Homogeneous EM Calorimeter R&D for EIC

(part of eRD1)

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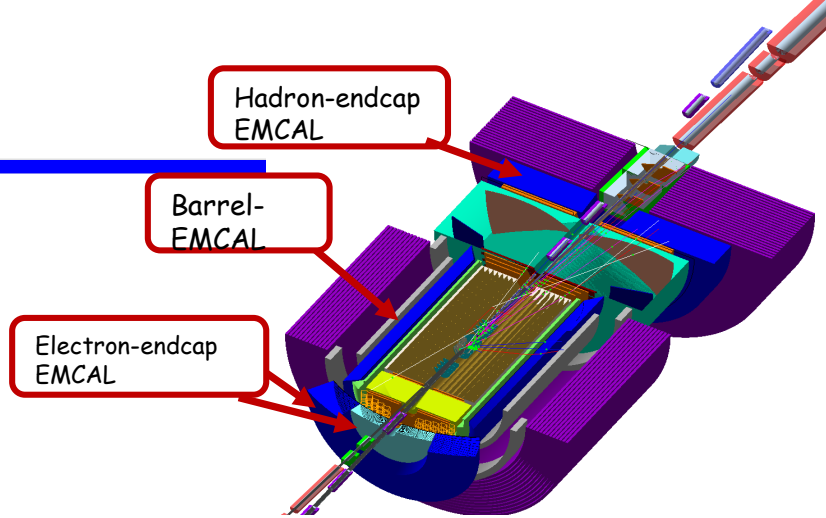
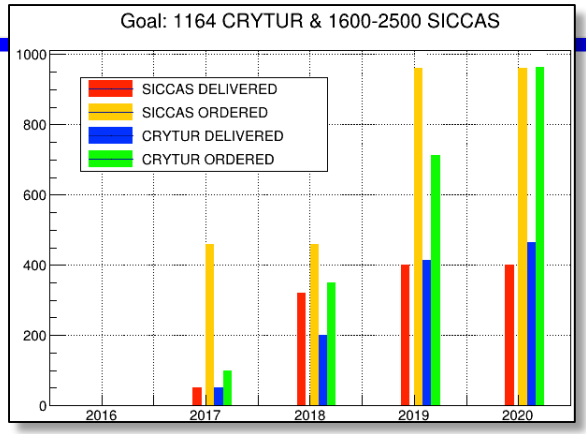
Overview FY20 Plans



- **Continue working with vendors on crystal/glass production** – optimize QA procedures, material characterization to provide feedback; investigate alternative sources of raw material
- **Fabrication method: produce larger glass samples** with adequate surface quality for physical, luminescence, and radiation hardness tests
- **Validation: Prototype beam test program** – quantify performance and response of crystal and glass to different photosensors and streaming readout
- **Design: Extend evaluation of homogeneous calorimetry –** develop MC for resolution studies and matching crystal/glass, increase efforts to other regions
- **Additional radiation hardness studies** – evaluate resistance to hadron radiation (MC40 synchrotron) and higher EM radiation doses (IPNO)
- **Submit SBIR/STTR proposal** – glass scintillator development

SCINTILEX

What was achieved in FY20 – to date



- ☑ Continue working with vendors on crystal/glass
  - Progress
  - **Received an additional 116 Crytur crystals**
  - **Meetings with SICCAS on QA – expect 500 crystals**
- ☑ Produce larger glass samples – fabrication method
  - Progress
  - **Produced five 2x2x2cm3 and two 2x2x20cm3 glass samples**
  - **Optimization of formulation, scale up, and polishing methods**
- ☑ Prototype beam test program - validation
  - Progress
  - **Documentation submitted and approved**
  - **Installation for 2020 test run ongoing – in collaboration with Hall B and the EIC SRO Consortium**
- ☑ Additional radiation hardness studies
  - Progress
  - **Hadron irradiation test completed at MC40 Cyclotron/Birmingham**
- ☑ Submit SBIR/STTR proposal
  - **STTR Phase 1 was awarded!**

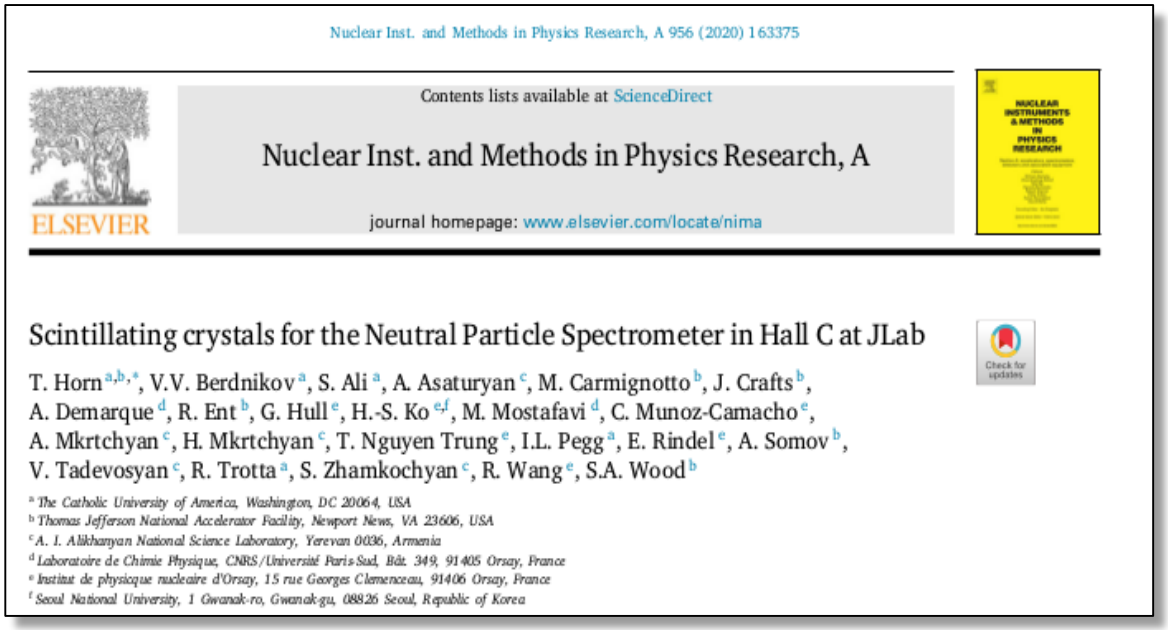
SCINTILEX

Crystal Activities – characterization and vendors

- **SICCAS**: failure rate ~13% of crystals produced in 2019/20 due to major defects – inspected onsite in Shanghai
  - Meetings with vendor, most recent on January 6th about QA

- **CRYTUR**: Strict quality control procedures – so far 100% of crystals accepted
  - Continuing meetings to improve capacity and discuss raw material availability

Publication on crystal studies in collaboration with NPS project



Nuclear Inst. and Methods in Physics Research, A 956 (2020) 163375

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Scintillating crystals for the Neutral Particle Spectrometer in Hall C at JLab

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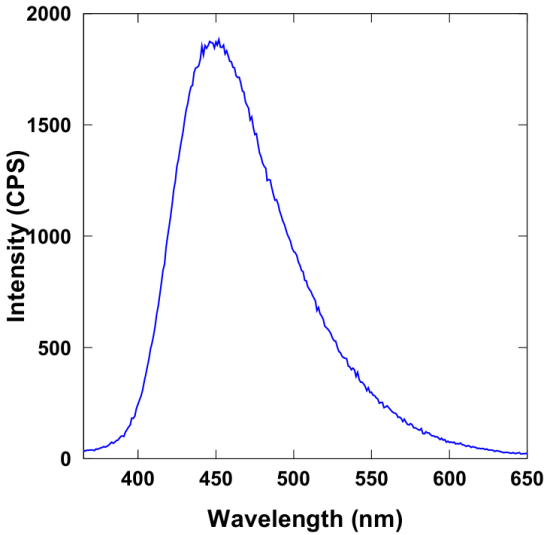
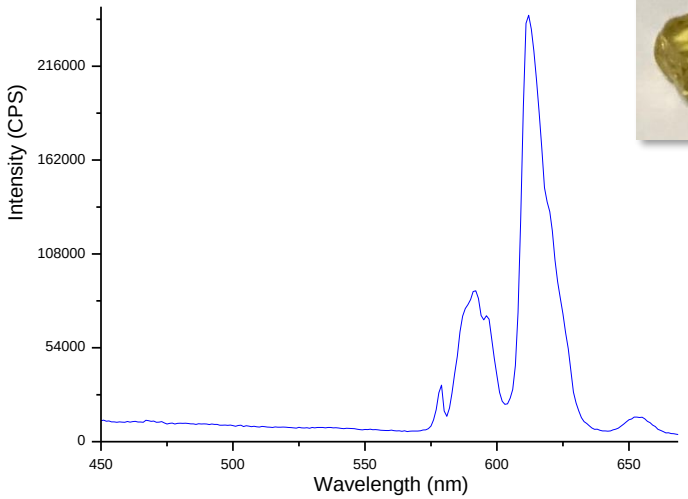
Glass Scintillator – formulation

- Two main glass formulations for calorimeter application

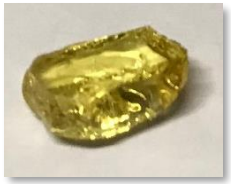
VSL-Scintilex-G4 (nominal)

Emission wavelength

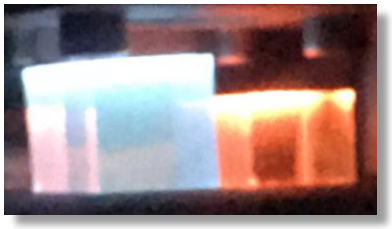




VSL-Scintilex-SC1



- Nominal: optimized LY, timing, radiation hardness, etc. ✔

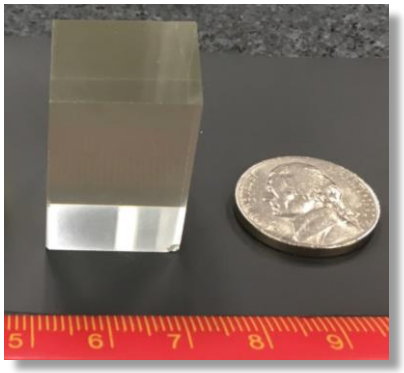


Scintillation light

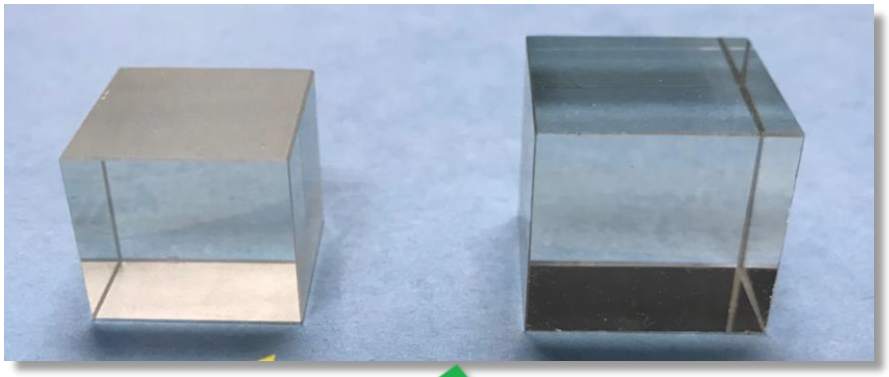
- Very high-density compared to nominal, emits at >550nm, good LY

Glass Scintillator – polishing

- Testing and optimizing different methods (specifications on: flatness, roughness, parallelism, perpendicularity)

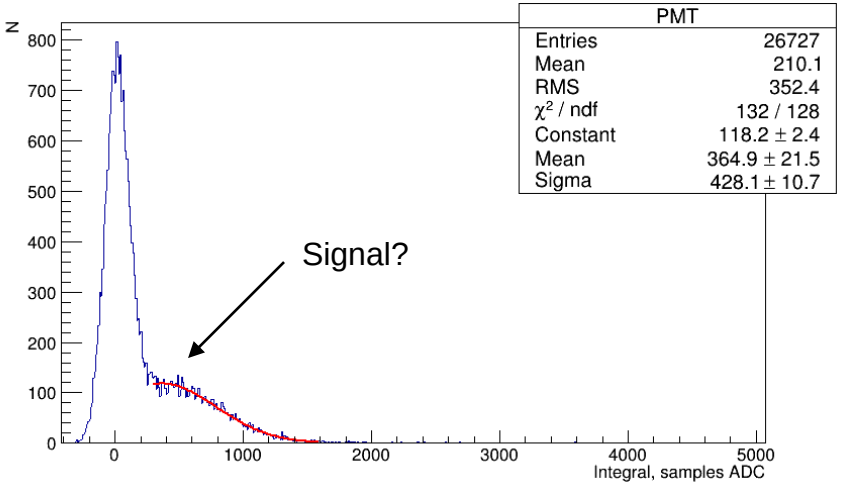


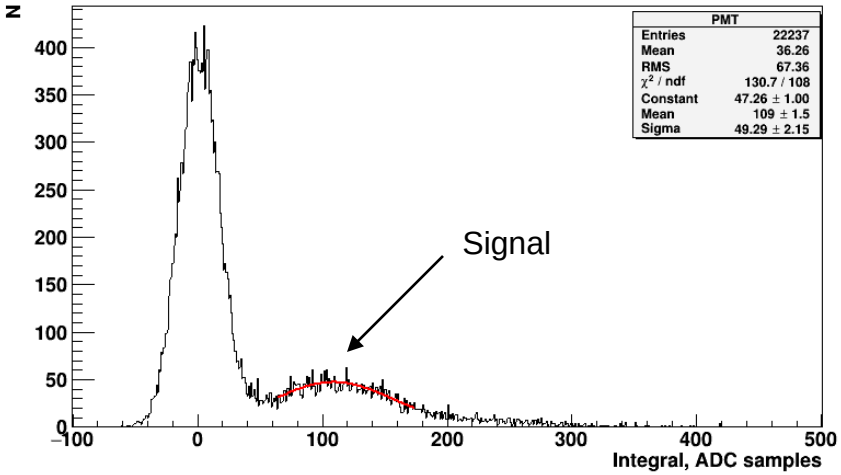
Method 1



Method 2

Method 3



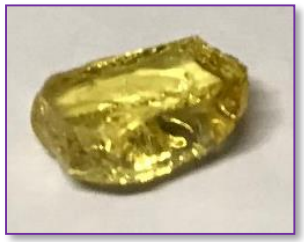


Glass Scintillator – Scale-Up

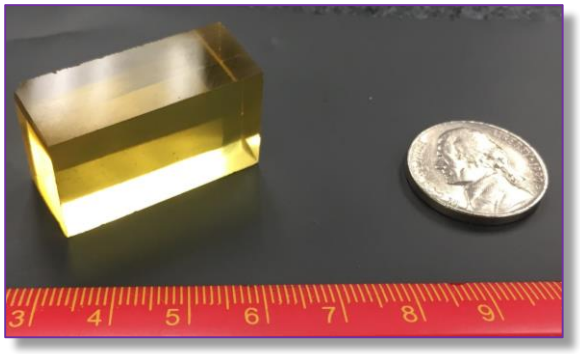
- Progress with scale-up – 2x2x20cm^3 samples produced, issues associated with further scale-up identified, solutions are being implemented and tested

Example: SC1 glass

1cm x 1cm x 0.5cm (test size)



2cm x 2cm x 4cm (medium size)



2cm x 2cm x 20cm (large size)

- Unpolished, Bubbles on surface only – will be removed during cutting and polishing

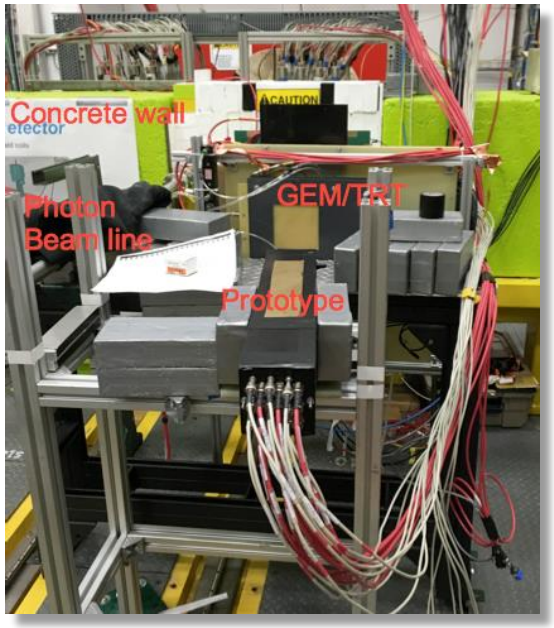
2019 → 2023

1cm x 1cm x 0.5cm

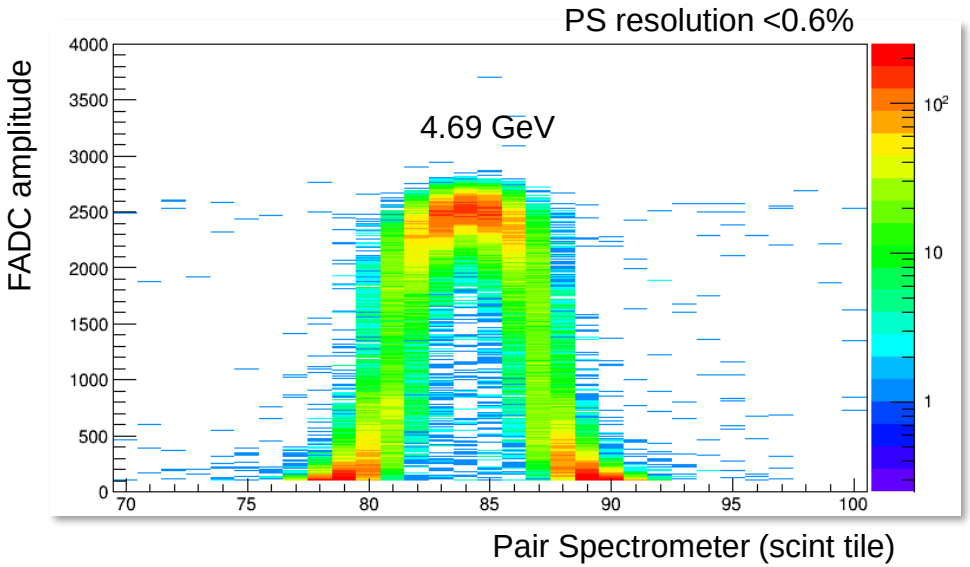
Up to 4cm x 4cm x 40cm

Glass Scintillator – Initial Beam Test Program

- Constructed a 3x3 prototype of geometry representative of NPS and EIC EMCal
- All documentation submitted for 2020 Spring beam tests, installation and running now!
  - Beam energy provided by pair spectrometer - select electrons going through the center of the middle crystal

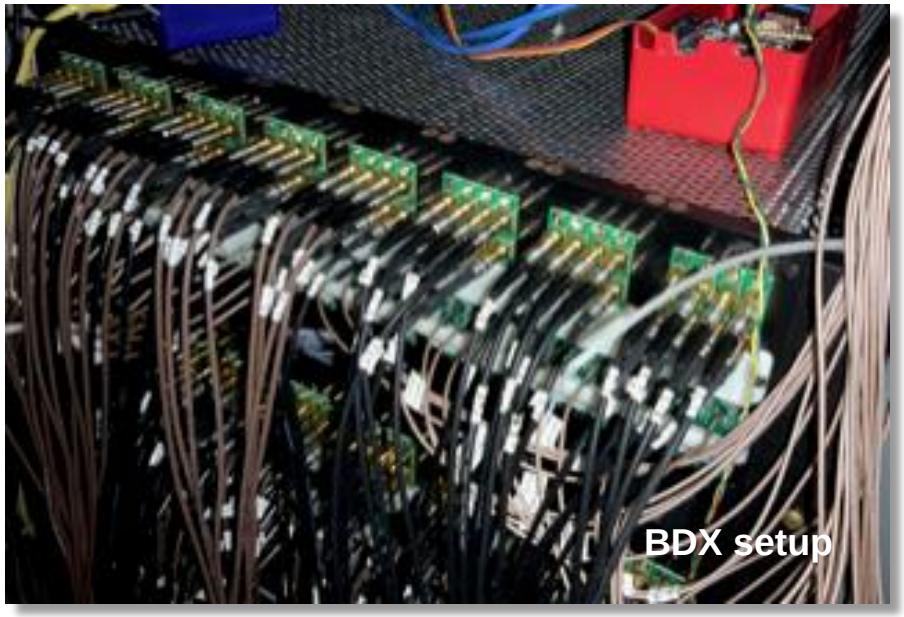


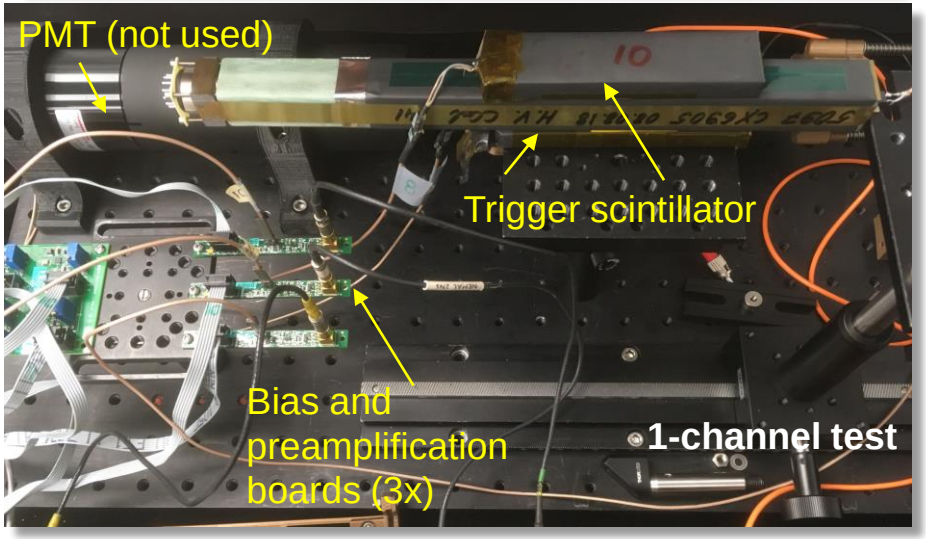
- Tests in collaboration with Hall B and EIC SRO Consortium and will include:
  - Crystal/glass with PMT
  - Crystal/glass with SiPM
  - Crystal/glass with Streaming Readout



Test Lab for crystal and glass Readout

- Based on BDX-MINI test runs at Jlab in 2019, INFNGE developed V2.0 of Waveboard digitizer to read out SiPMs
- Work on synchronization MRPC and crystal/glass readout ongoing
- Instrumenting 9 channels (to begin with) to test and optimize the entire readout chain: SiPM, preamps, fADC, and Streaming DAQ system





Glass/crystal – Schedule for TDR 2023

- **What achievements are required for TDR 2023 readiness**
  - Finalize glass formulation and fabrication method
  - Completion of crystal/glass design in simulation
  - Validation of performance with prototype

- **How much time do you envision to complete your ongoing project**

Item	Task	2019	2020	2021	2022	2023
			FY20	FY21	FY22	FY23
Glass fabrication	Composition optimization					
	Characterization					
	Scale up and additional geometries					
	Show uniformity and reproducibility					
	Fabrication process optimization					
	Performance tests with prototype					
	Process design verification to scale up					
	Large scale production study					
Software	Prototype					
	Design options					
	Cost/performance optimization					
Prototype	Base version					
	Initial commissioning					
	Upgrade and commissioning					
Beam test	Beam test					
	Data analysis					

Glass Scintillator – Radiation Hardness

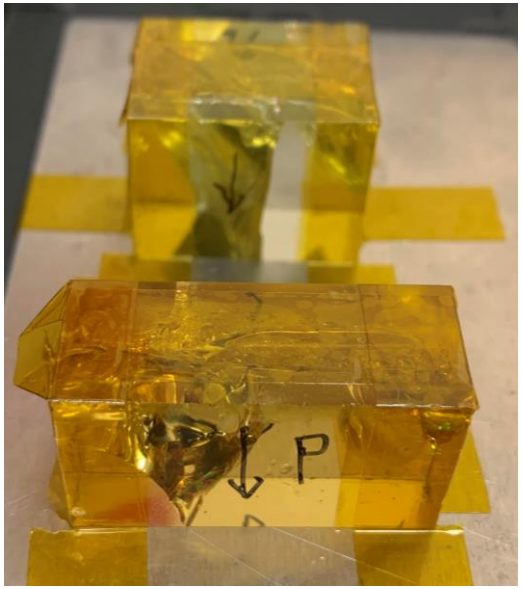
- Low dose rate EM and hadron irradiation completed

VSL-Scintilex-G4 (nominal)

Before irradiation

After 2min 160KeV Xray at >3k Gy/min

VSL-Scintilex-G4 (nominal) and SC-1 glass



Fluence: 2E15 p/cm^2

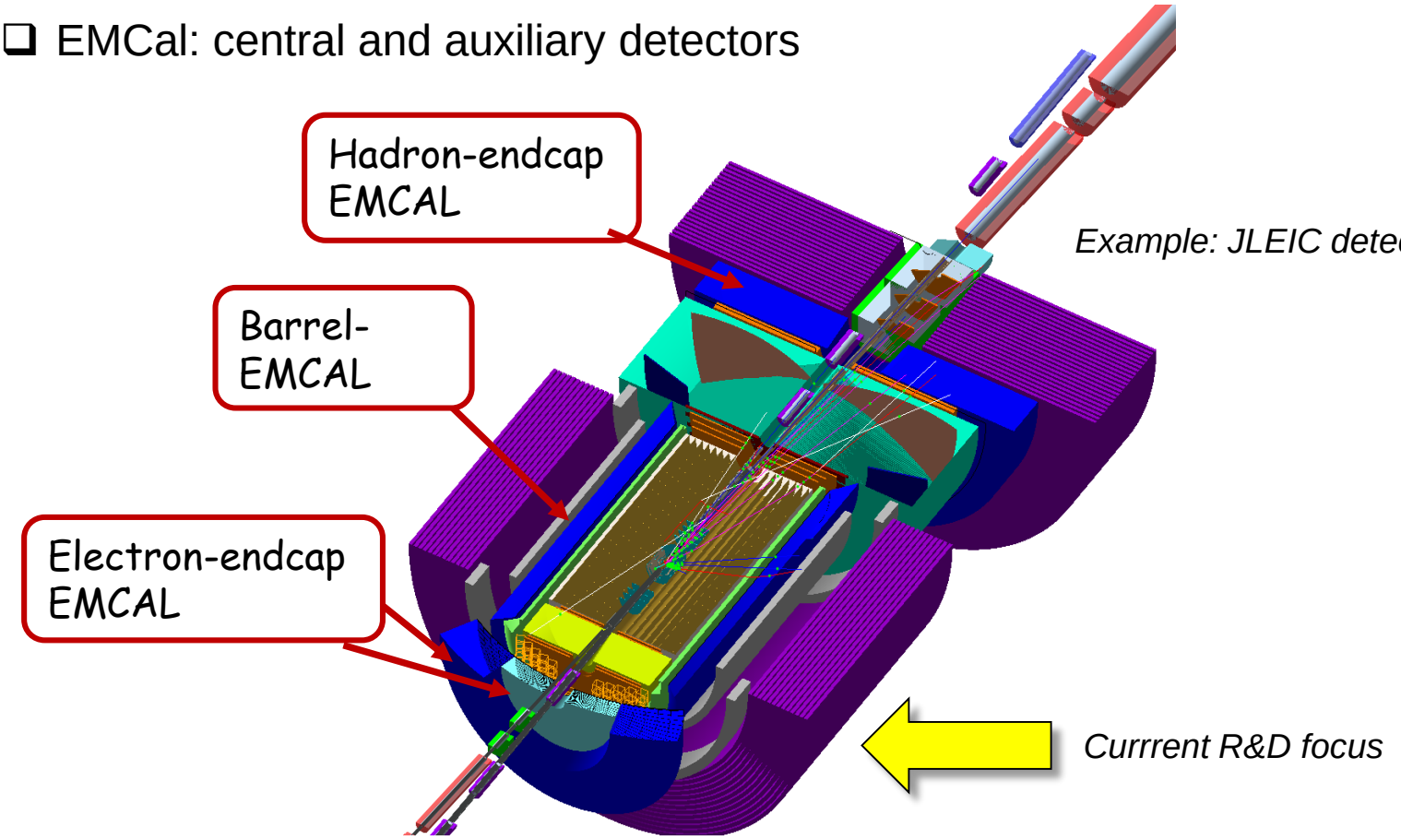
Fluence: 1E15 p/cm^2

Photograph taken immediately after irradiation.
No visual evidence of radiation damage

- G, T, SC, EC series are EM radiation hard
- G, SC series are radiation hard under hadron irradiation

Homogeneous EM Calorimetry

- EMCal: central and auxiliary detectors



- Materials:
  - **Lead Tungstate ($PbWO_4$) –** high resolution, \$15-25/cm^3, limited vendors
  - **Glass (DSB:Ce) –** alternative active material, easier to manufacture than crystals and more cost effective