

MiniDIRC

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DIRC Collaboration Meeting, 6-June-2026

Interaction Region for a Second EIC Detector

Downstream Ion Focus

- Proposed beamline for a second EIC detector includes a high-dispersion focus in the ion beamline 45m downstream from the IP.
- This enables detection/tracking of ions with magnetic rigidity deviating as little as $\pm 1\%$ from beam rigidity. This is an order of magnitude greater acceptance than the IR-6 beamline for ePIC
- Goal: prove the principle that a high precision (thin SiO_2) Cherenkov detector could identify the charge of any ion from proton to uranium detected by the tracking detectors at the 2nd focus.
 - For any beam ion $A > 1$, protons will not read the second focus, but deuterons will
- Nuclear fragments reaching the Roman Pot detectors are essentially spectators, traveling at beam velocity.
 - Beamline spectrometer analyzes magnetic rigidity, which essentially separates fragments by A , but not Z .

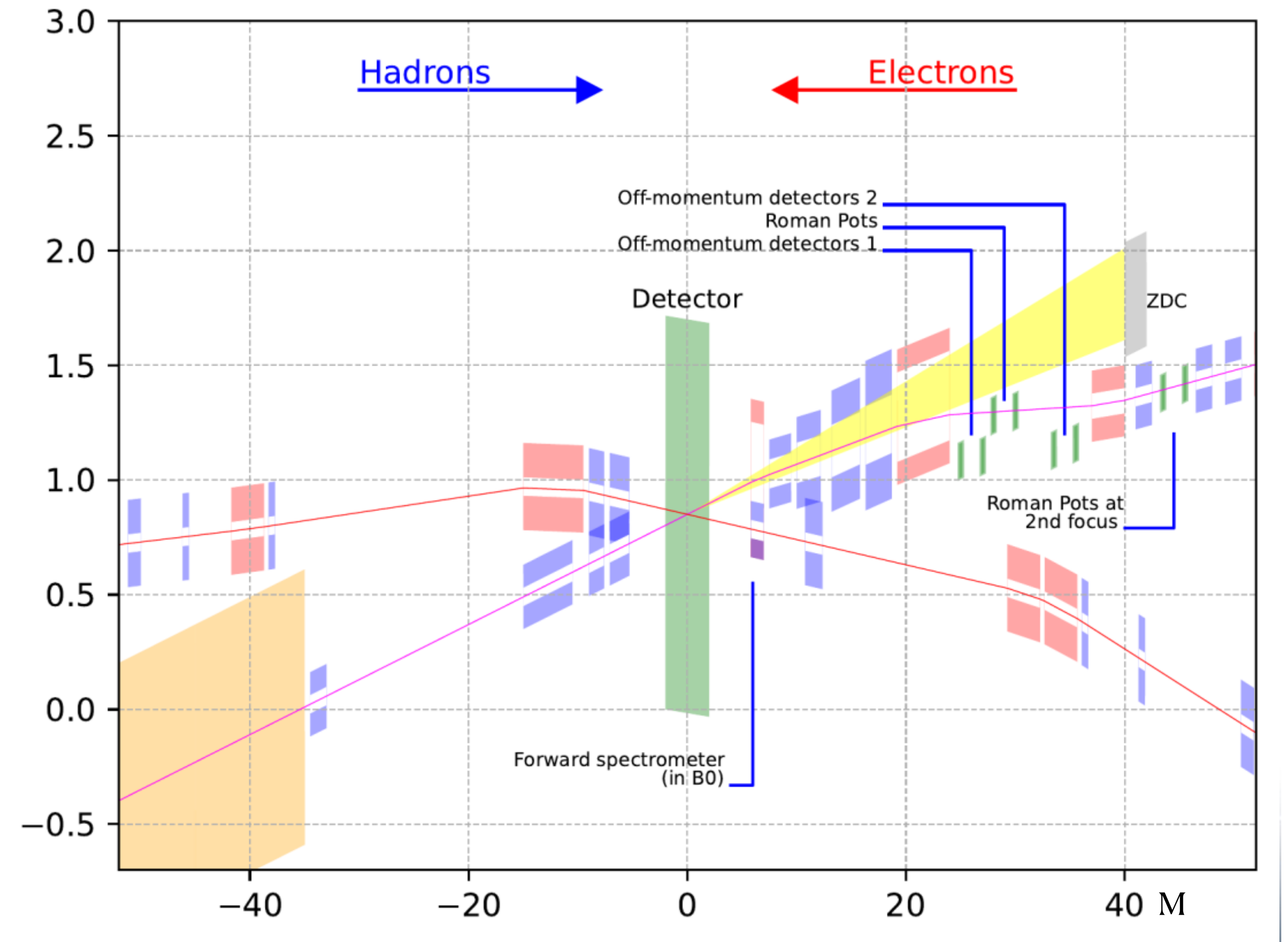
IR-8 Layout

Preliminary

Second Focus
 $D_x = \text{Dispersion} = 0.48 \text{ m}/100\%$
 $1-x_L = \pm \text{Beam-Stay-Clear} \leq 1\%$

Parameters at the 2nd focus for different energies

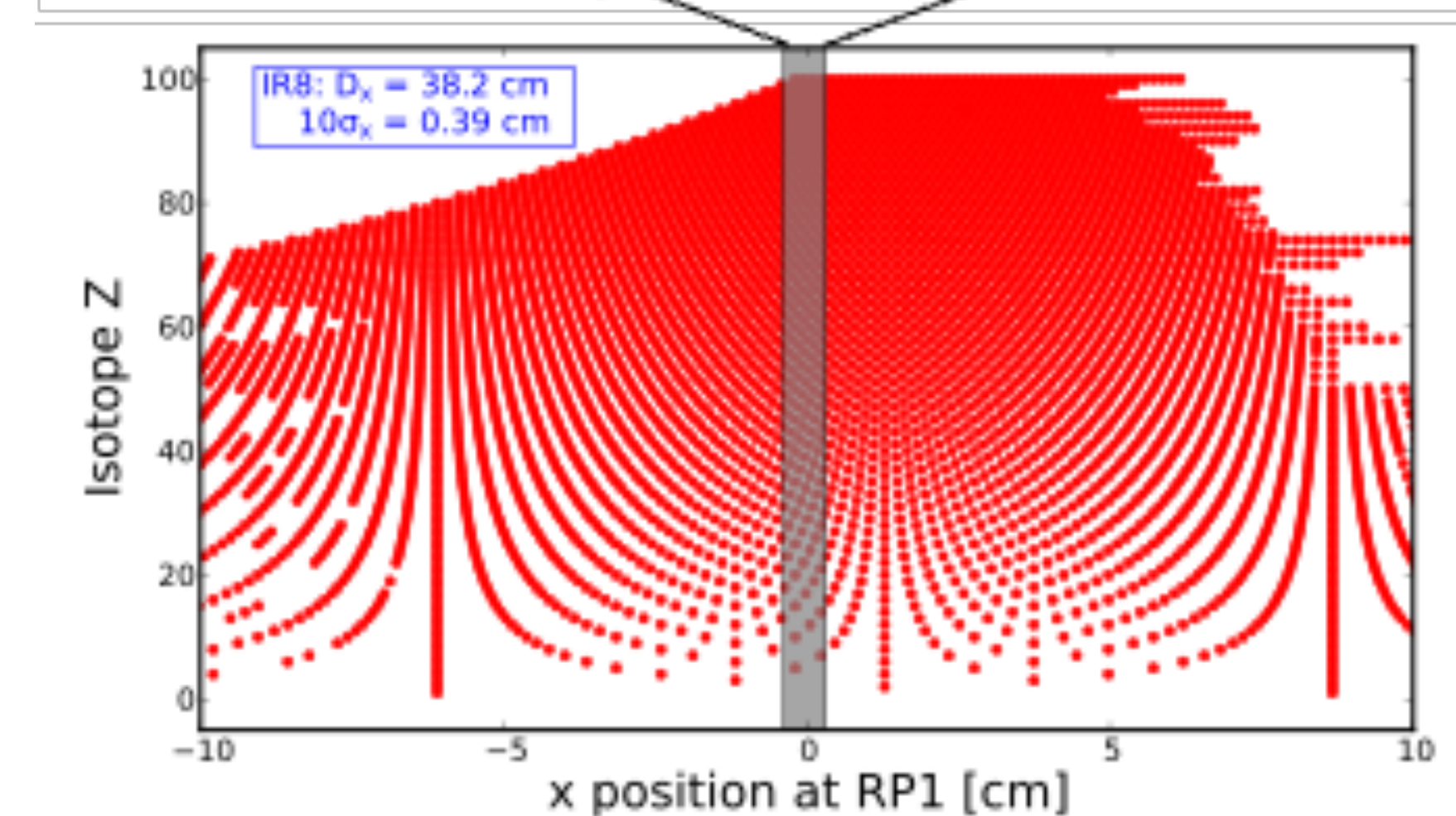
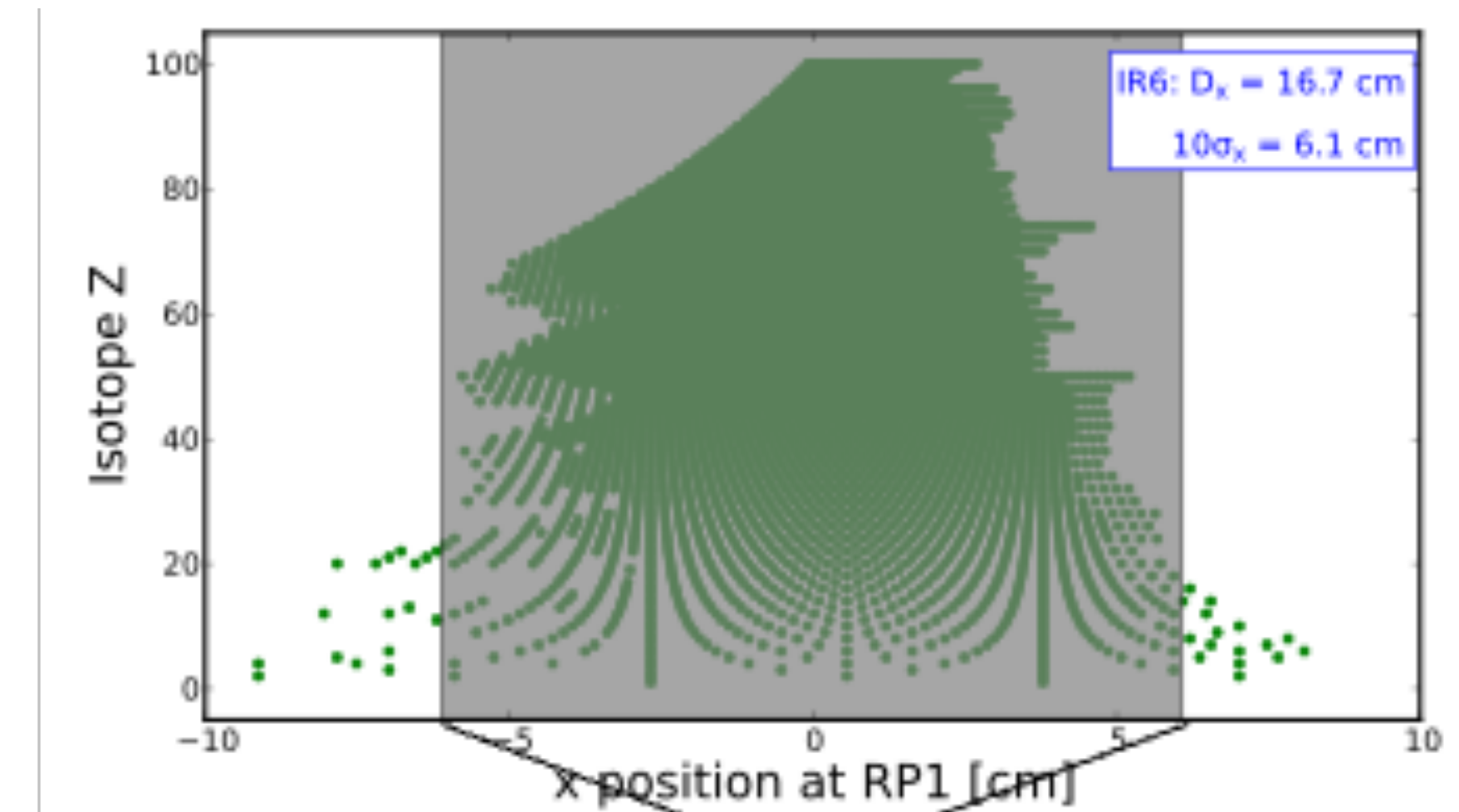
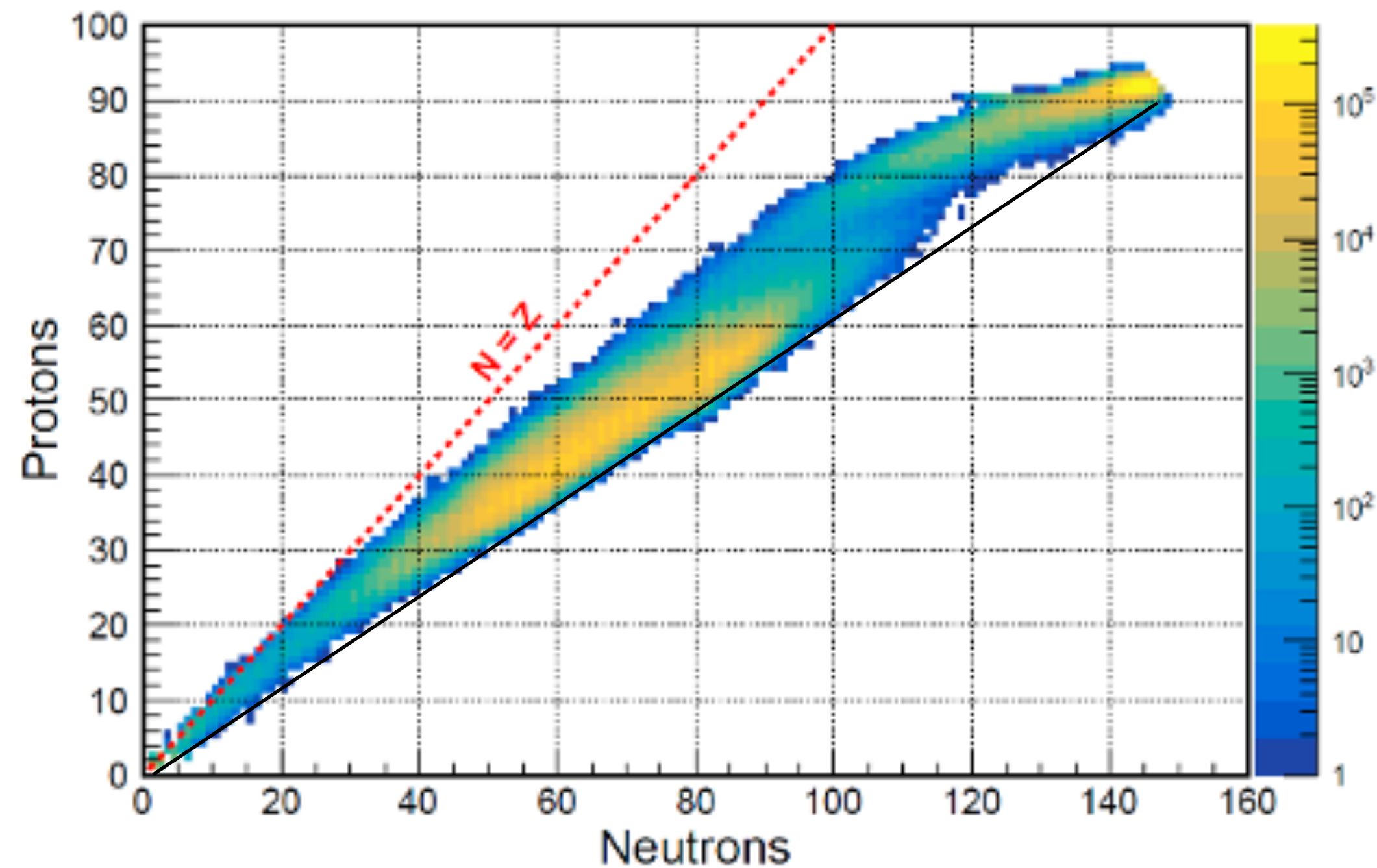
Parameter	Value at			Units
	41 GeV	100 GeV	275 GeV	
β_x	0.85	0.8	0.5	m
D_x	0.48	0.48	0.47	m
ϵ_x	44	30	11.3	nm
$\sigma_\delta (10^{-4})$	10.3	9.7	6.8	-
$1 - x_L (10^{-3})$	4.16	10.2	7	-



Fragmentation Study

Brynna Moran, MS Thesis, SBU

- Ion Fragmentation from $^{238}\text{U}(e,e')$



Fission Fragments mostly both on same side of beam

Magnetic Rigidity

Tune of Ion Ring

- Protons have momentum P_0 , Rigidity $K_0 = P_0/1$

- Ion ring is tuned to magnetic rigidity

- $K_0 = K_A = P_A/Z$

- $P_A = Z P_0$

- $P_A/A = (Z/A) P_0 \approx 0.4P_0$ for ^{208}Pb

- Daughter ion $^{A'}Z'$

- Spectator, $P_{A'} \approx \frac{A'}{A} P_A = A' \frac{Z}{A} P_0$

- Rigidity: $K_{A'} = \frac{1}{Z'} P_{A'} = \frac{A' Z}{Z' A} K_0$

Examples ^{208}Pb

$$Z'=81, A'=207 \implies K' = 1.007 K_0$$

$$Z'=82, A'=207 \implies K' = 0.995 K_0$$

$$Z'=82, A'=206 \implies K' = 0.990 K_0$$

Rates

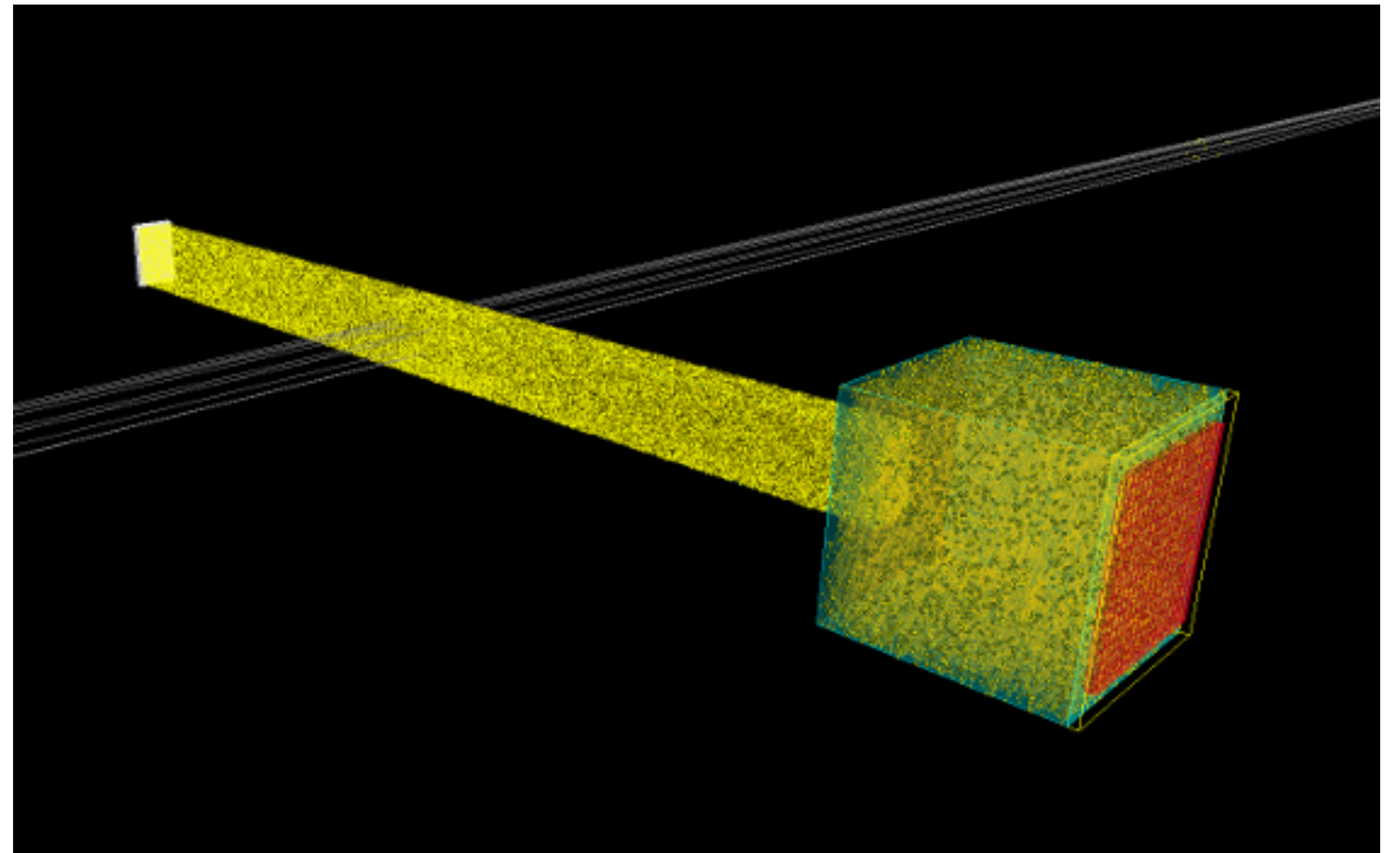
My estimates, a few years old

- At maximum eA design luminosity
 - Project photo-nuclear rate from eA collisions at IP (mostly nuclear GDR)
 - ~ 500 KHz
 - I don't recall if there is much A -dependence to this rate.
 - Background rates from beam gas collisions are less, and mostly from beam gas region after FFQ

Initial MiniDIRC Studies

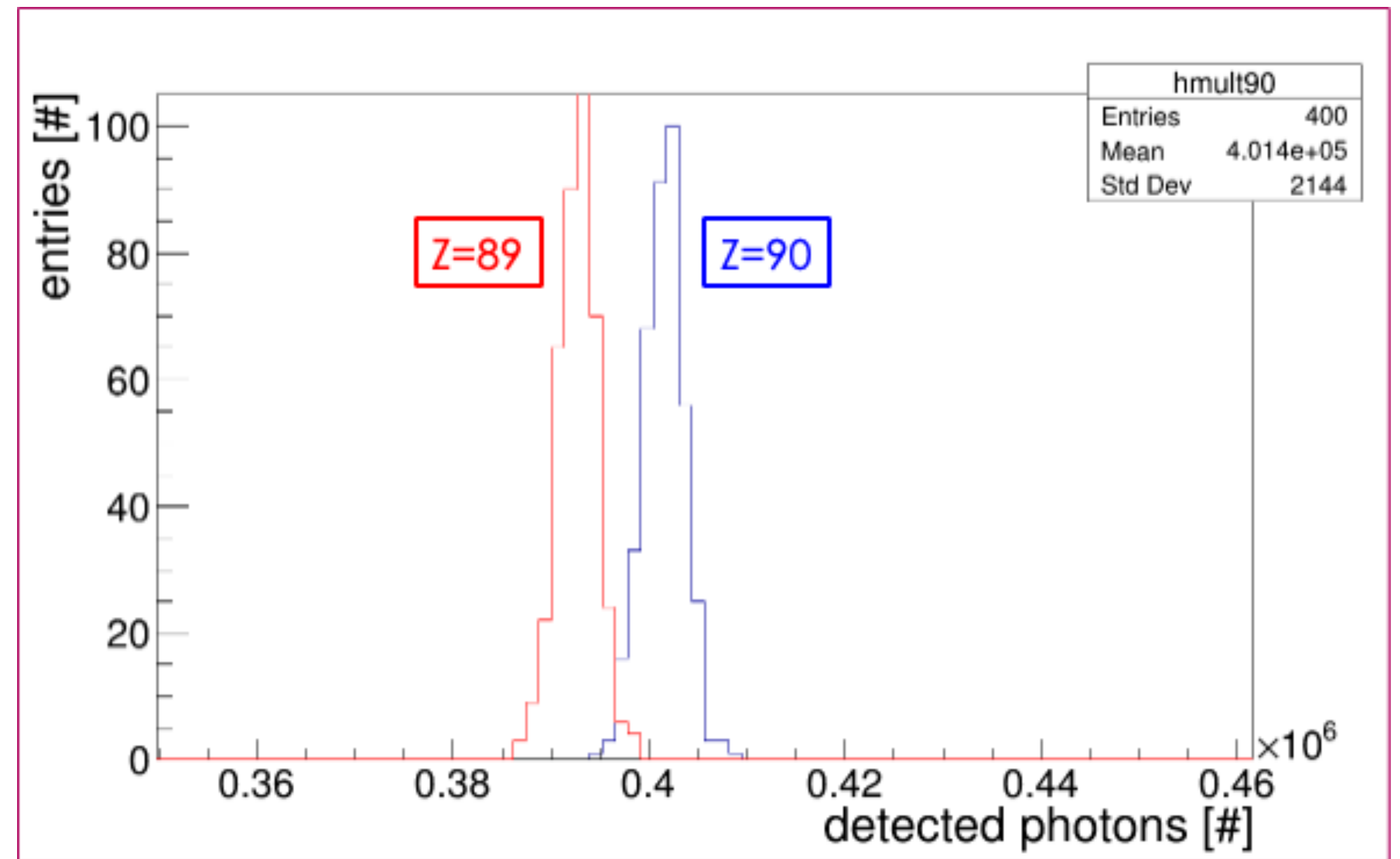
Completed Oct 2024

- Roman Dzhygado minidirc simulation code
- SiO₂ Radiator
 - 6x10x150 mm³
 - Photon yield $\propto Z^2$
- Expansion volume (25 mm)³
- Photosensor 20x20 mm²



Simulation of $Z=90$ & $Z=89$ daughter ions

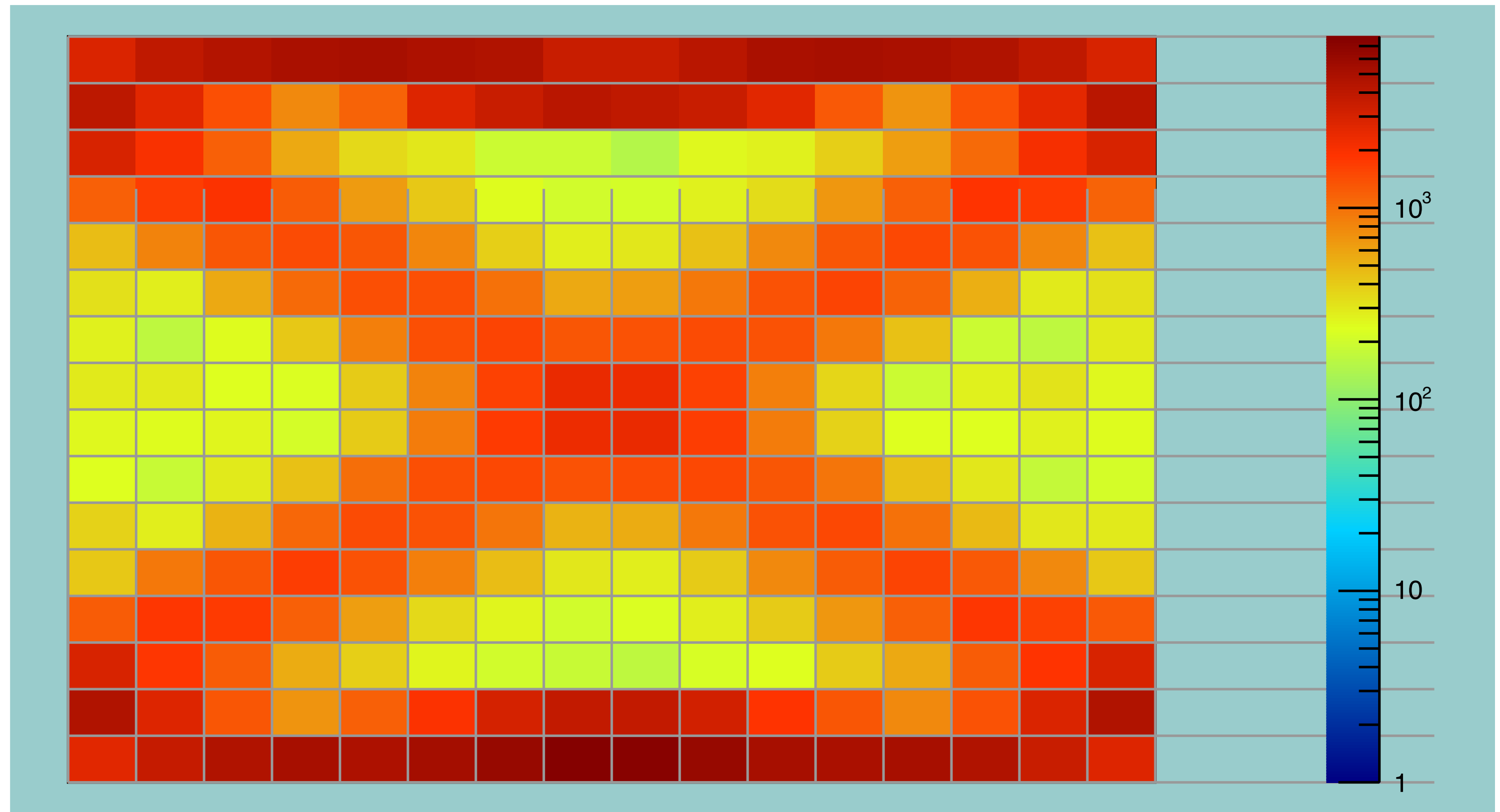
- Detected phot-statistics cleanly separate the two species
- Follow-up studies required
 - Z^2 production of delta-ray secondaries not considered
 - Saturation of photo-sensor pixels



Variations in Expansion Volume

AuraTek MCP

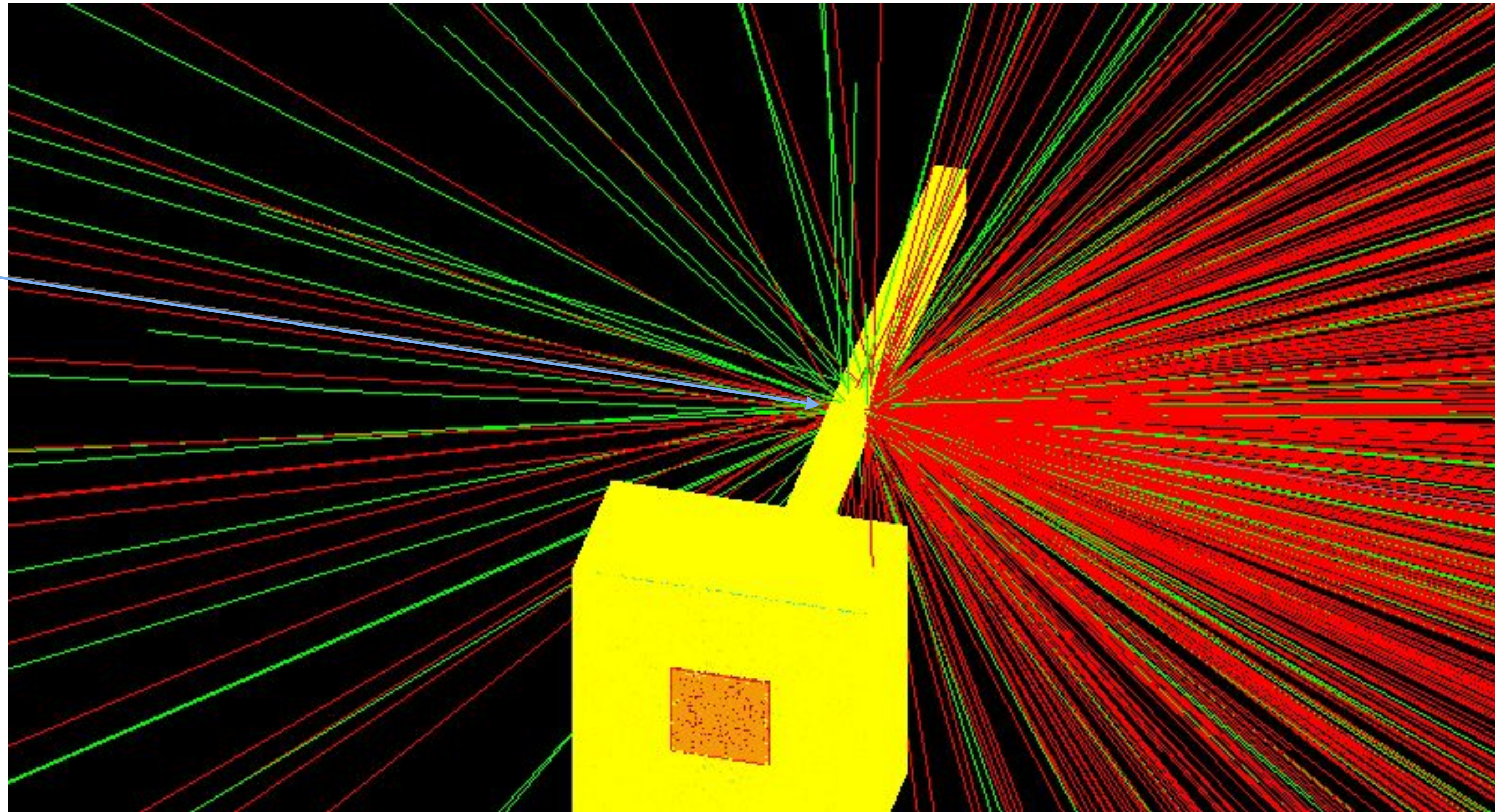
- EV 25x55x55 mm³
- Up to 6000 p.e. per pixel
- Hits strongest at edges (reflections?)



Delta-ray secondaries from ionization

`./mdirc -w 3`

- Huge number of secondaries (probably most below Cherenkov threshold)
 - Increase in light yield
 - Broadening of light yield statistics
 - $Z=89/90$ separation > 3 -sigma



Photosensors

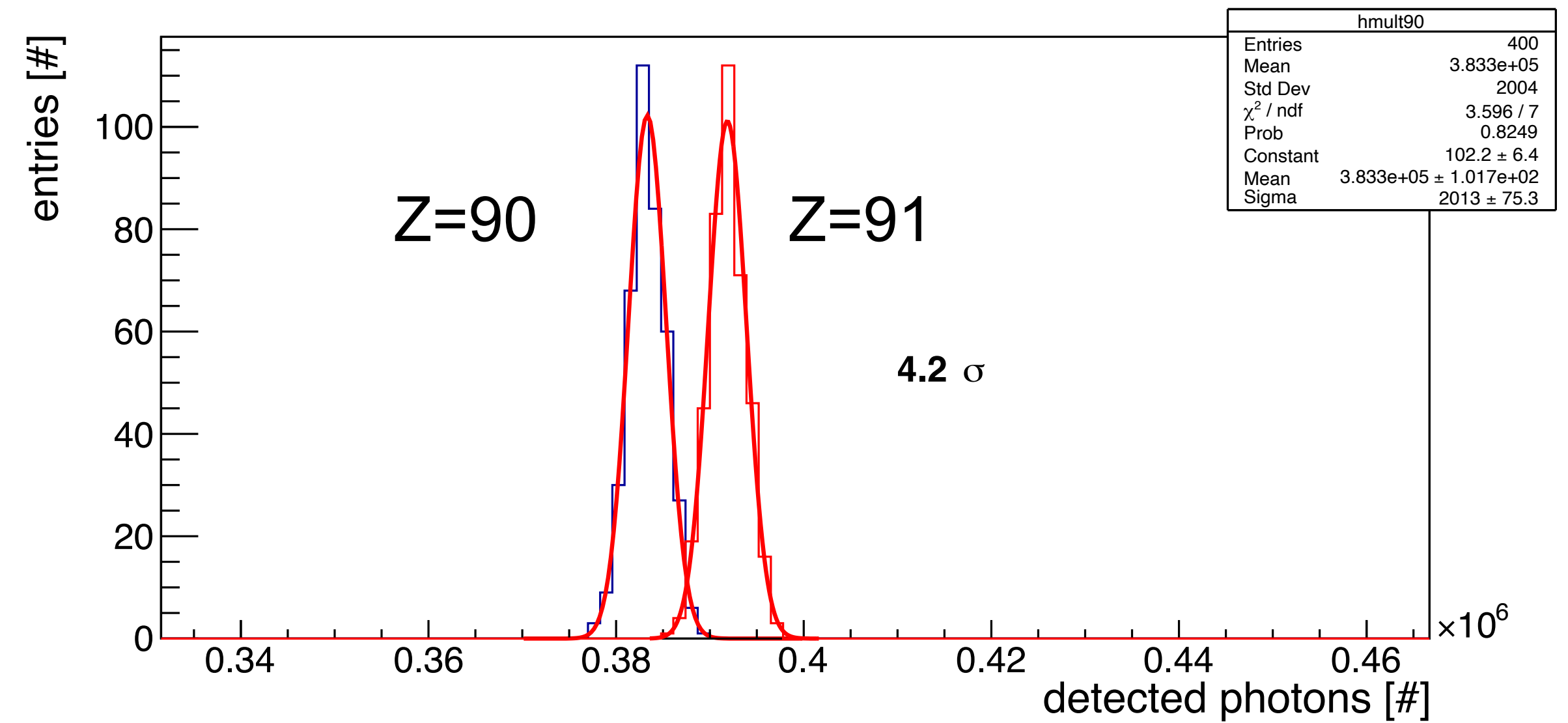
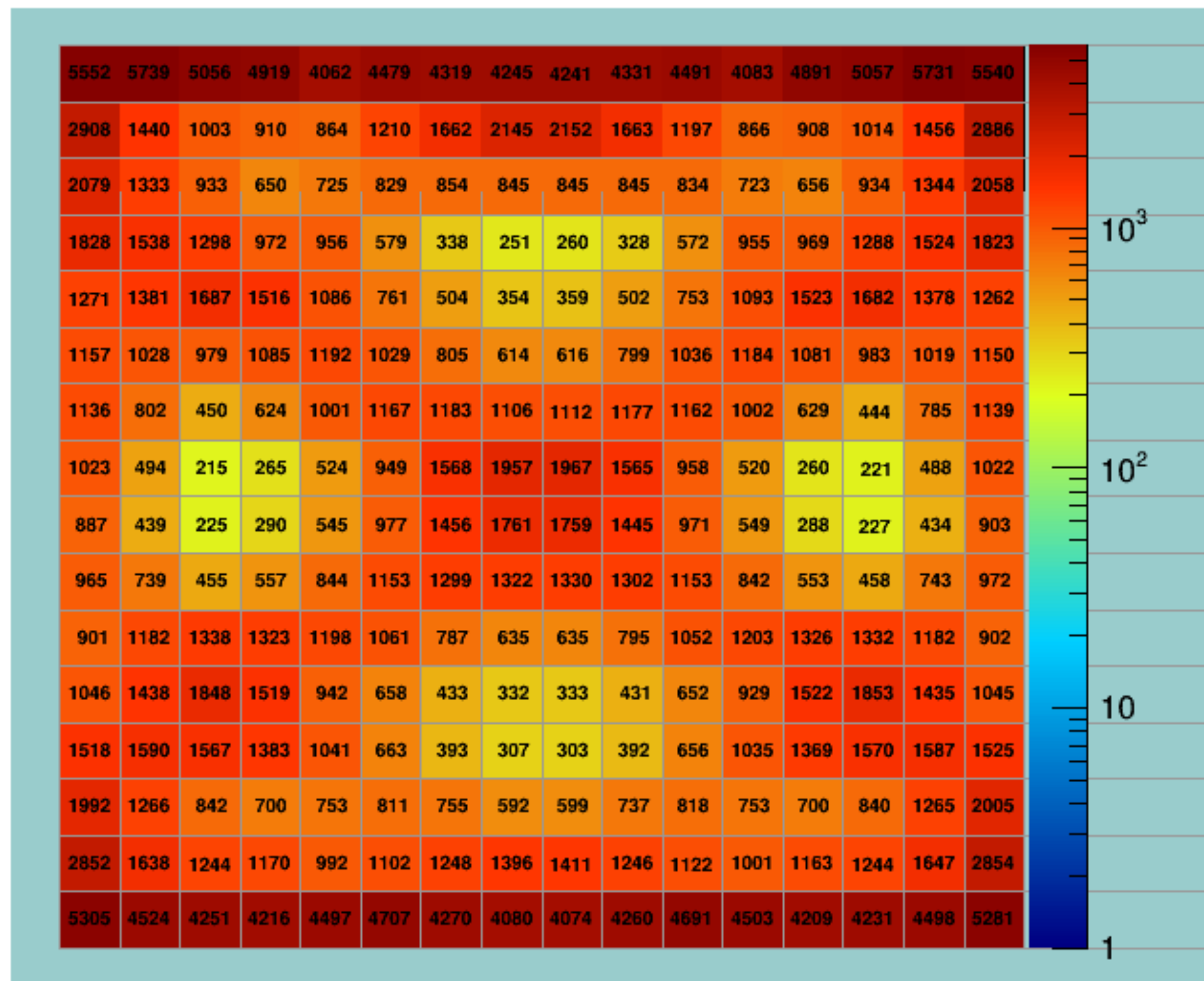
Hamamatsu MPPC/SiPM

- S14161-3050HS-08
 - 8x8 array of 3x3 mm² pixels compatible with tiling, 74% fill factor
 - $50 \times 50 \mu\text{m}^2$ micro pixels (3150 out of nominal 3600 per pixel)
 - Overall size 25.8 x 25.8 mm²
- S13360-25
 - Single 3x3 mm² pixel module with 14400 micropixels (25 microns),
 - 5.9 x 6.5 mm² external size: 47% fill factor
 - Lower fill factor is not an issue since we have an 'excess' of photons.
 - Higher micro pixel density to reduce saturation effects

Variation in EV

30x60x60 Internally Reflective Faces

- No saturation effect applied
- Maximum Pixel occupancy 4700 p.e
 - Driven by reflections?



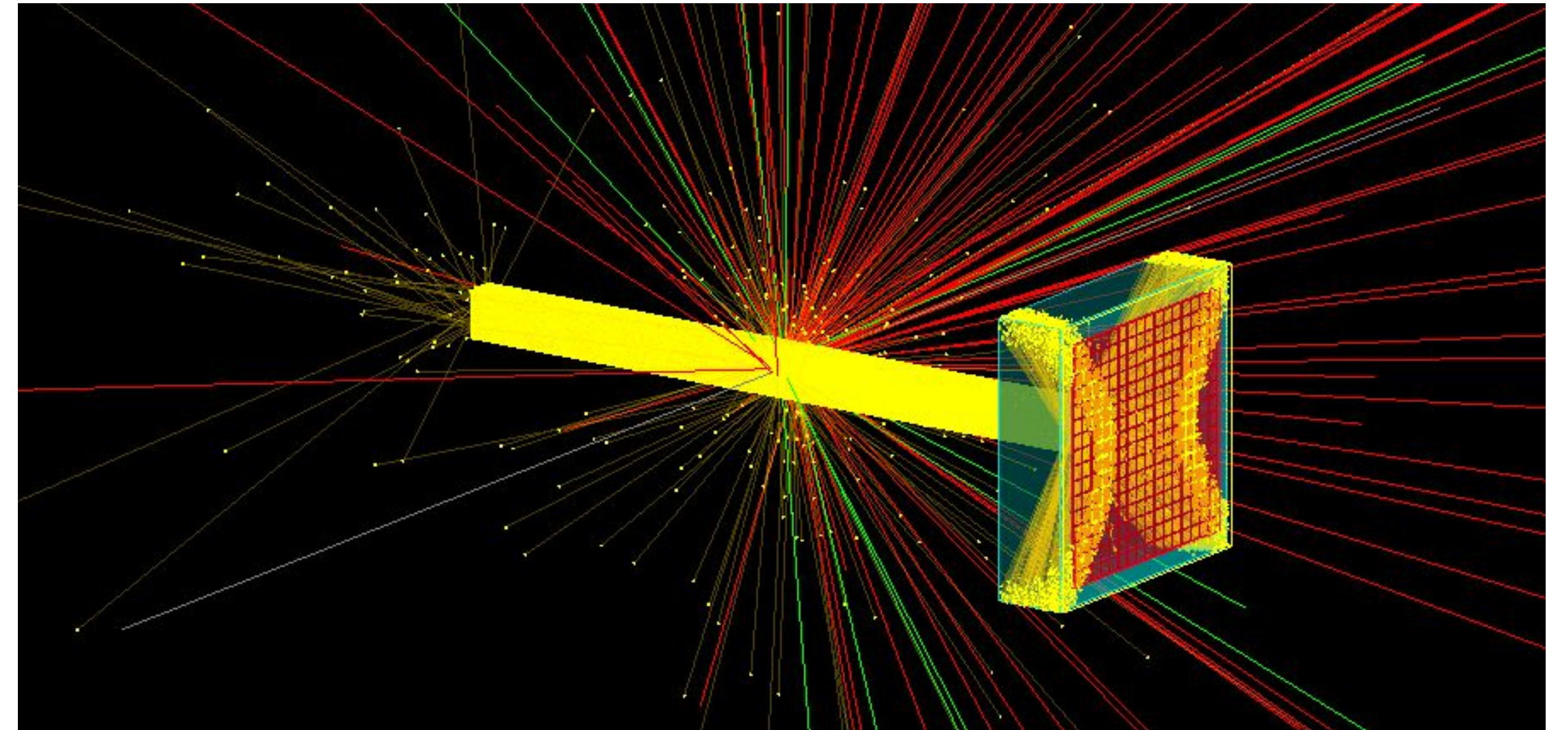
Includes secondaries

-w 3

Variation in EV

15x60x60 mm³

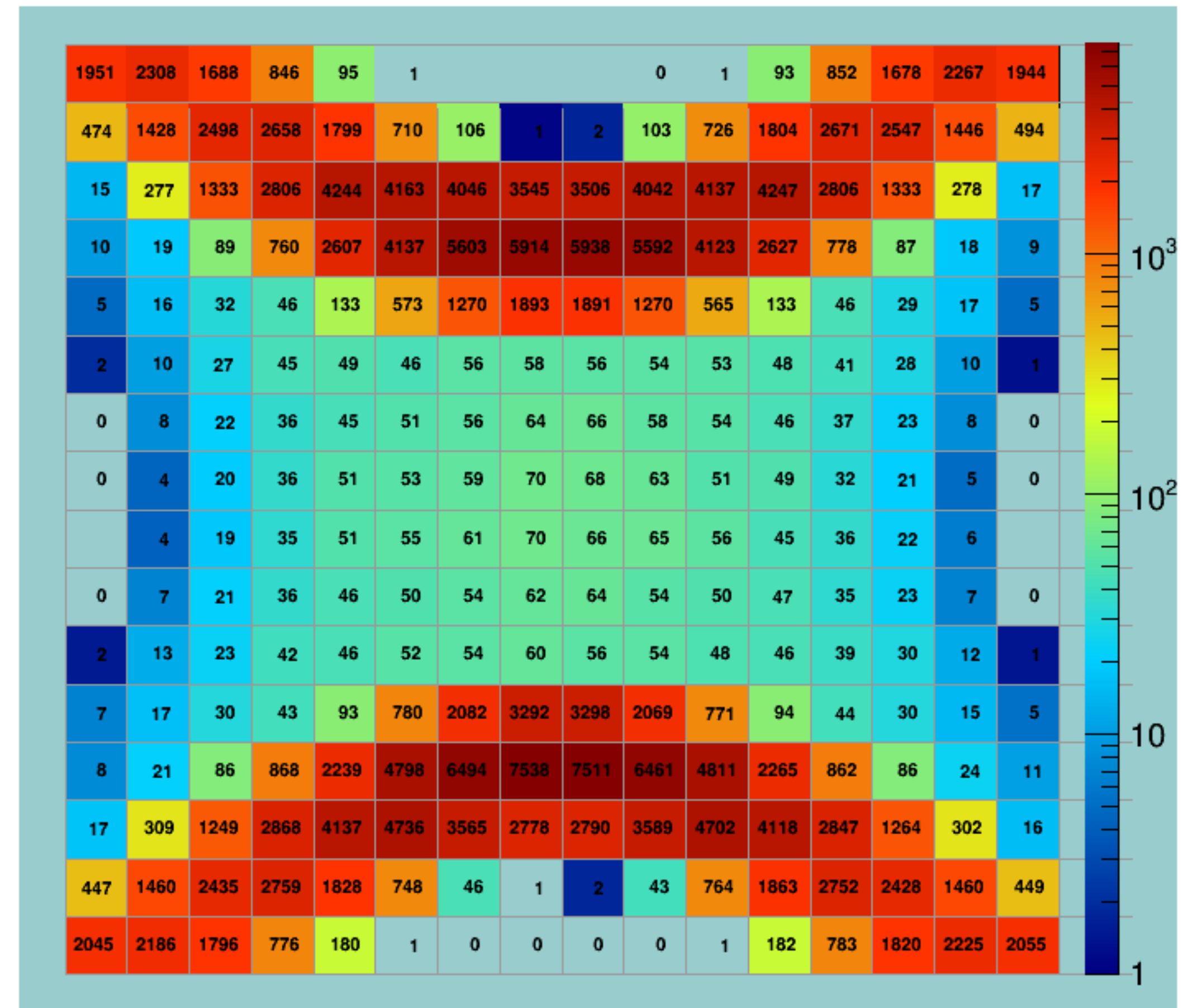
- Short EV: Naively expected this to suppress reflections on sides
- However, this is not the case, so made the sides black
- Example of Z=40 ion
 - Black EV illustrates first bounce
 - Large number of photons emitted near vertical plane



Z=90 Hit Pattern

EV 15x60x60, black

- Up to 7500 photo-electrons in a single pixel (only 3150 micro-pixels)
- Possible solutions
 - Change EV to better diffuse illumination
 - Apply optical filter to reduce photon intensity x10.
 - This would be OK for everything from He to U, but would reduce Deuterons to ~4 p.e.
 - Put optical filter only on top half
 - Top half for heavy ion fragments
 - Bottom half for ultra-light fragments, will saturate for heavy fragment events. Is this a problem for sensor lifetime?



Simplistic Saturation Study

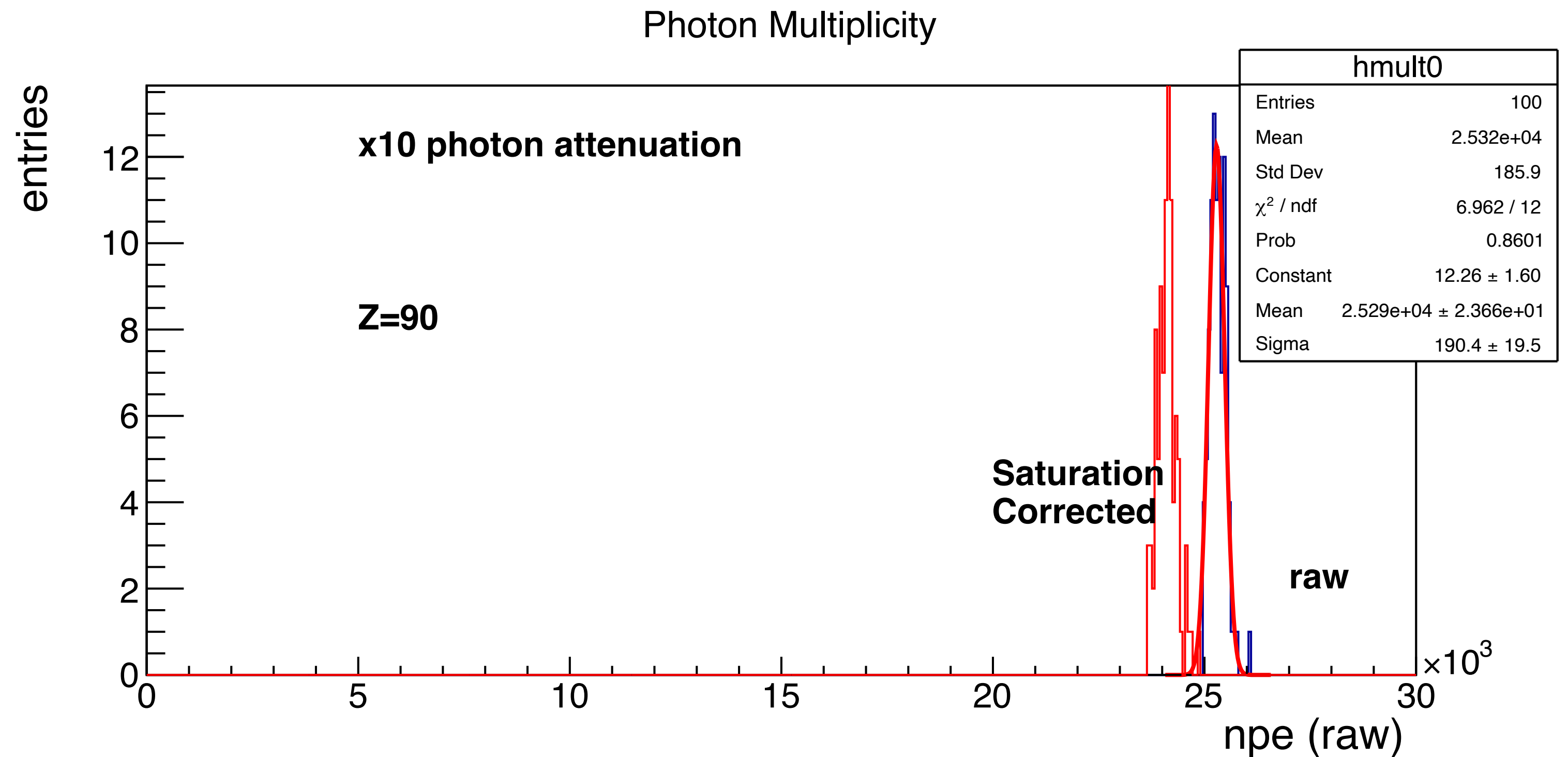
Binomial distribution

- Given M p.e. uniformly produced in N micro-pixels
 - Probability of m p.e. in one micro-pixel is Poisson $e^{-\mu} \mu^m / m!$ with $\mu = M/N$
 - Probability of $m > 0$ is $p = 1 - e^{-\mu}$
 - The SiPM amplitude distribution is Binomial $p^n (1 - p)^{N-n} \frac{N!}{(N-n)! n!}$, where n is the effective number of photo-electrons (signal = $n \cdot \text{Gain}$)

Saturation Example

Saturation study with factor of 10 attenuation of photons

- Z=90 Example
 - (Mean, σ) = (25290, 190) shifted to (24094, 230)
- Repeat for Z=91, compare saturation multiplicities
 - 3.2 σ separation of Z=90,91 reduces to 2.3 σ



Outlook for Simulations

Variations in EV and Photosensor

- Regular (internally-reflective) surfaces vs black sides of EV?
 - How to reduce concentration at edges (slide 9)?
 - Defocussing lens?
- Shrink EV area to more closely match photosensor?
- Suggestions?
 - Split EV into 4 quadrants to enhance dispersive quality of reflections
 - Diffusing filter or surfaces
 - Filter to reduce photon intensity
 - Lower fill-factor SiPM with 4x higher micro pixel density
 - Dark current induced event-by-event fluctuations? What is integration time?
- SiPM/MCP lifetime (100 Coulomb?)?
- Report due in 2 months. Would like to expand to NIM article

Beam Tests?

Minidirc tests only needs ion beam energies > 1.3 GeV/nucleon

- Discussion to develop ion beam lines at AGS following RHIC shutdown
 - Space radiation effects (DOD, NASA interest)
 - Detector tests
 - Physics
 - Limited funding to BNL from DOD for feasibility study
- workshop announced for February 2025 then ~indefinitely postponed
 - Contact person at BNL: Xiaodong Jiang
 - Proposed beams proton ≤ 25 GeV, He - Bi up to 9.8 GeV/u
 - Long term discussions still ongoing with DOD/MDA
 - NSRL (Booster injector to AGS) ion beams up to 1 GeV/u

Prototype?

Funds still available from Generic R&D project

- Hamamatsu quote, \$6000 for SiPM array
 - Without DAQ, maybe better to try a single ordinary 2" PMT?
 - FEE to sum SiPM channels?
- DAQ?
- Specs for radiator (recent contact with Nikon and Chinese vendors)?
 - Parallelism to 2mr?,
 - Corner radii?
 - Smoothness criteria?
 - Thickness uniformity over e.g. separation of Z=90 & Z=91 fragments
 - spec 25 micron max thickness variation in 6 mm dimension
 - 0.05 to 0.1 mm chamfer on long edge of radiator?