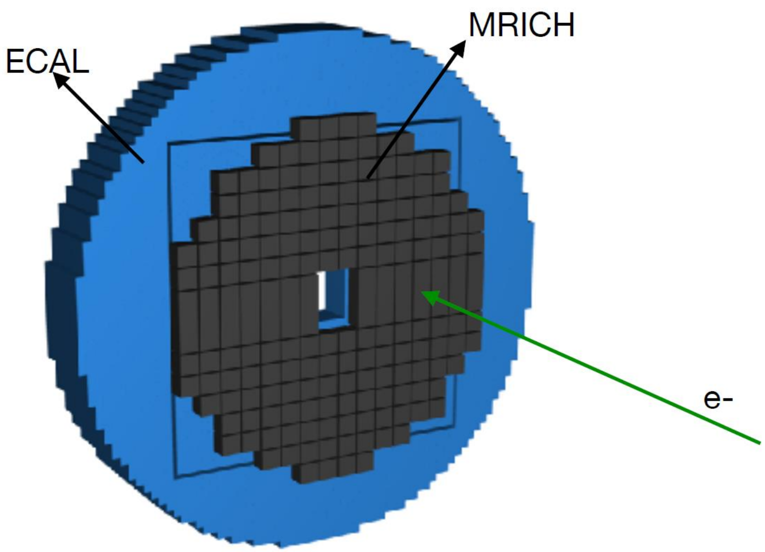
Total: 14 weeks
Crystals/SciGlass 20cm: ~2-3 weeks
SciGlass 40cm: ~2-3 weeks

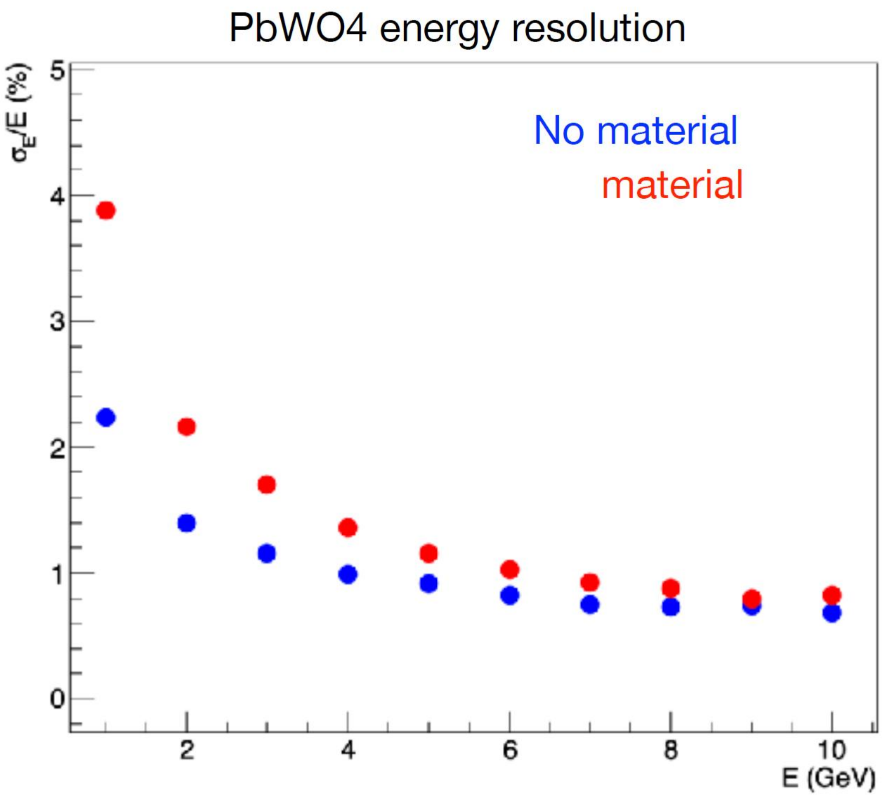
R&D project	EEEMCal1	EEEMCal2	TPEX5x5	GEMTRD	MPGDs with Capa Sharing R/O	mRICH	OTRFT
Contact person	T. Horn (hornt@cua.edu)	T. Horn (hornt@cua.edu)	Douglas Hasell (hasell@mit.edu)	Yulia Furletova (yulia@jlab.org)	K. Gnanvo (kg6cq@virginia.edu)		Y. Sharabian (youris@jlab.org)
Detector box							
Dimensions (mm)	120x120x500	180x180x700	230x230x1000		25 x 25 x 40	140 x 140 x 250 (mRICH box). The support frame size is ~500 x 500 x 500	Z < 250 mm (along beam direct.) X=Y < 700 mm. The support frame size is ~250 x 250 x 500
Depth in Rad. Length (X0)	20	20(?)	20	3%	6 x 1%	small (will be quantified)	~ 0.5 mm thick glass in vacuum
Weight (kg)	12	30	60	2	6 x 0.5	~10 kg	About 10 Kg
Number of ADC channels	9 or 18	18 or 36	25	512	6 x 512	1024 TDC channels	4 to 6
Services							
Gas supply	No	No	No	yes	yes	no	No
Number of HV channels (voltage)	9ch (~1kV)	9ch (~1kV?)	25	2 ch (up to 8kV)	8ch - neg 5kV	4 ch (up to 1kV)	4 to 6
Low voltage (V)	Pos/neg 5V	Pos/neg 5V	2	7V	N/A	Pos/neg 5V	TBD
Cooling	TBD	TBD	Possible	No	N/A	TBD	No
Tracking	No	No	No	Yes	standalone	yes	Yes
Electronics FE	SiPM Preamp, bias	SiPM Preamp, bias	PMT	GASII-fADC125	APV25-SRS standalone	"CLAS12"	
DAQ and Trigger							
DAQ mode	standard Hall D/GlueX	standard Hall D/GlueX	trigger signal	standalone	standalone	standalone	standard Hall D/Gluex
DAQ mode alternative	SRO	SRO	SRO		APV25-SRS / CODA - GlueX		
Trigger	PS	PS	?	PS	PS		PS
Running conditions							
Constraints	<10% RL in front	<10% RL in front	<10% RL in front				Minimal RL in front
Kinematics	~4.5 GeV (min 1 point, additional kinematic points desirable)	~4.5 GeV (min 1 point, additional kinematic points desirable)	2-5 GeV	>1 GeV	Ok with current 3-6 GeV	> 1 GeV	Above 2 GeV
Configuration changes	~5	~5	0	~12	~10	~2	~12
Time needed per access	1 hour (on average), complex configuration changes: 4 hrs	1 hour (on average), complex configuration changes: 4 hrs	10 minutes or zero if platform remotely controlled	20-45min	typically a couple of hours	< 1 hr	About 1/2 hr
What is needed from JLab/HallD							
Survey and alignment	Initial installation	Initial installation	Initial installation	Initial	Initial installation	initial installation	Initial Installation
Slow controls and support	N/A	N/A	N/A	HV-interface/PLC		?	TBD
Tech support	Initial installation and some (complex) configuration changes	Initial installation and some (complex) configuration changes	Initial installation	Mechanical installation	Initial installation -mech support	mechanical support	Alignment checks
Electronics group support	SiPM preamp, bias	SiPM preamp bias, cables (9)	No	No	Network setup		No
Equipment, e.g. crates	VXS crate for SRO	VXS crate for SRO	Rack for our equipment	VXS crate	movable and rotatable XY stage		TBD
Interest in improvements	movable platform for calorimeter calibrations	movable platform for calorimeter calibrations	movable platform for calorimeter scans	movable and rotatable XY stage			

Simulation Activities (1)

Adapted from talk by M. Bondi
12/17/20

Impact of material in front of the EEEMCal





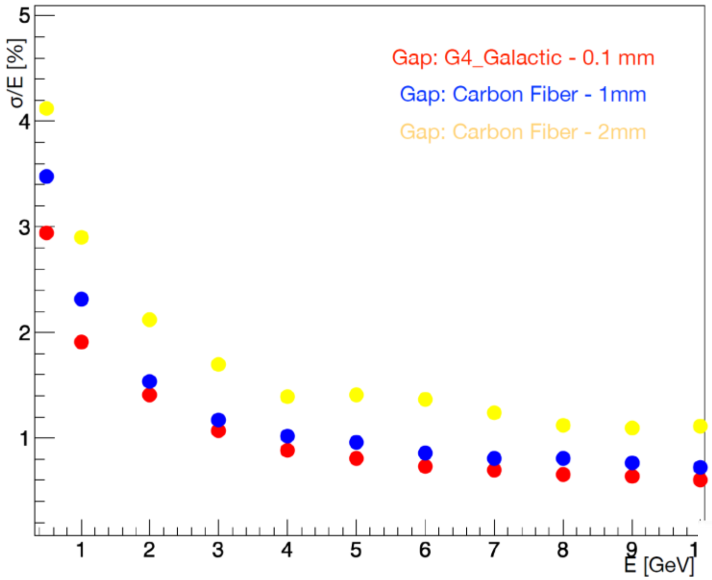
- MRICH bars material is quartz

- ECAL gap between crystal : 1mm
- ECAL gap: Carbon fiber

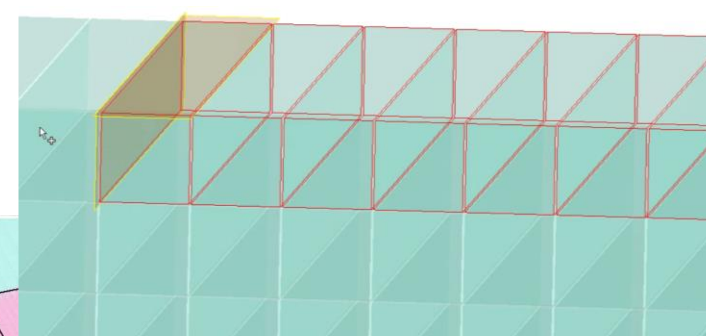
- Electron energy: 1 - 10 GeV

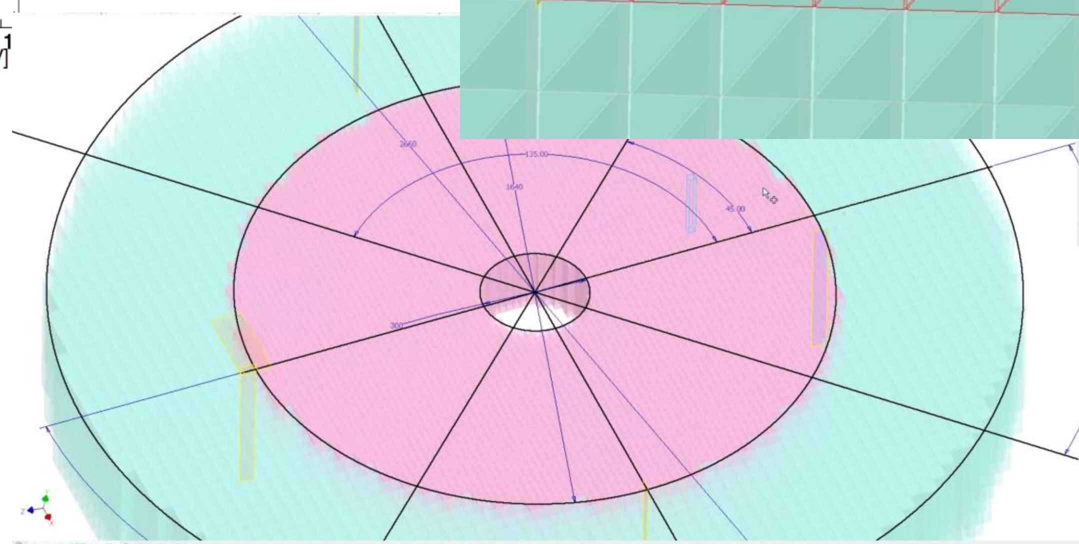
Simulation Activities (2)

Carbon fiber frame impact on resolution and structural support



- ❑ For resolution <=1mm carbon fiber between blocks seems fine

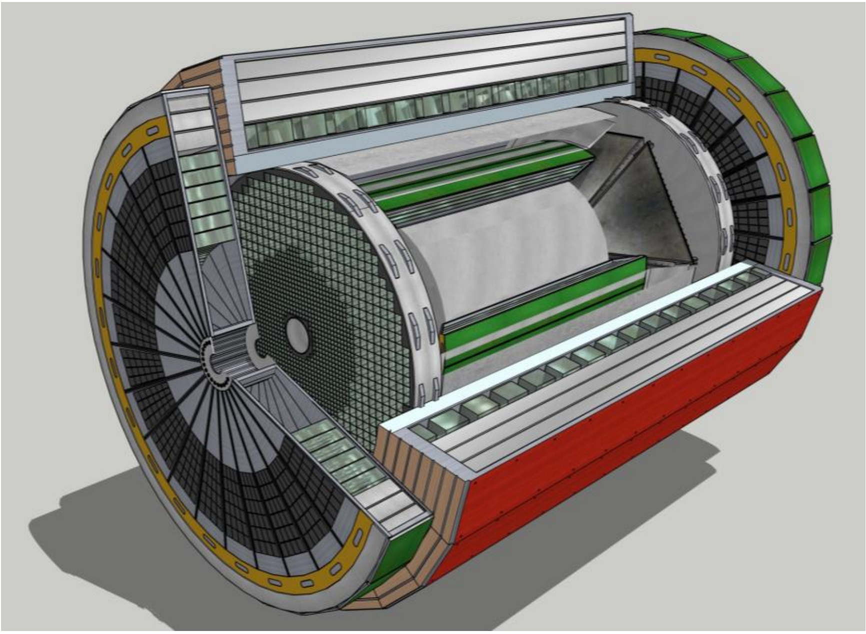


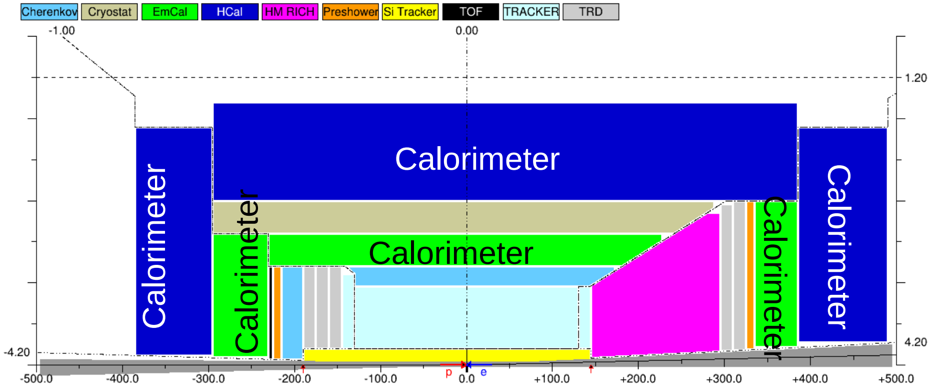


- ❑ Stress tests with CAD model ongoing

Simulation Activities (3)

Use AI models to optimize material selection for best performance of EM and joint EM/hadronic calorimetry





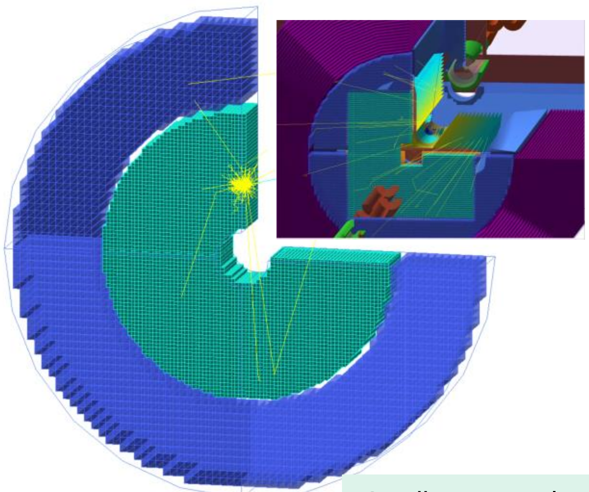
<u>The team</u>:
M. Battaglieri, V. Berdnikov, M. Bondi, C. Fanelli, Y. Furletova, T. Horn, I. Larin, D. Romanov, R. Trotta

- ❑ EIC central detector requires EM and EM/hadronic calorimetry in the barrel and the two endcaps
    - EIC auxiliary detectors also need calorimetry
- ❑ Material selection is important for balancing calorimeter performance and cost

Simulation Activities (3) - details

Adapted from talk by M. Bondi
in EIC YR Calo WG 7/14/20

Detector simulation to optimize the shared rapidity between crystal and glass



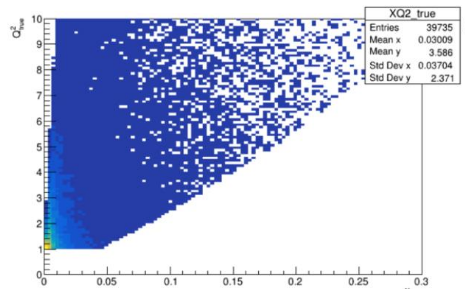
Credit to Y. Furletova, D. Romanov, I. Larin

- ❑ Electron Endcap requires an inner part (crystal) with high resolution and an outer part (glass) with less stringent requirements
- ❑ Optimizing the radius to which high resolution is needed may reduce the number of crystals

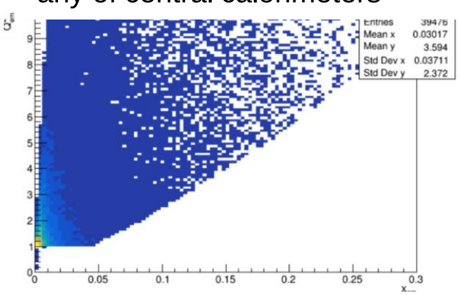
❑ Major activities

- Implementation of geometry and digitization
- Hybrid calorimeter reconstruction algorithm being developed
- Analysis plugin for studies of e.g. Impact of EmCal resolution on reconstructed quantities
  - A.I. optimization

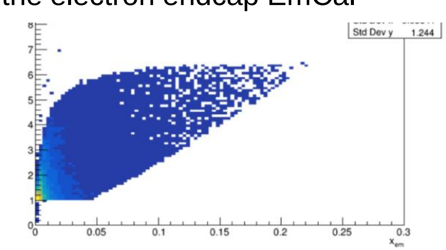
True values



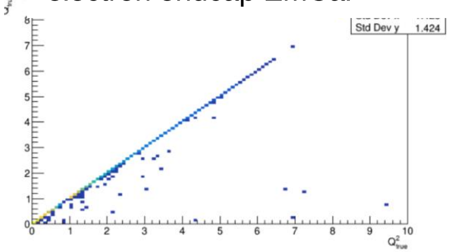
Reconstructed from tracks hitting any of central calorimeters



Reconstructed from tracks hitting the electron endcap EmCal



Reconstructed Q2 vs true electron endcap EmCal



Simulation Activities (4)

Cherenkov and scintillation light in the same detector

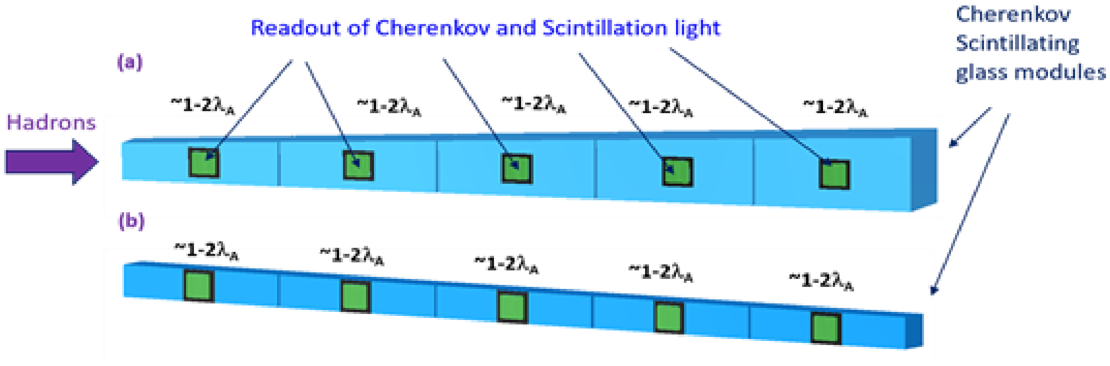


Fig.1 *Schematic showing a possible cell (two configurations) for the hadron calorimeter dual readout concept. It removes the traditional boundary between EMCal and HCal, and thus eliminates the effect of dead materials in the middle of the hadronic shower development. It is similar to typical homogeneous EMCal cell, but has segments with a total length of 1-2*λ_A*. Readout devices could be mounted on the side faces.*

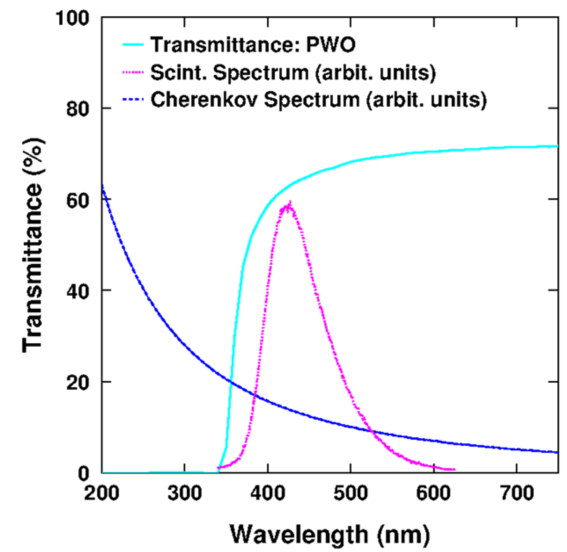


Fig. 2: *Representative Scintillation and Cherenkov spectra. To distinguish Scintillation and Cerenkov components materials with slow and >500nm scintillation light are beneficial.*