Crystal characterization

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on behalf of NPS collaboration

NPS/CPS Collaboration Meeting (JLab, 2/1/19)

Outline

- **NPS calorimeter requirements**
- **Quality assurance of CRYTUR and SICCAS crystals**

  Visual inspections and surface quality

  Visual inspections with green laser

  Transmittance

  Light Yield

  Radiation Hardness measurements

  Rejection rates

- **Beam tests**

  3x3 prototype

  Comcal/NPS prototype

- **Outlook path to completion**

NPS requirements

$PbWO_4$ crystal specification				
Parameter	**Unit**	**NPS Required**	**COMCAL/FCAL**	**PANDA specifications**
Light Yield at RT	phe/MeV	≥15	≥9.5	≥16
LY uniformity between the blocks (%)		<10 (<20)		
LY(100ns)/LY(1us)	%	>90	>90	>90
Longitudinal Transmission at				
λ = 360nm	%	≥35 (≥25)	≥10	≥35
λ = 420nm	%	≥60	≥55	≥60
λ = 620nm	%	≥70	≥65	≥70
Transverse Transmission and LY uniformity along the crystal	%	10		
Inhomogeneity of Transverse Transmission				
D λ at T=50%	nm≤	≤5	≤6	≤3
Induced irradiation absorption coefficient dk at λ =420nm and RT, for integral dose >10Gy	m-1	<1.1 (<1.5)	<1.5	≤1.1
Mean value of dk	m-1	≤0.75		≤0.75
Tolerance in Length	μm	≤±100	+0/, -100	≤±50
Tolerance in sides	μm	≤±50	+300, -0.	≤±50
Surface polished, roughness Ra	μm	≤0.02		
Tolerance in Rectangularity	degree	≤0.1		≤0.01
Mo contamination	ppm	<10		<1
La, Y, Nb, Lu contamination	ppm	<40ppm (≤100)		≤40

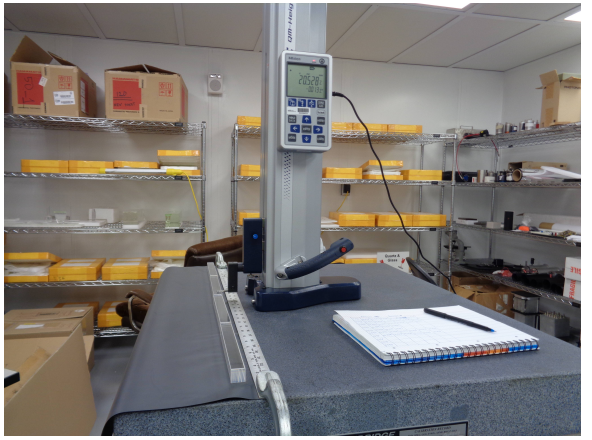
Also require no defects like cracks, chips, dots, glue spots, chemical films, old labels and etc. since these impact NPS crystal performance

QA and measurements status

Vendor	Samples	Delivered
SICCAS	460	FY 2017
CRYTUR	100	FY 2018

	Experimental investigation	CRYTUR	SICCAS
	Visual inspections including 5mW green laser	100%	100%
	Dimension measurements	100%	100%
	Transmittance measurements	37%	100%
	Light yield measurements	30%	70%
	Radiation resistance, sample of 10 pieces	to be done	done
	Beam tests (additional)	to be discussed	done; data analysis ongoing
	Chemical and surface analysis few samples (optional)	done	done

Dimension measurements



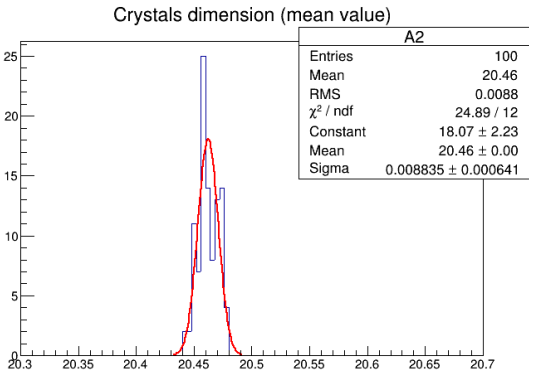
Mitutoyo tool ~ 7um accuracy on AA granite

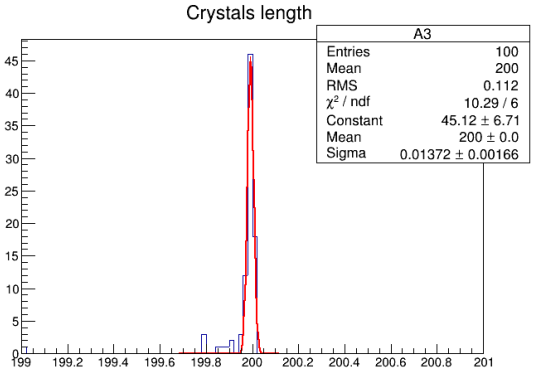
CRYTUR dimensions:

X,Y 20.46±0.01 mm
Z 200.0±0.01 mm

<u>20.46x20.46x200.0 mm^3</u>

No rejections



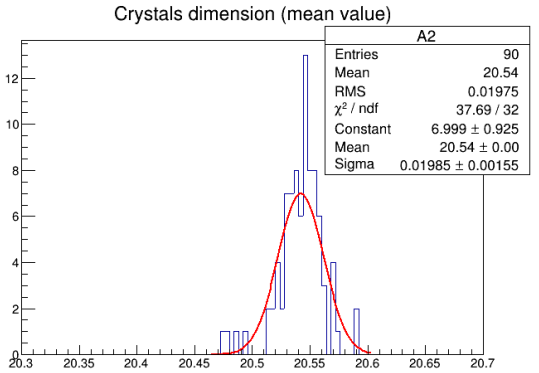


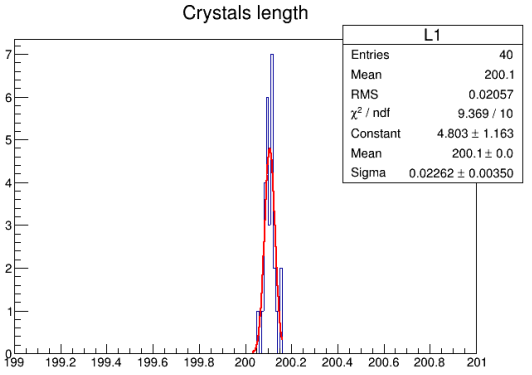
SICCAS dimensions:

X,Y 20.54±0.02 mm
Z 200.1±0.02 mm

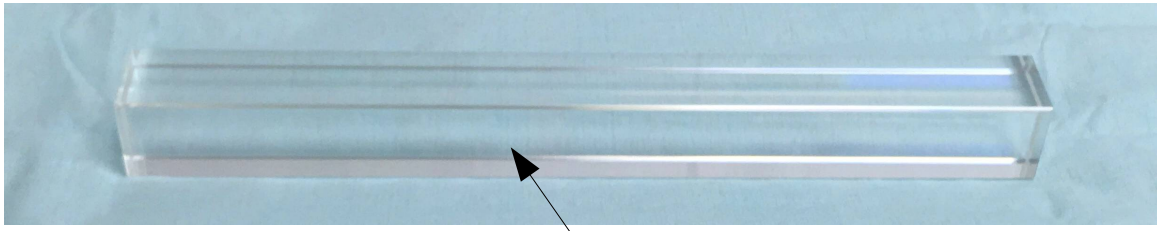
<u>20.54x20.54x200.1 mm^3</u>

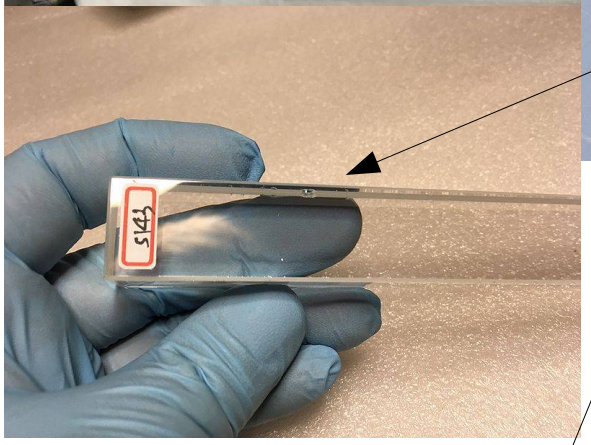
3 crystals rejected (size ~20.1)

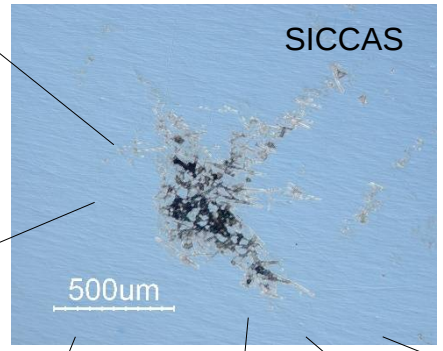


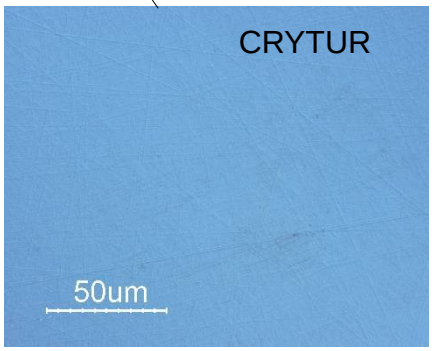


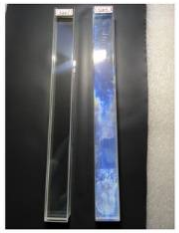
Visual inspection and surface quality

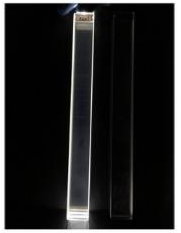


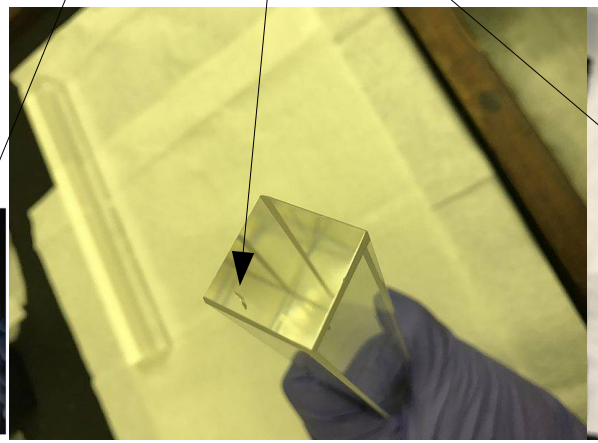


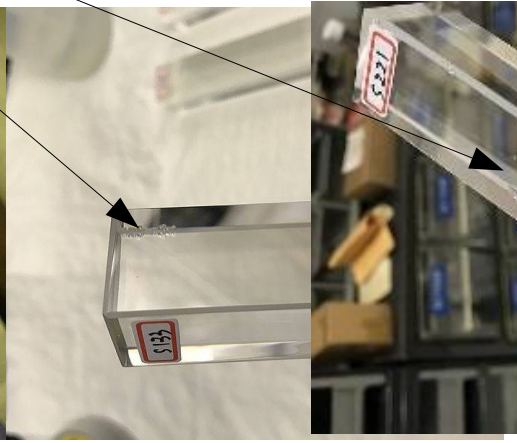


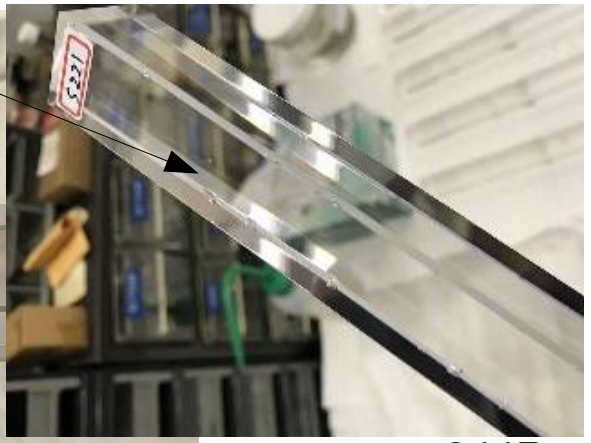












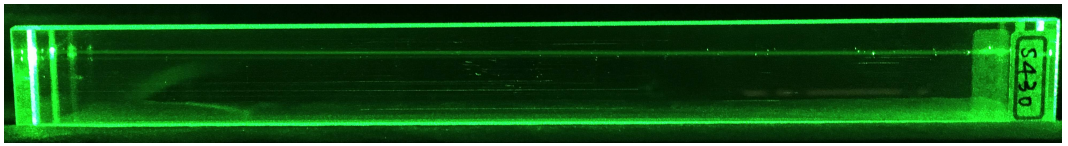
Observed visual defects :

CRYTUR [30% crystals]
- small chip(<1mm)
- not deep scratches

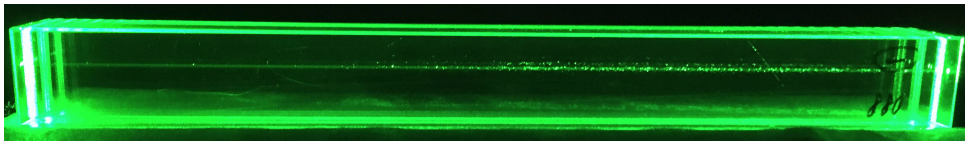
SICCAS [70% crystals]
- Long,deep scratches and cracks
- Excessive number of small chips along edges
- Large chips on corners
- Pits, old Labels, chemical film

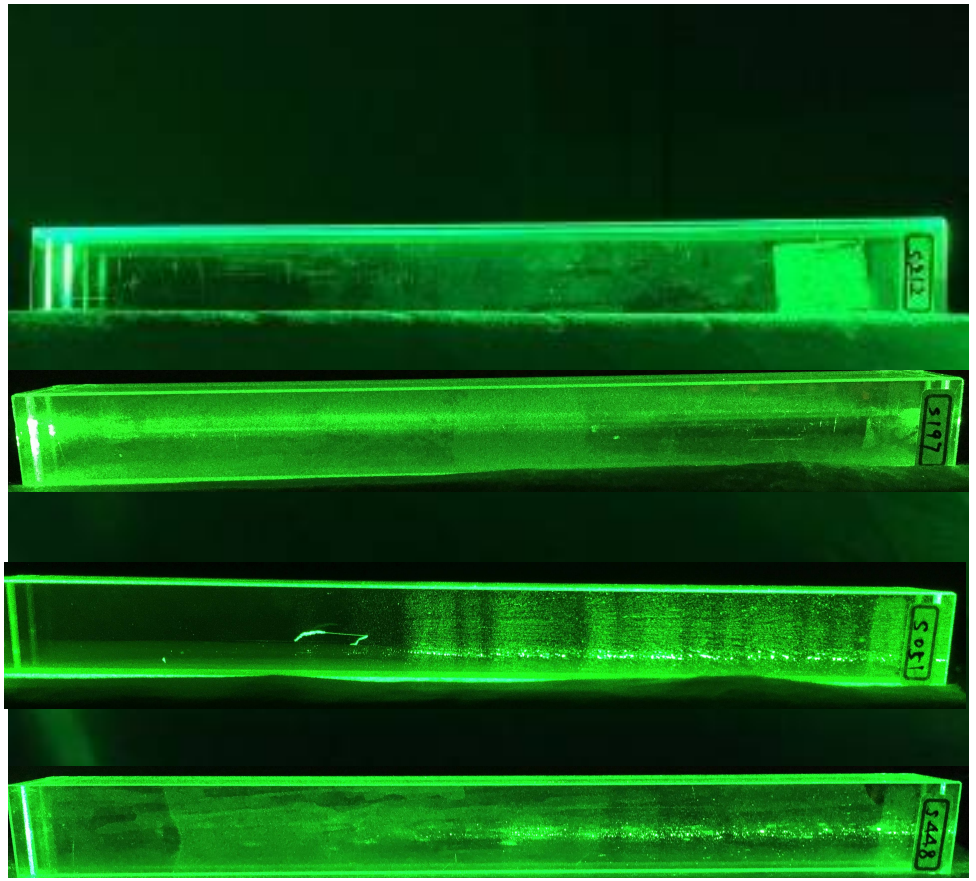
Visual inspection with green laser

SICCAS



CRYTUR





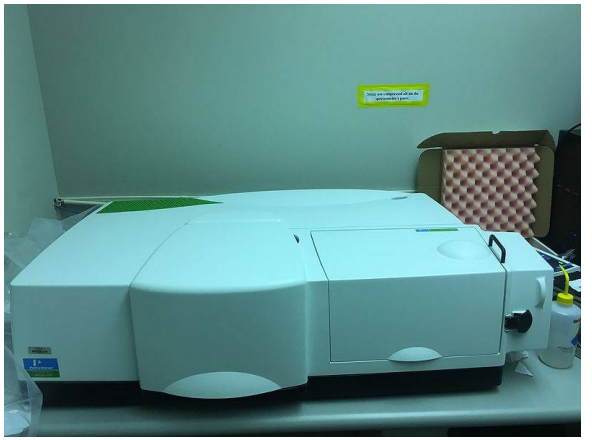
CRYTUR:

- Some small dispersion bubbles in bulk much less than 25% of crystal volume

SICCAS:

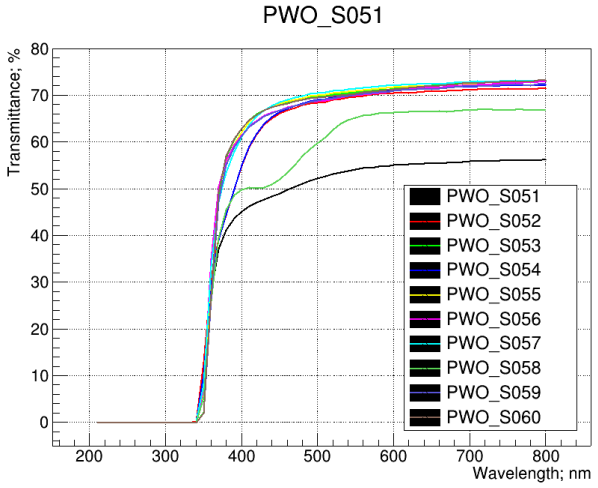
- Medium dispersion bubbles in bulk up to 50% of crystal volume
- Excessive number of bubbles (>50% volume) in bulk (“X-mas tree”)
- Chemical film on surface (“Milky crystals”)
- Traces of old labels or markings on surface(“Shabby”)

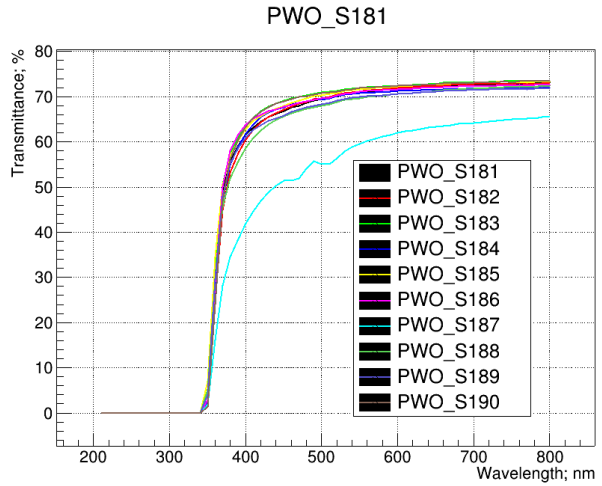
Transmittance measurements



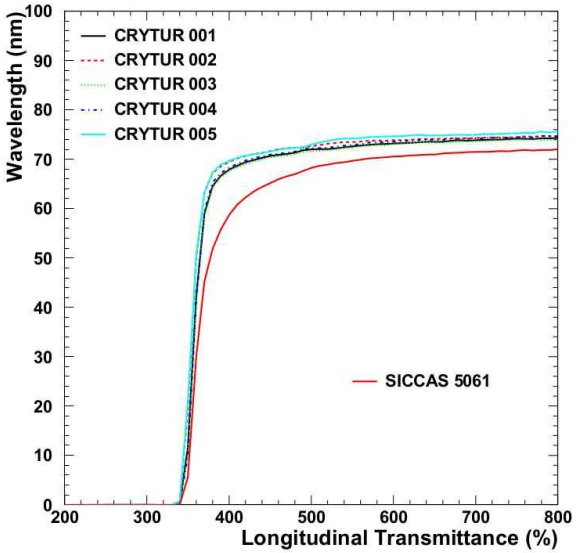
PerkinElmer Lambda 950 spectrometer

SICCAS





CRYTUR



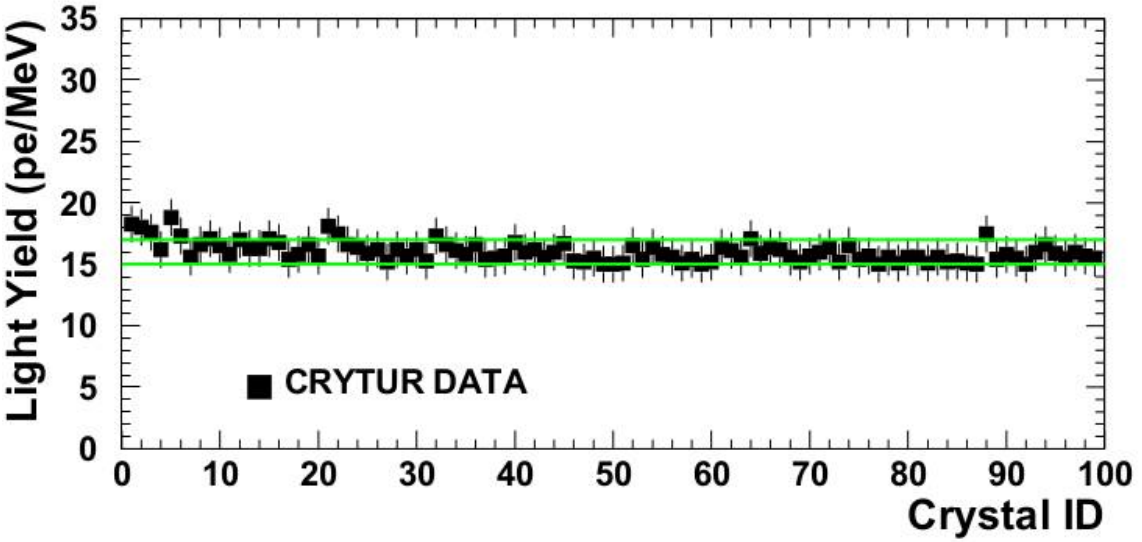
CRYTUR:

- Uniform transmittance spectra
- Better transmittance compare to SICCAS

SICCAS:

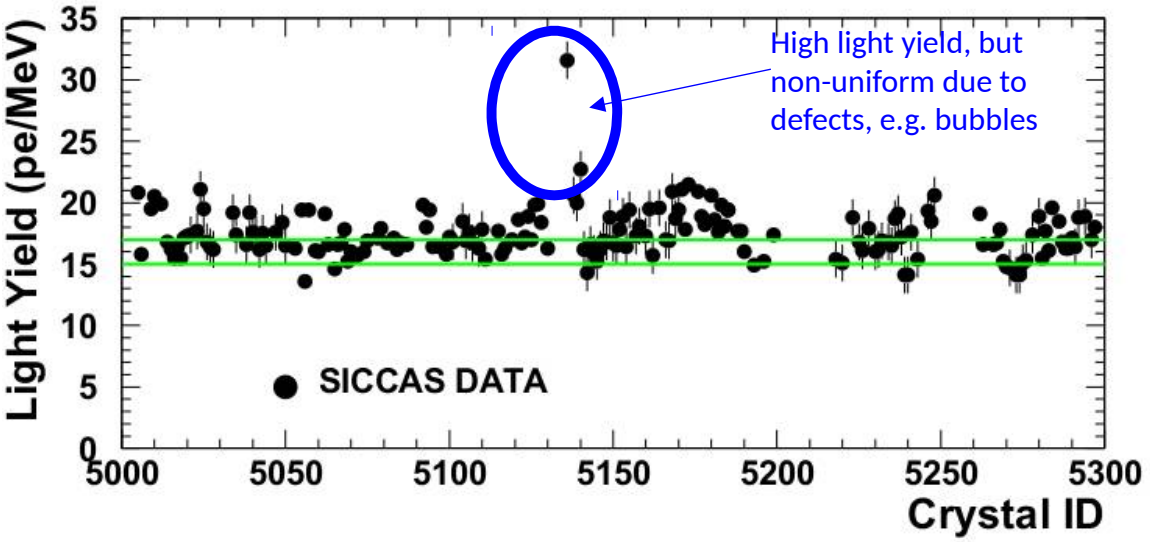
- Nonuniform transmittance spectra
- Correlation between bad spectrum and visual defects
- Some bad spectrum due bad composition and doping

Light Yield measurements



CRYTUR:

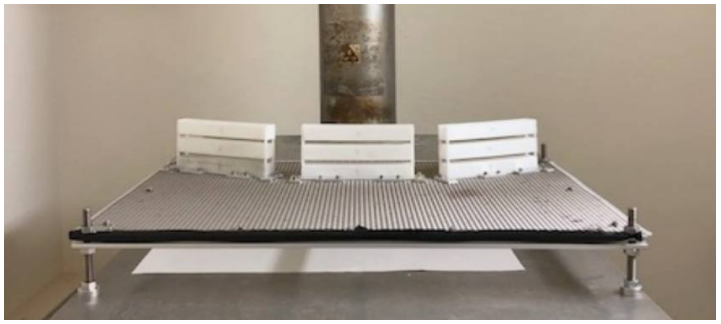
- Light yield is uniform



SICCAS:

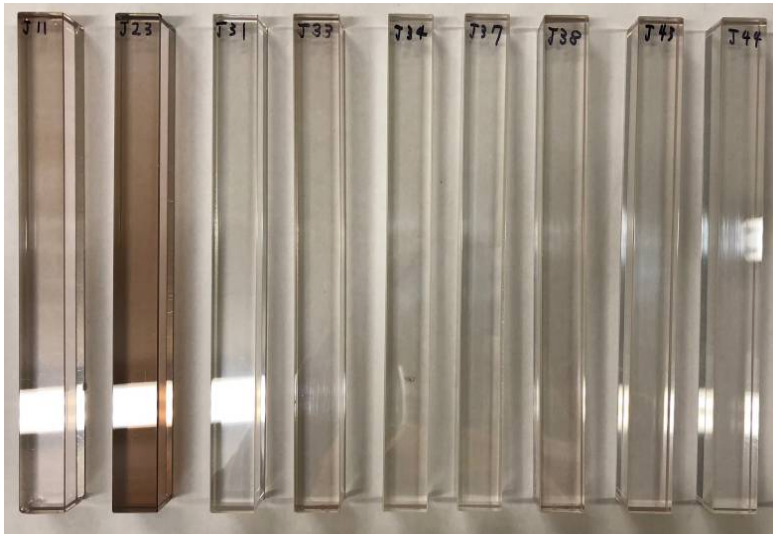
- Large variations in light yield
- Non-uniformity of light yield within one crystals due to defects in bulk

Radiation hardness

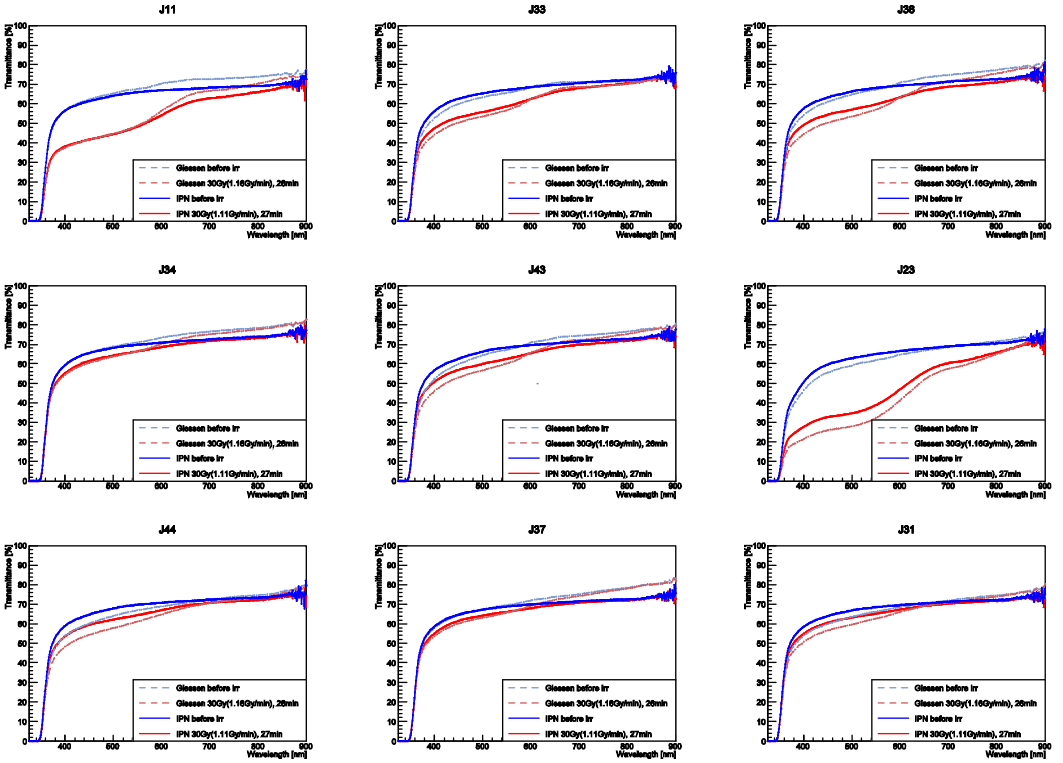


High intensity Co60 source at IPN-Orsay
30 Gy total dose, at a rate of ~1Gy/min
Fricke dosimetry solution to measure actual dose

SICCAS crystals after irradiation



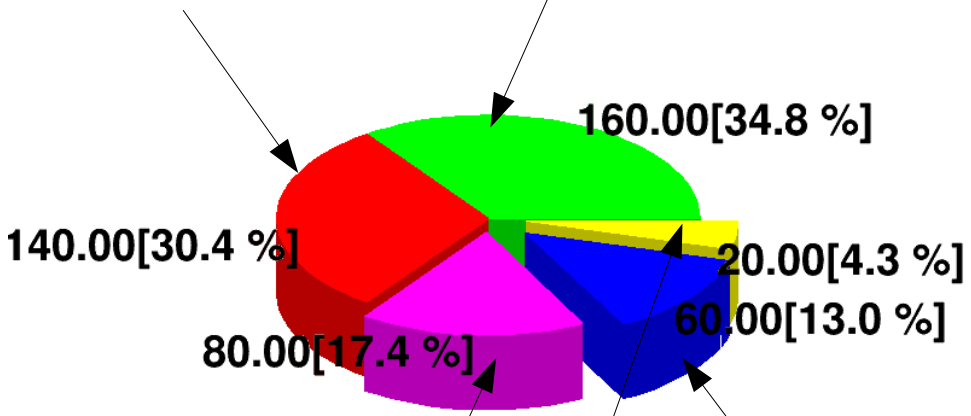
Crystal transmittance before and after irradiation



Rejection rate

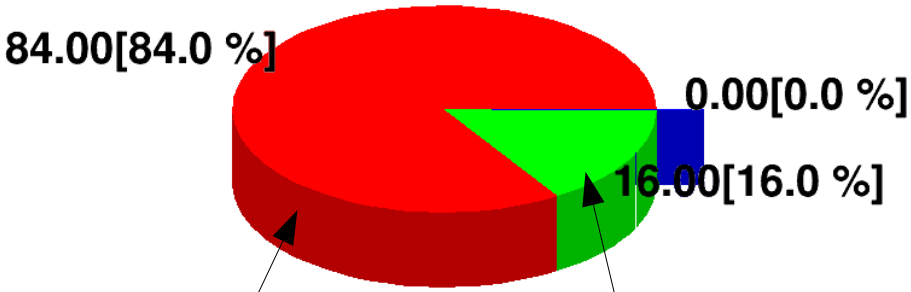
SICCAS

- Crystals with small defects
- Good crystals



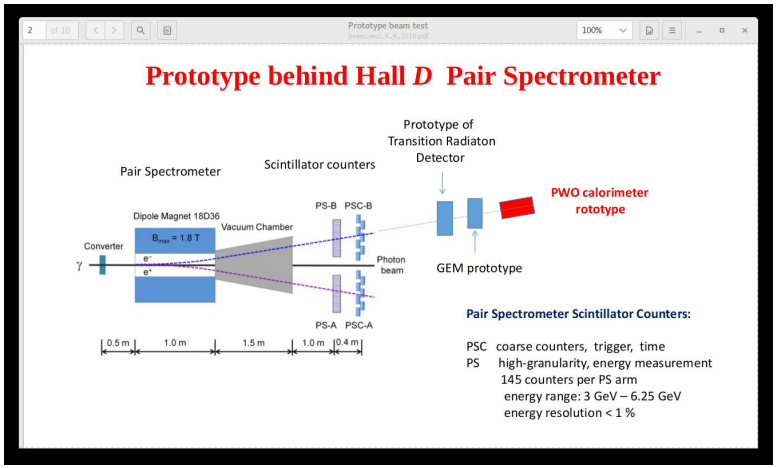
- LY and other defects
- Milky crystals, X-mas trees, Shabby
- Bad transmittance and visual defects

CRYTUR



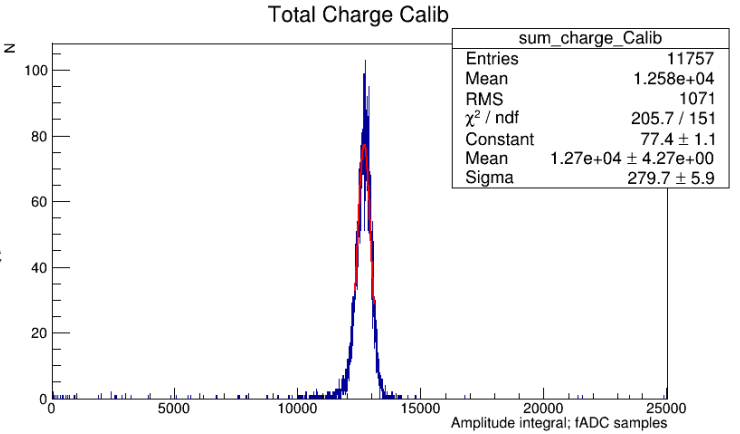
- Great crystals
- Some negligible defects (chips, scratches)
- 0 rejected crystals

3x3 prototype beam test

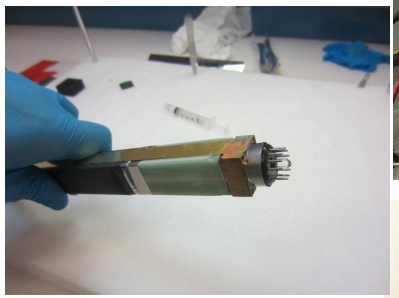


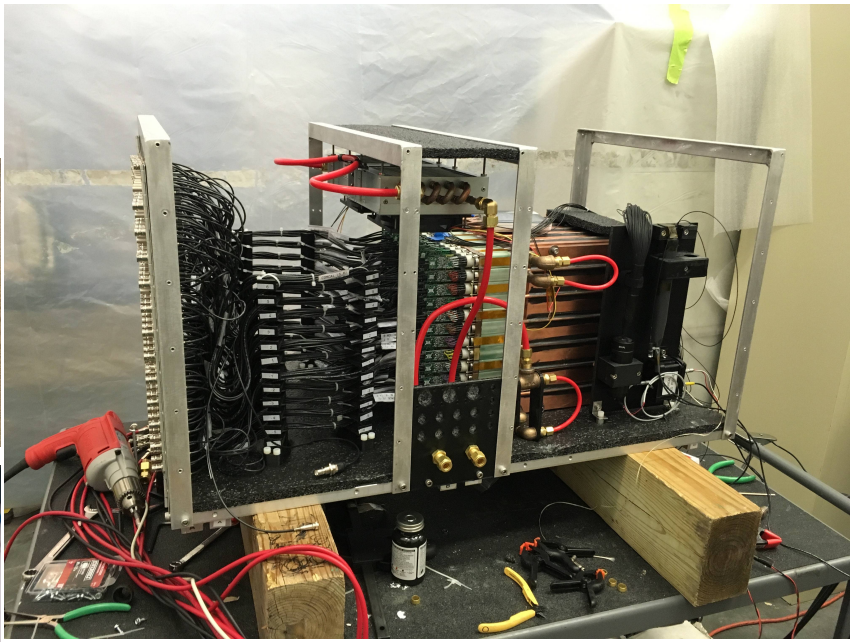
3x3 Prototype tested in HallD during spring run 2018

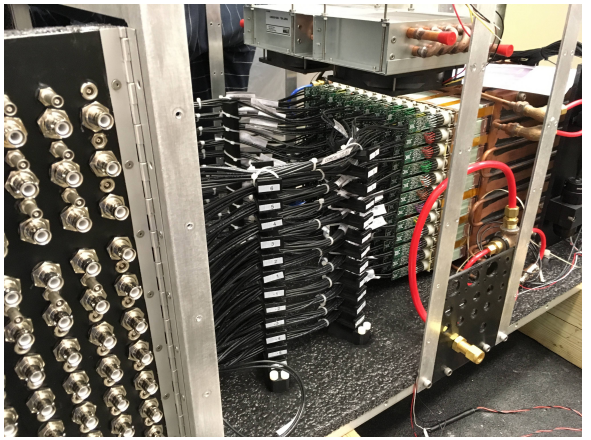
- Integrated into HallD global DAQ and data recorded with GlueX PS trigger
- Selected 4.6GeV electrons going through the center of the middle module
- HV was set to 750V to make sure FADC amplitudes were within 1V dynamic range
- σ(E)/E~2.2 %
- https://logbooks.jlab.org/entry/3563789



COMCAL/NPS prototype



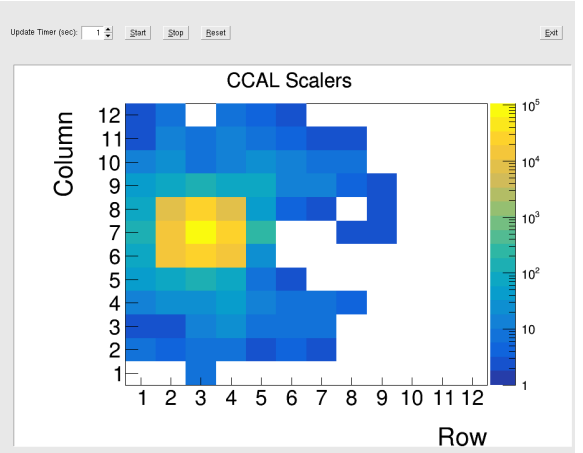




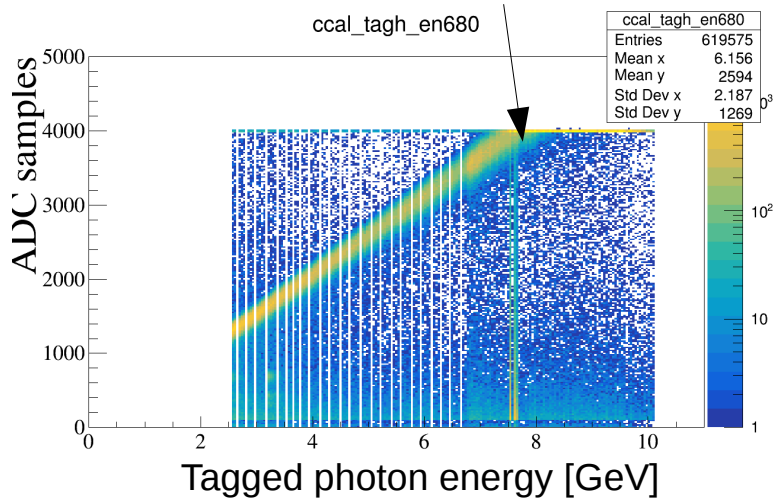
- 12x12 Matrix (140 crystals)
- Primex module assembly design
- NPS HV divider
- 250 fADC readout
- Environment control
  (temperature,humidity, light sensors)
- Water cooling (~17C)
- Monitoring system consisting of
  LED and α-source
- Moving platform
  (insertion into beam line for calibration)

Commissioning phase I. Low intensity photon beam

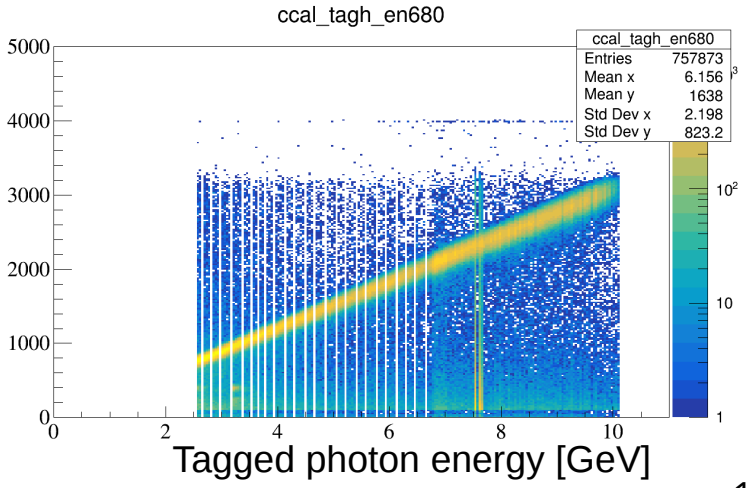
- Beam energy 10.3 GeV
- 1-3nA 5mm photon beam in center of each sell
- Position of the center of each cell with 1mm precision
- Tagged photons with ~0.4% energy resolution
- FADC saturation observed
- HV reduced to 650V (still saturate couple of channels)
- Data analysis is ongoing
- *See Alex Somov talk for details*
- https://logbooks.jlab.org/entry/3633958
- https://logbooks.jlab.org/entry/3639399



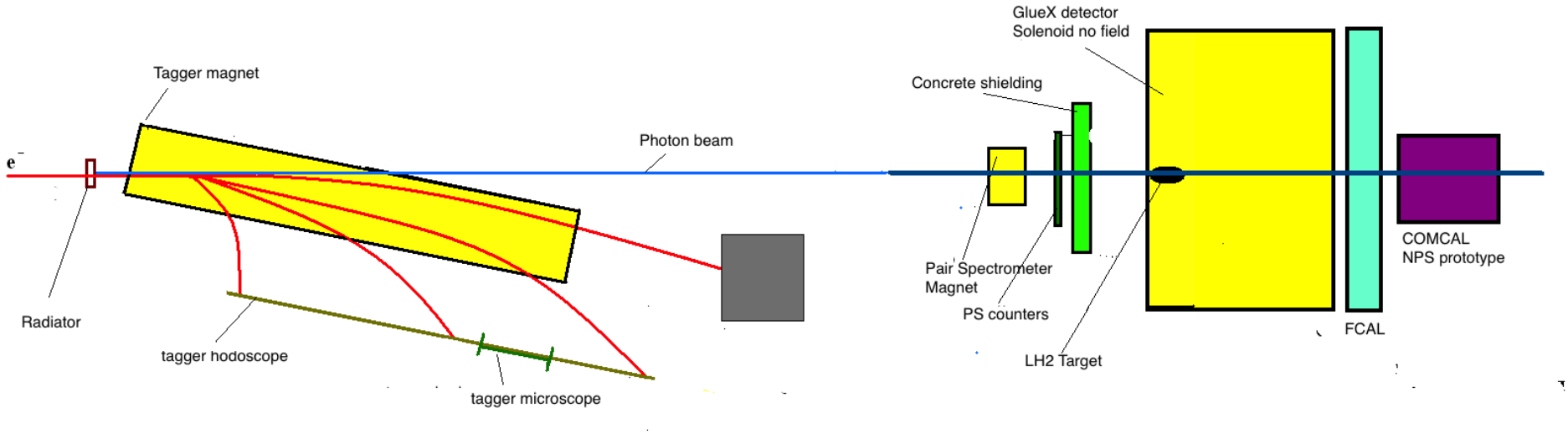
Saturation



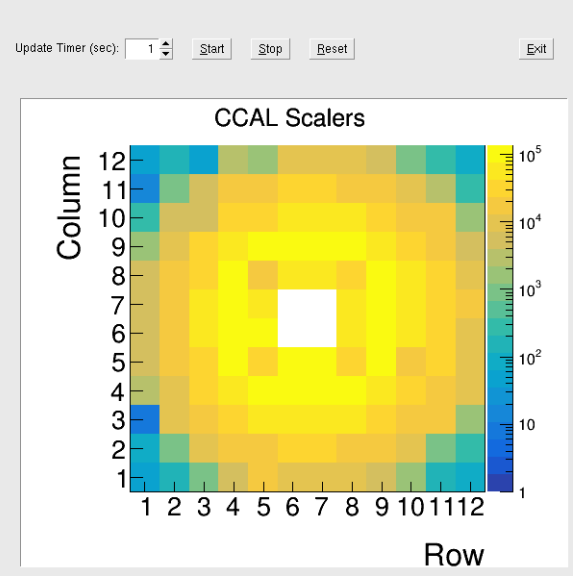
Good (HV adjusted) spectrum



Commissioning phase II. Production mode



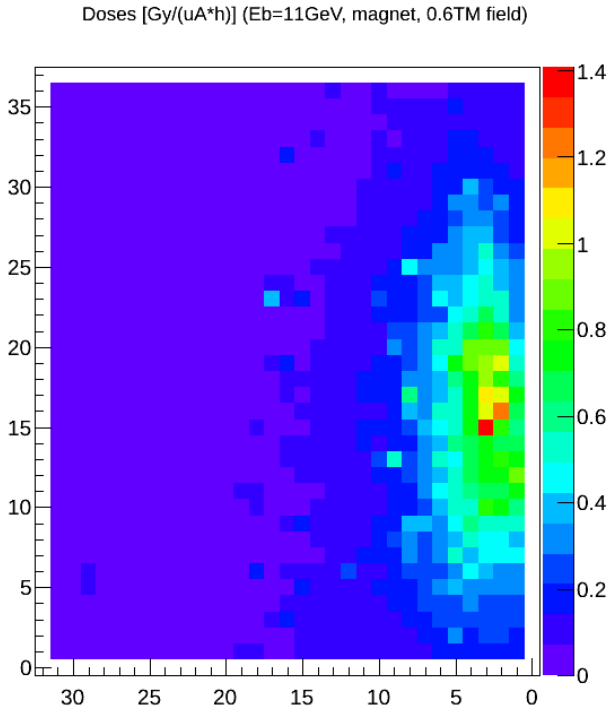
- Beam energy 10.3 GeV
- Amorphous 10^-4 R.L. radiator, 750 um converter, beam current (100 - 350) nA.
- PrimEx nominal current - 320 nA assuming runs with the 10^-4 R.L. radiator
- Trigger type: FCAL & CCAL, total energy deposition > 2 GeV
- Data analysis is ongoing
- *See Alex Somov talk for details*
- *https://logbooks.jlab.org/entry/3635391*



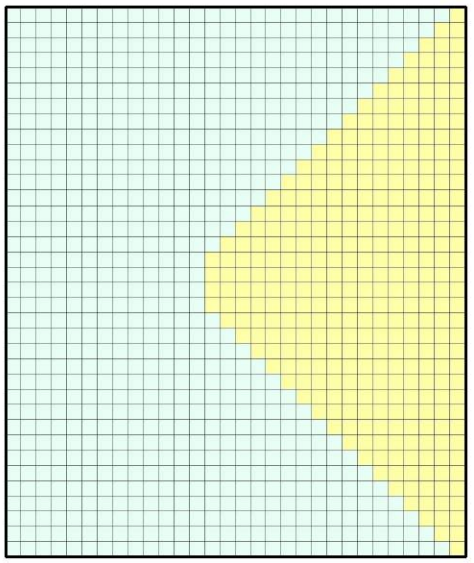
Path to completion

SICCAS	**CRYTUR**
+460 (received)	+100 (received)
- 160 (rejected, sent back)	- 0 (rejected)
+ 160 (replacement, waiting for delivery)	
- 145 (to HallD Comcal)	
315	100
400 (next order wait for SICCAS sign)	250 (ordered) 20 on the way 200 (FY 2020 ?)

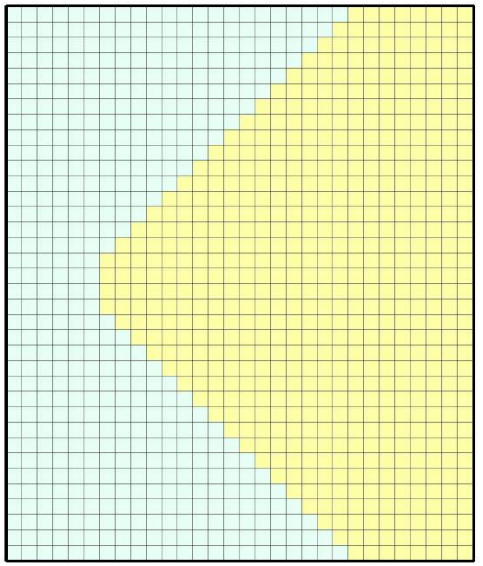
Possible stacking options according to simulated dose rate



340 CRYTUR + *740 SICCAS*



592 CRYTUR + *488 SICCAS*



Figures by Hamlet and Vardan

Summary

- Received 460 crystals from SICCAS and 100 from CRYTUR
- QA methods is established and experience gained
- Characterized SICCAS and CRYTUR crystals, feedback to vendors
- More crystals purchased, expected delivery starting summer 2019
- Prototype including real readout system and temperature monitoring assembled and tested with photon beam in HallD
- Developing analysis/calibration software for prototype beam test program
- Continue prototype data taking and data analysis to determine calorimeter actual performance parameters