F.RETIERE IN COLLABORATION WITH J.P. JANEZ (ALBERTA) AND D.GRANT (MICHIGAN)

HYBRID PHOTODETECTORS

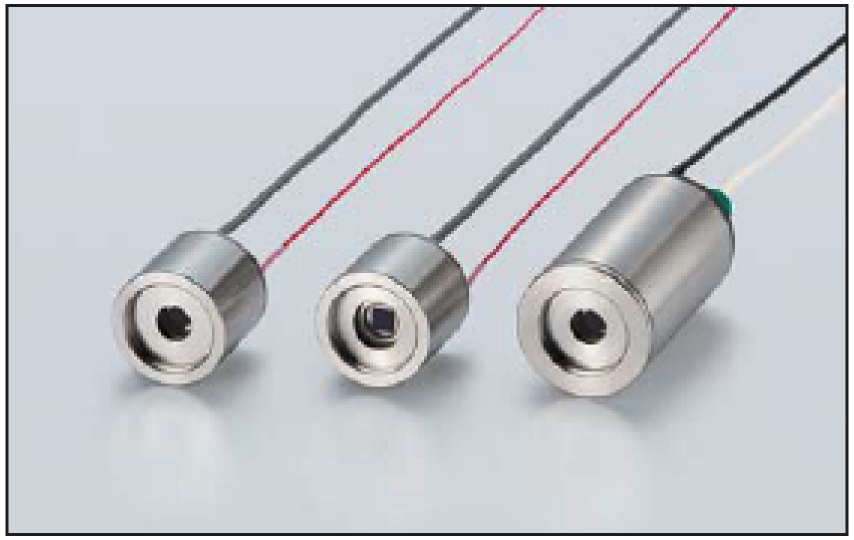
HAMAMATSU

PHOTON IS OUR BUSINESS

HIGH SPEED COMPACT HPD (Hybrid Photo Detector) SERIES R10467U SERIES / R11322U-40 / H13223-40

FEATURES

- High-speed response
- High time resolution
- High sensitivity
- Directly connects to the HPD power supply (R10467U-xx-01, R11322U-40-01, H13223-40)

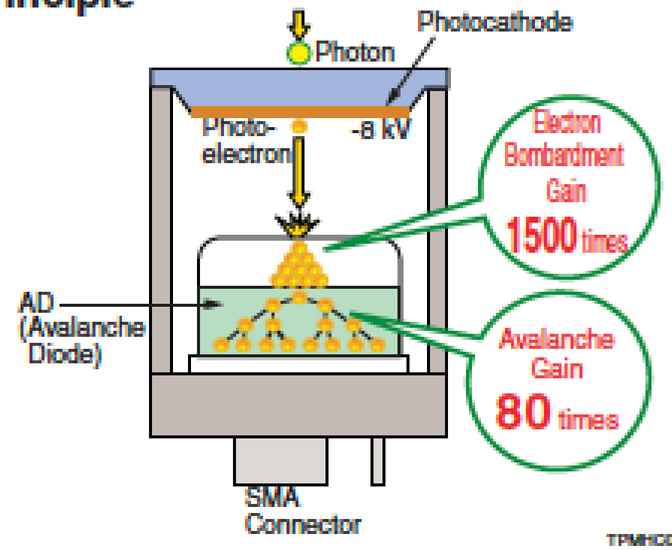


Left: R10467U-40, Center: R11322U-40, Right: H13223-40

APPLICATIONS

- Laser scanning microscope (Confocal / Two-photon)
- FCS (Fluorescence Correlation Spectroscopy)
- LIDAR (Light Detection and Ranging)
- TCSPC (Time-correlated Single Photon Counting)

■Principle



IMPRESSIVE PERFORMANCES ...

Parameter		R10467U-06	R11322U-40	R10467U-40 H13223-40	R10467U-50	Unit
Spectral response		220 to 650	300 to 720	300 to 720	380 to 890	nm
Photocathode	Material	Bialkali	GaAsP	GaAsP	GaAs	—
	Effective area	ϕ6	ϕ5	ϕ3	ϕ3	mm
Window material		Synthetic silica	Borosilicate glass			—
Window type		Plano-concave	Flat			—
Operating ambient temperature		+15 to +35				°C
Storage temperature		0 to +40				°C

MAXIMUM RATINGS

Parameter	Value	Unit
Photocathode voltage	-8500	V
Avalanche diode (AD) reverse bias voltage	Vb -10 *1	V
Average photocathode current	200	pA

*1: Vb is the AD bias voltage at the leakage current 1 µA. The voltage of Vb is from 300 V to 500 V.

SPECIFICATIONS (Typ.)

Parameter		Description / Value				Unit
Quantum efficiency		28 *4	45 *5	45 *5	14 *6	%
Gain *2		1.2×10^5				—
Time response	Rise time	400				ps
	Fall time	400				ps
	Width	600				ps
T.T.S. (Transit Time Spread) *3	FWHM	50	170	90	130	ps

*2: At the photocathode voltage of -8 kV and the AD bias voltage of Vb (breakdown voltage) -10 V.
*3: At the single photon state and the full illumination on photocathode, specified as FWHM (Full Width at Half Maximum).
These valves include the jitter of the electronics about 30 ps.
*4: At 350 nm *5: At 500 nm *6: At 800 nm

Except small area and large dark current

WHY HPD FOR ASTRO-PARTICLE PHYSICS?

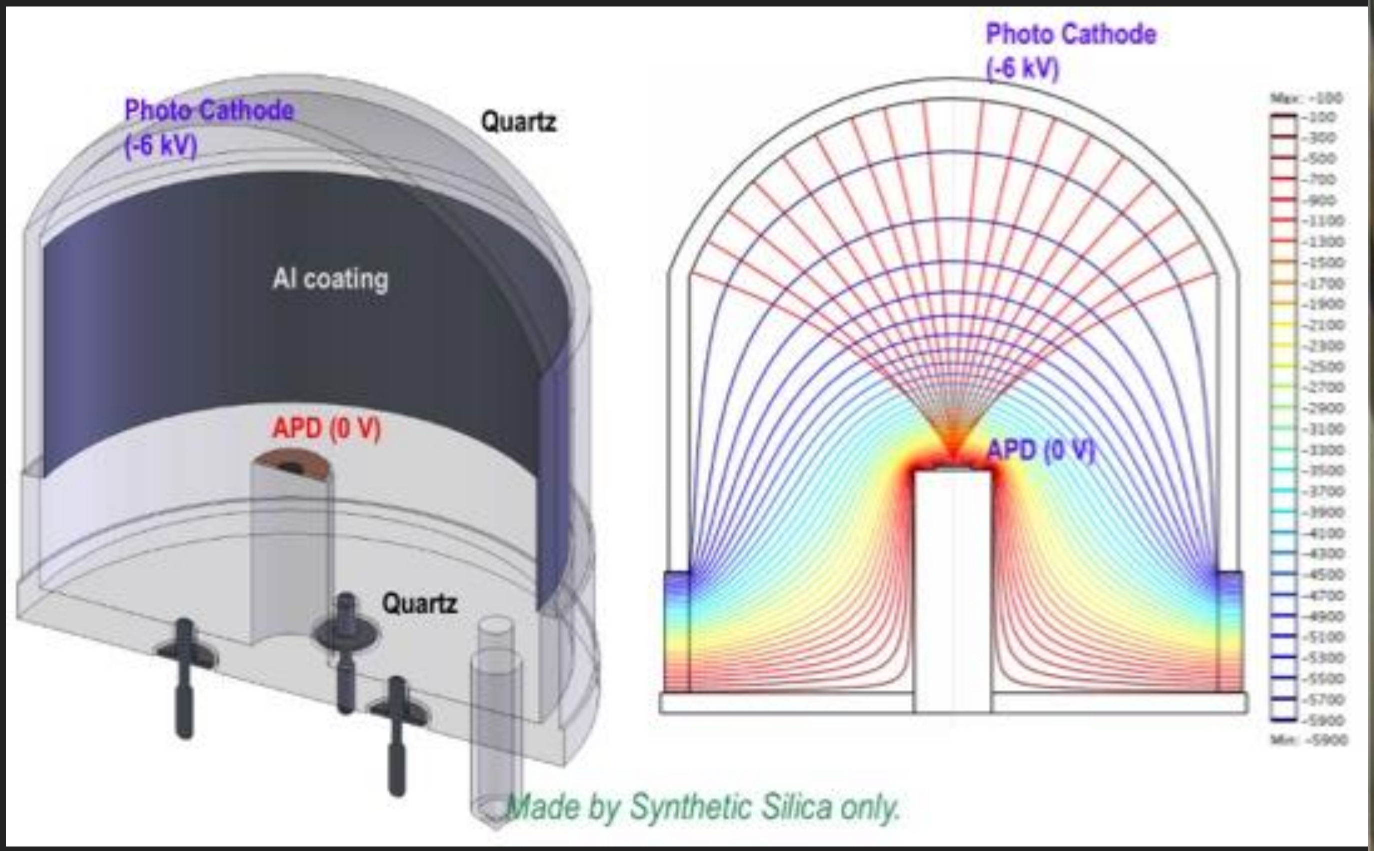
- Low dark noise at room temperature over large area
  - SiPMs are way too noisy for water Cerenkov and liquid scintillator
- Simplify the gain stage -> cheaper
- Smaller transit time spread
  - Easier to manage field line to a flat gain stage
- Possible imaging capabilities

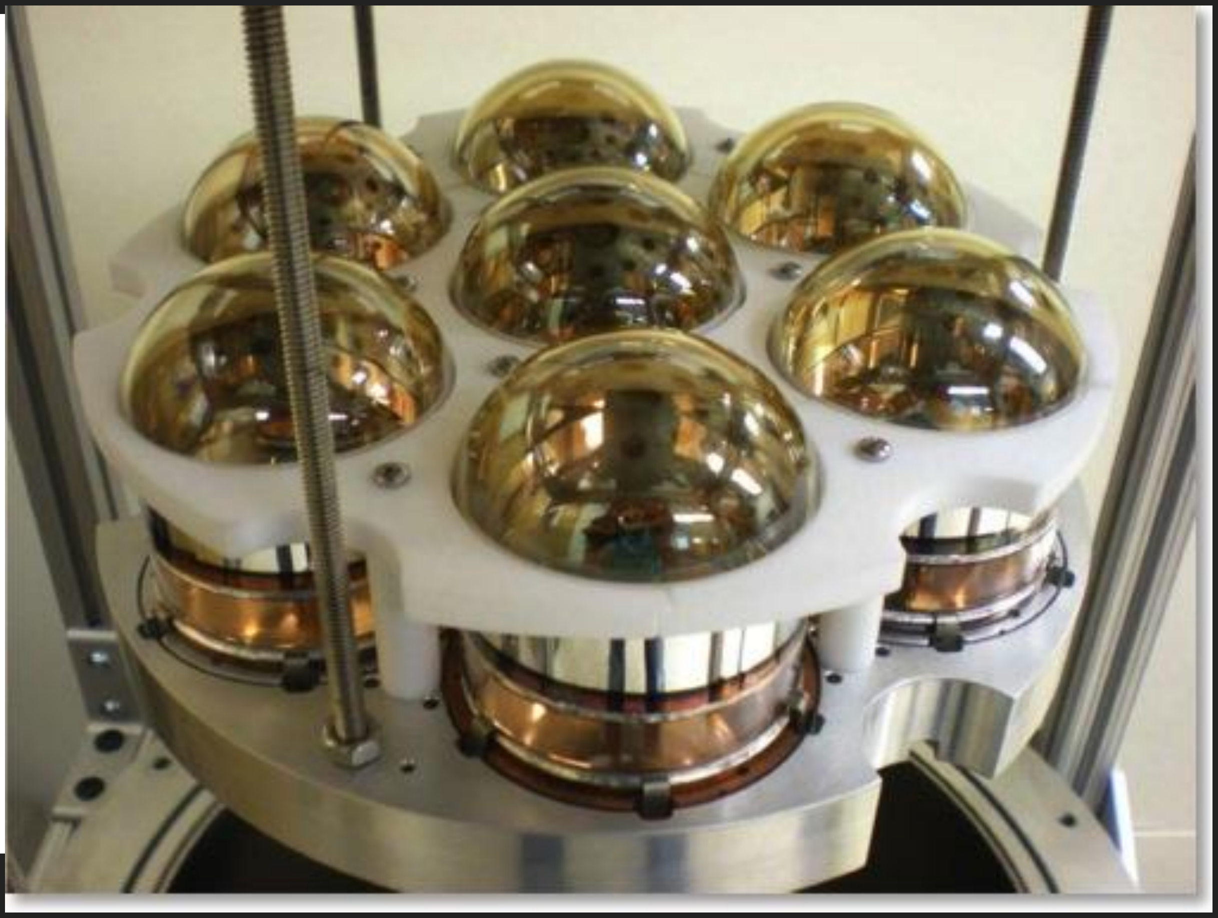
OUTLINE

- Other existing HPD
  - CUPID/SIGHT
  - Chinese PMT for JUNO
  - ABALONE
  - VSiPMT
- HPD development in Canada: the digital HPD

LOW RADIOACTIVITY HPD

- UCLA – Hamamatsu collaboration

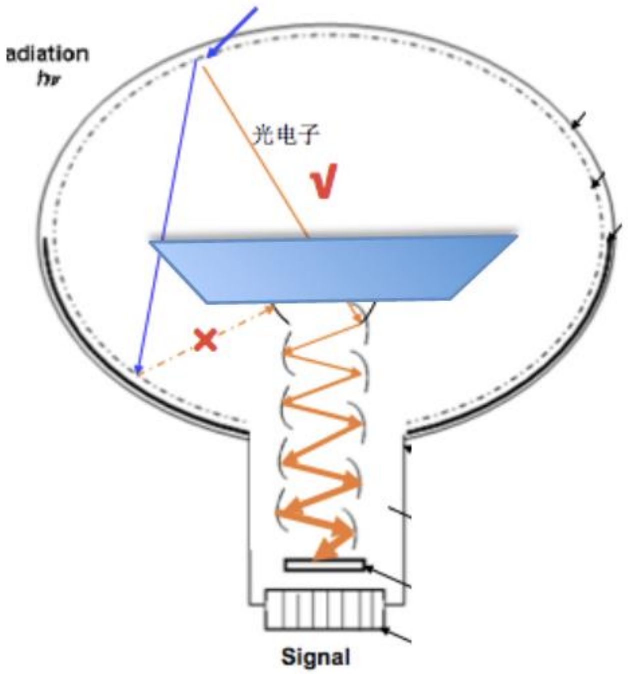


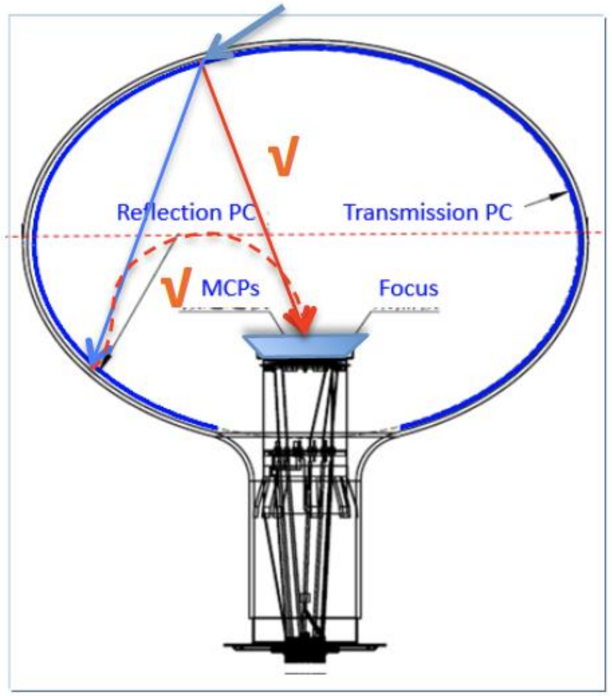


EXISTING HPDS

1.3 the 20 inch prototypes with HDE performance

In 2015, the MCP-PMT work group did the best to improve the CE of the MCP modules, and finally, the CE of the MCP-PMTs was improved from 70% to 100%.

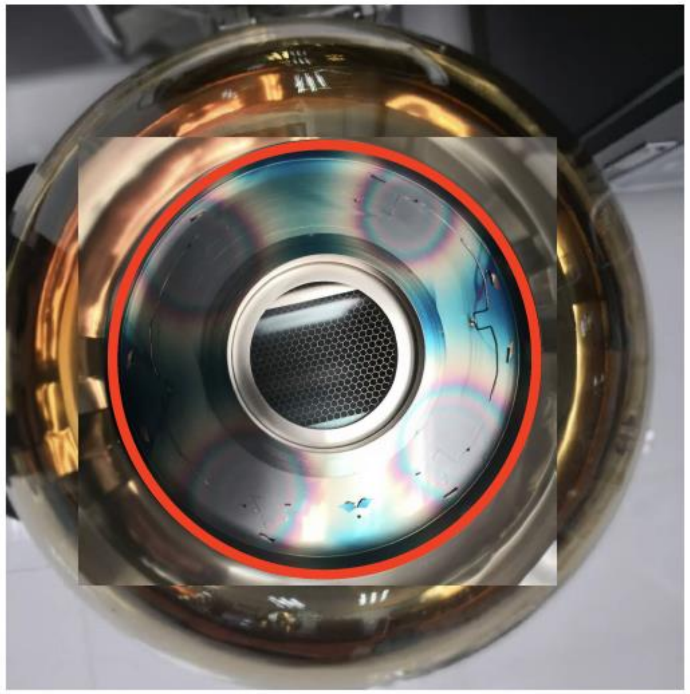


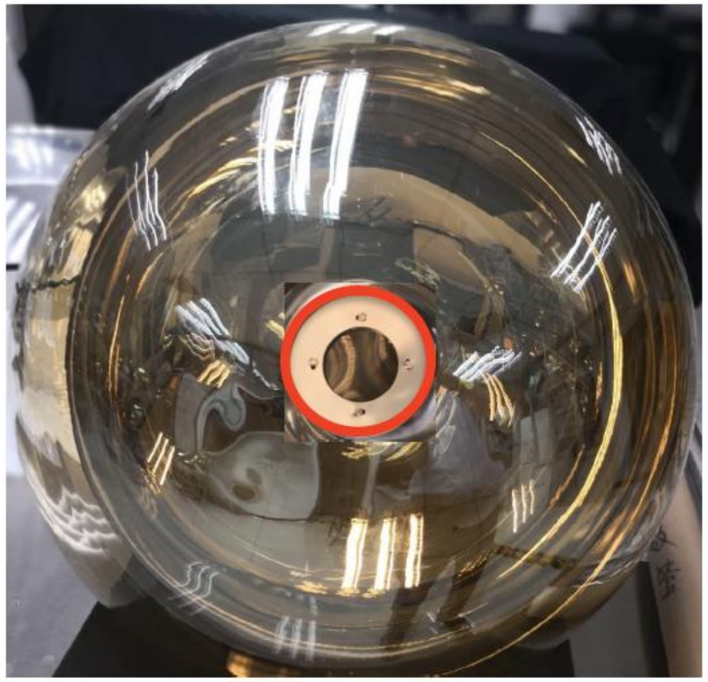


QE=20% → QE=30%

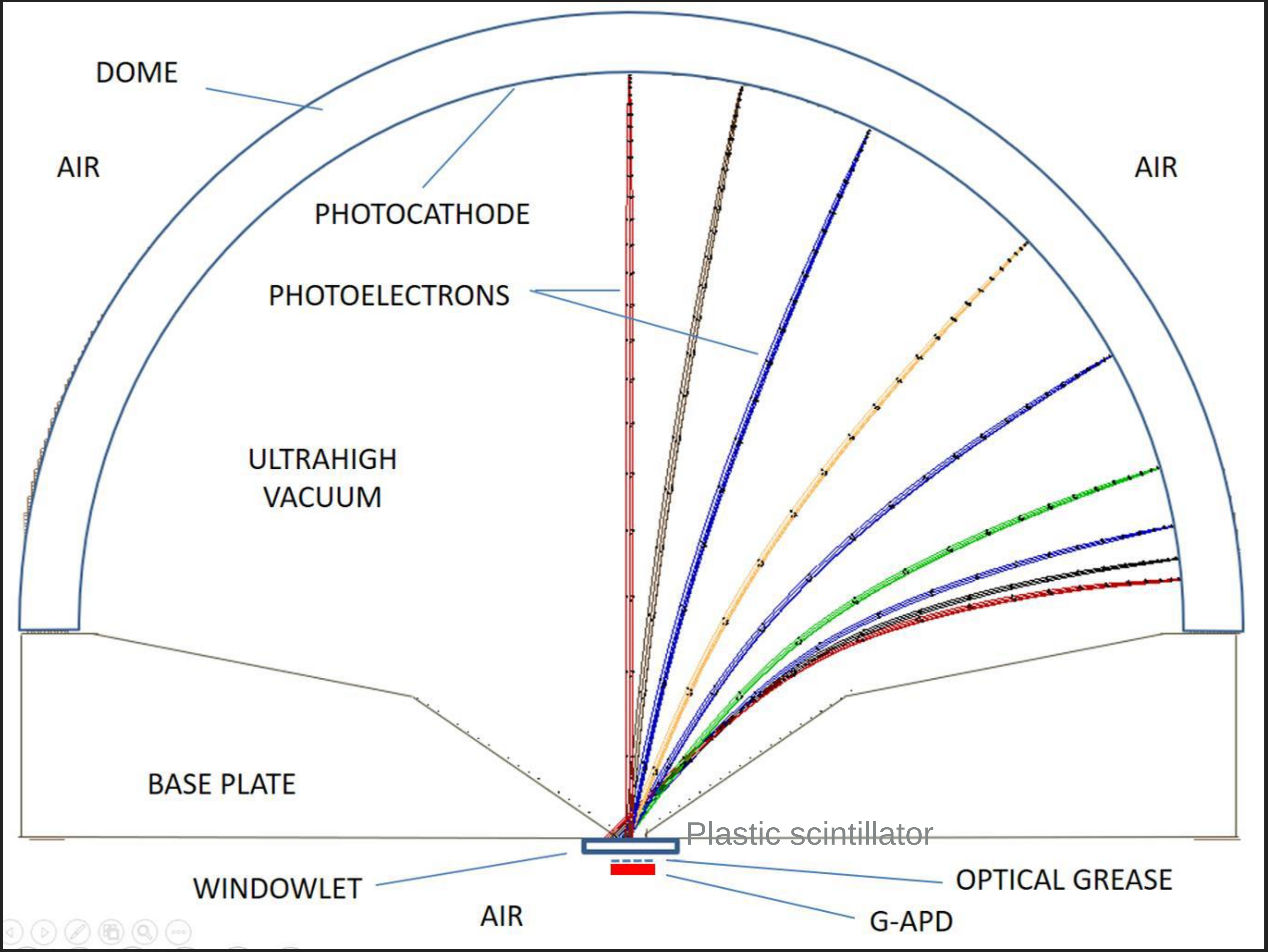
CE=70% → CE=100%

DE=14% → DE=30%





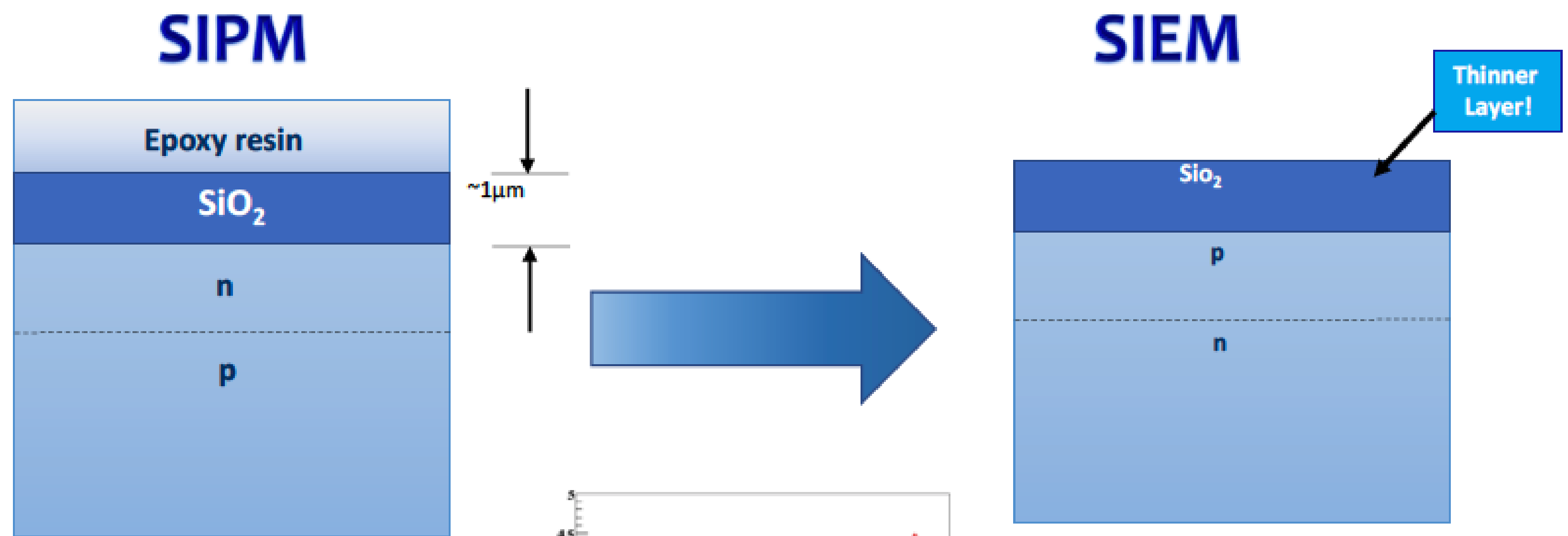
ABALONE - FOR COMPLETENESS

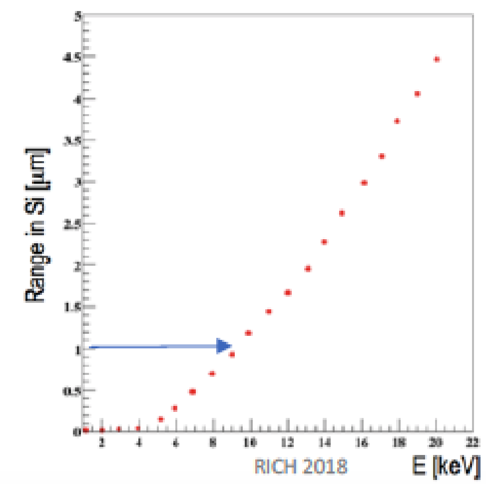


RICH 2018 - MOSCOW

Another step in photodetection innovation: the 1-inch VSiPMT prototype

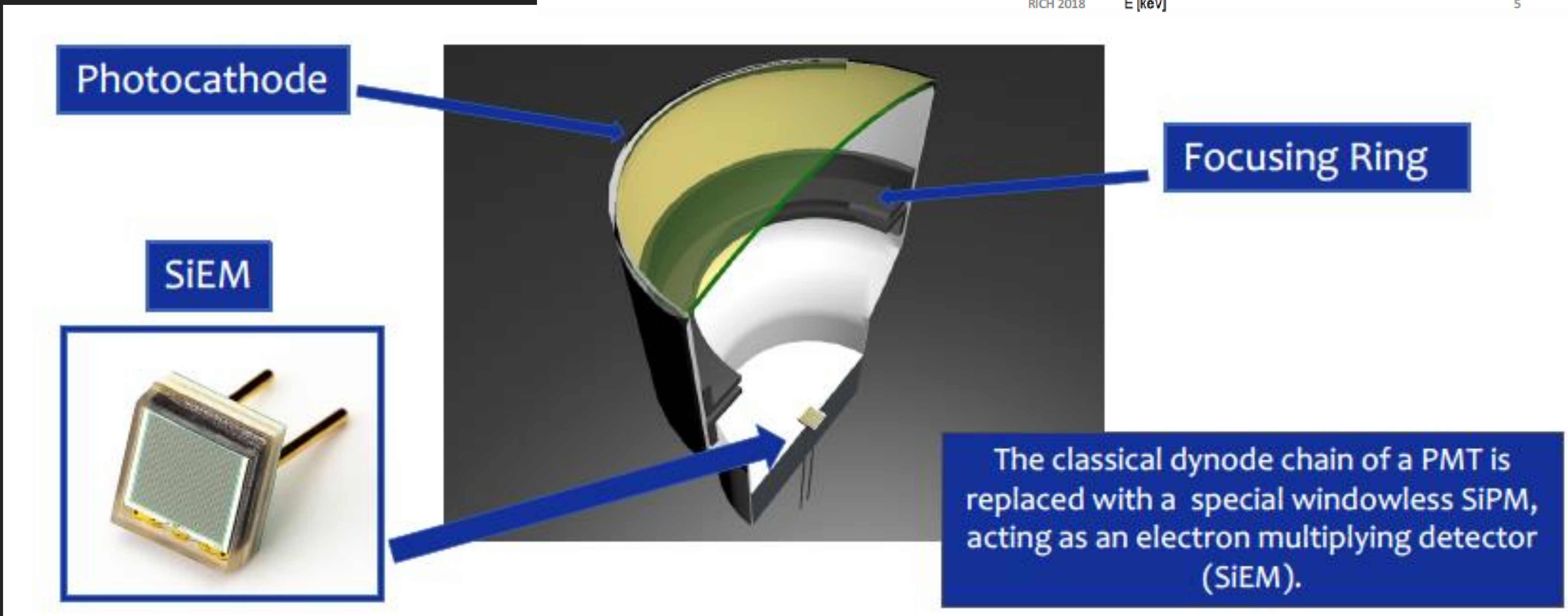
F.C.T. Barbato

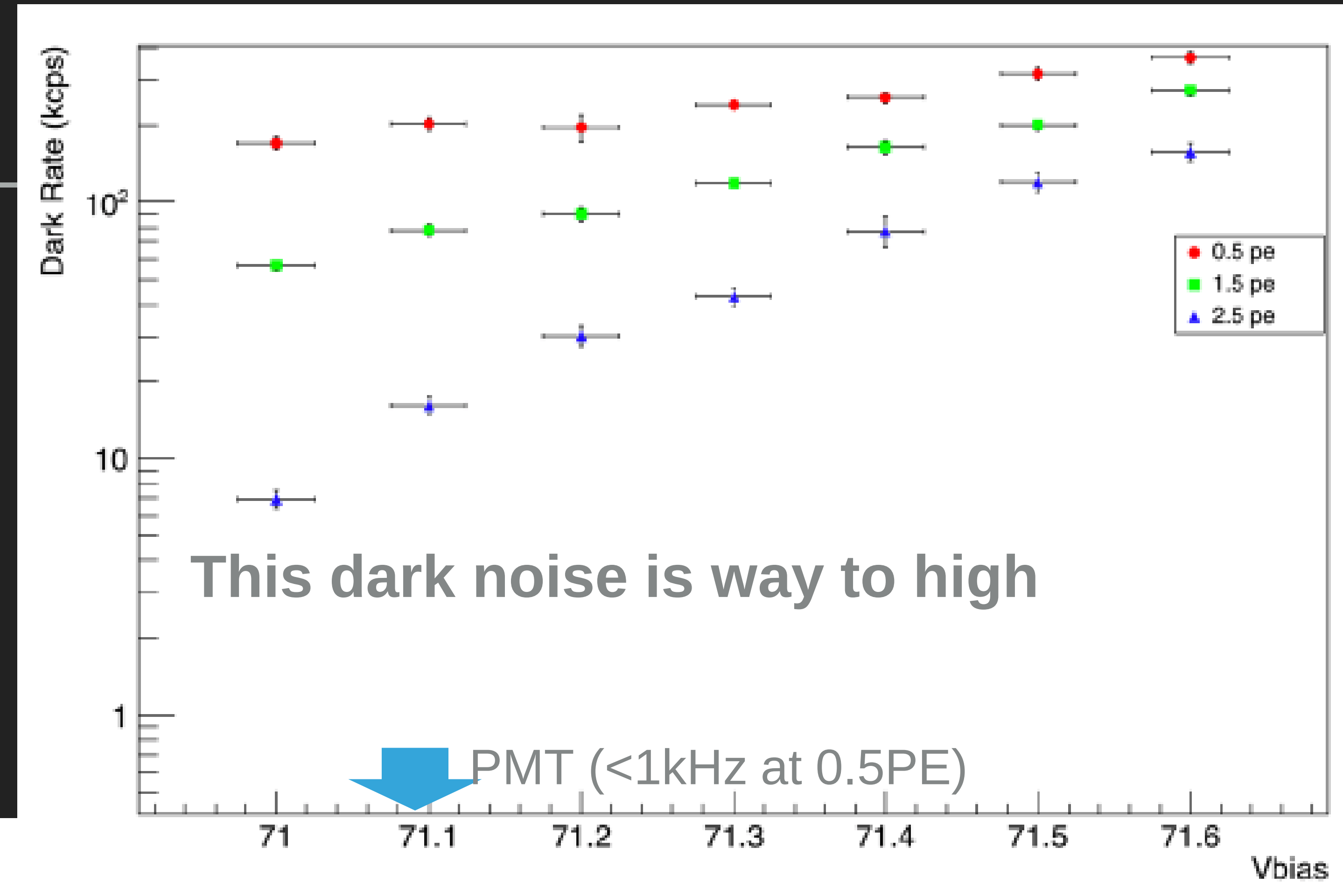


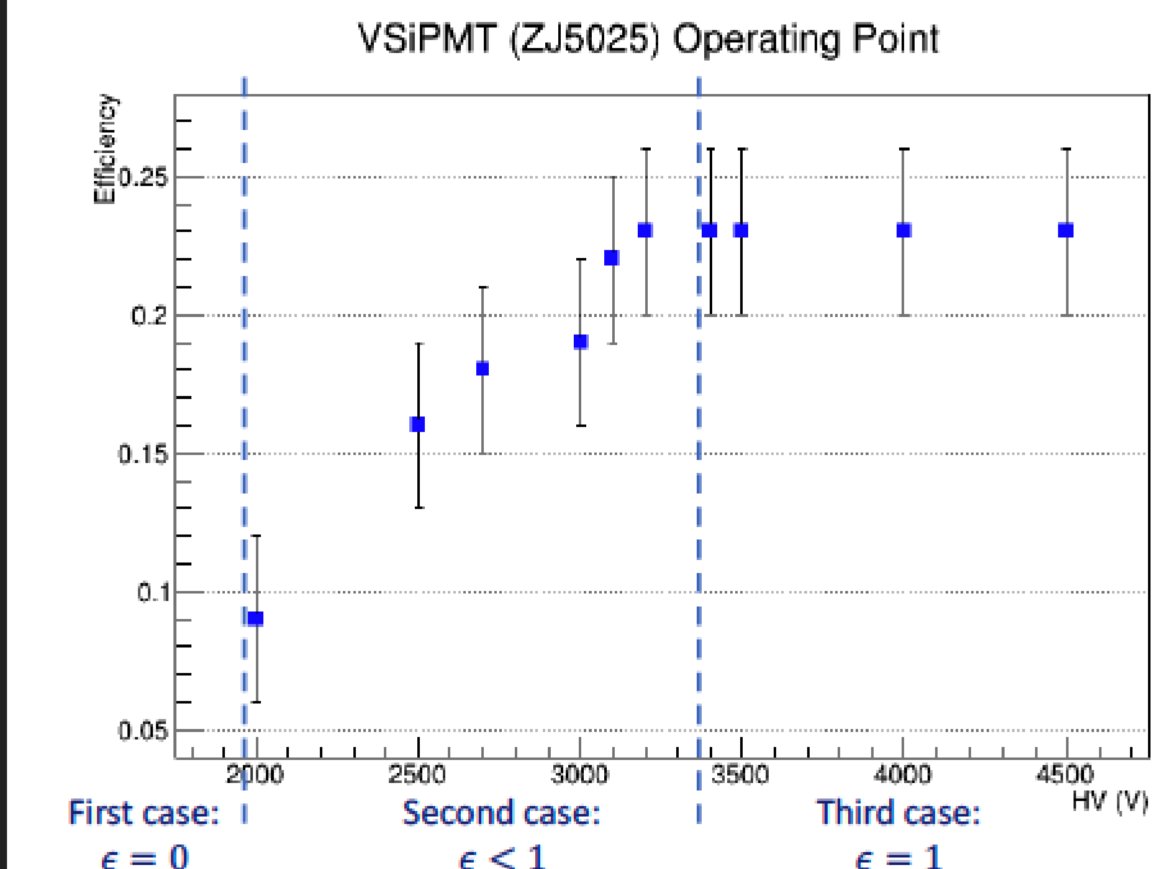


SiEM (Silicon Electron Multiplier)

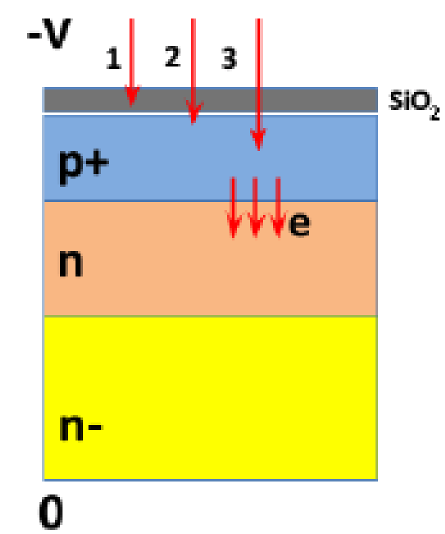
- No epoxy resin
- Thinner SiO_2 layer
- P over n junction







Efficiency is highly stable over 3200 V.
No need for high voltage stabilization.



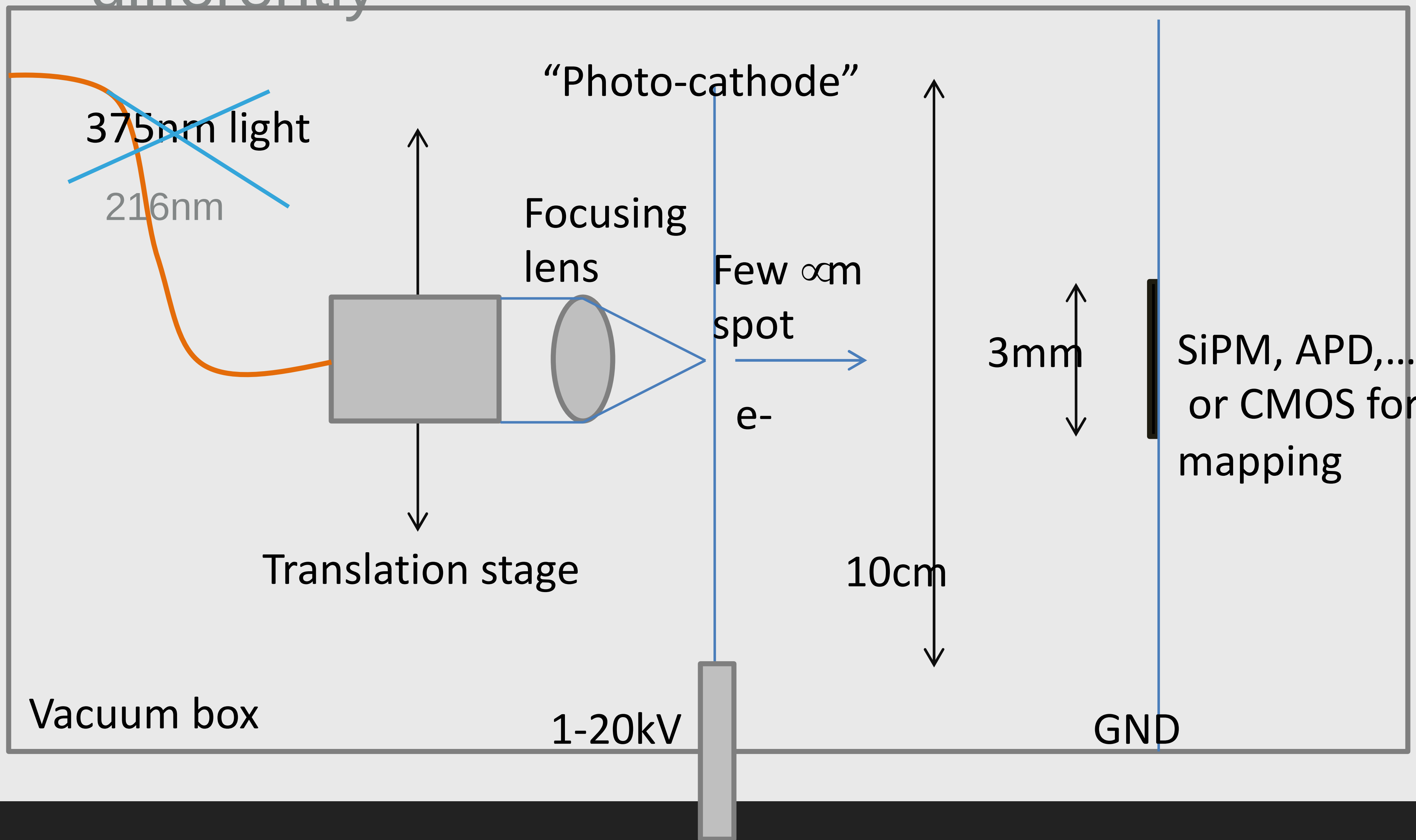
- HV: photoelectron transfer → NO power consumption (NULL current)
- LV-based gain → EASY STABILIZATION
- Reducing the SiO_2 coating layer it will be possible to reach the plateau region at even lower voltages.

DOING BETTER THAN VSIPMT

- Use VUV SiPM design to reduce HV
  - Very thin dielectric on top of Silicon (~20nm)
  - Very shallow junction with collection very close to the surface (from a few nm)
- Play some tricks to generate multiple avalanches per photo-electrons
- Use digital 3D integrated avalanche diode
  - Photon to digital converters
- Then with other issues: PE back scattering, photons from avalanches saturation

TESTING THE GAIN STAGE

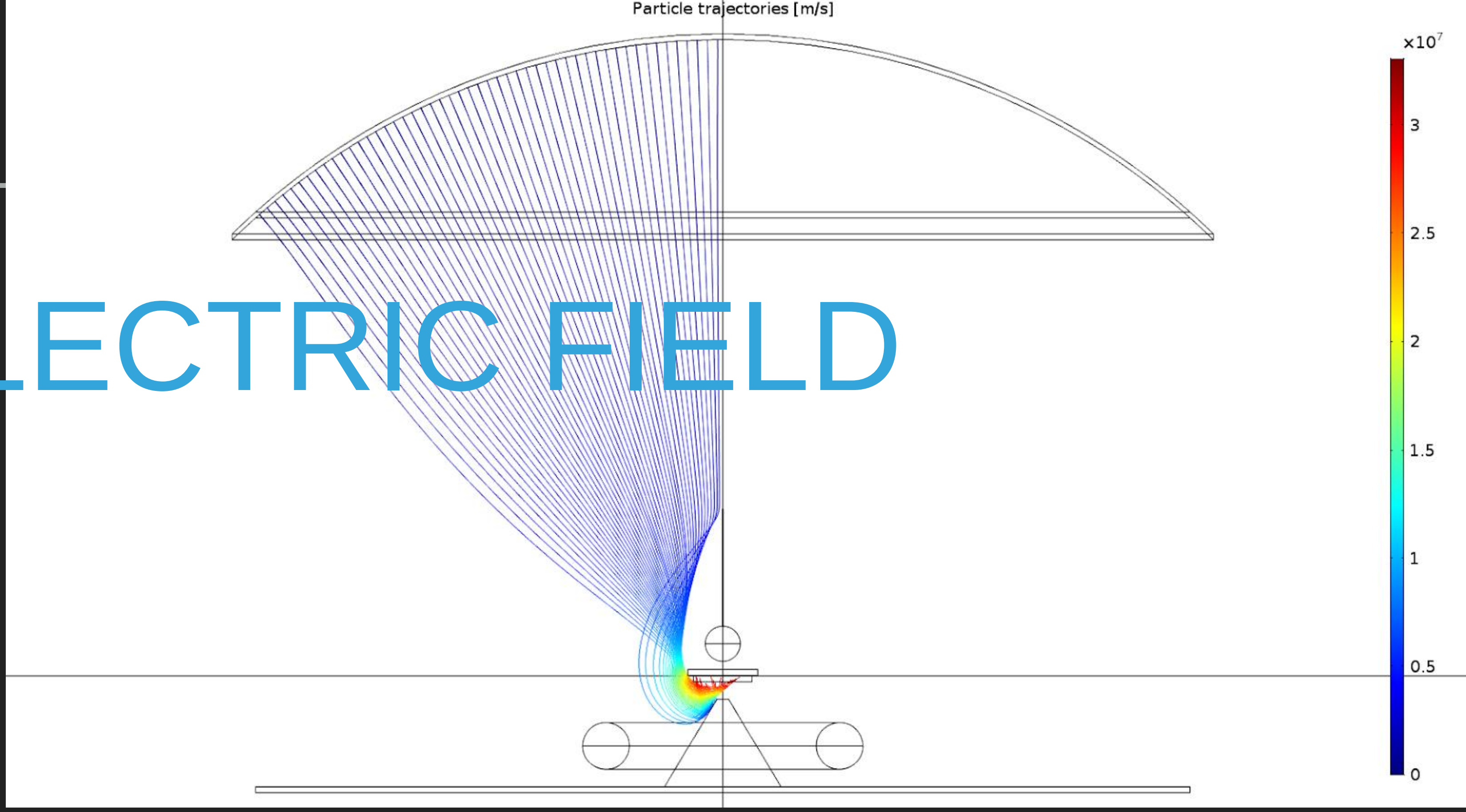
- A concept from 5 years ago
  - JP Janez will implement this concept at UofA, probably differently

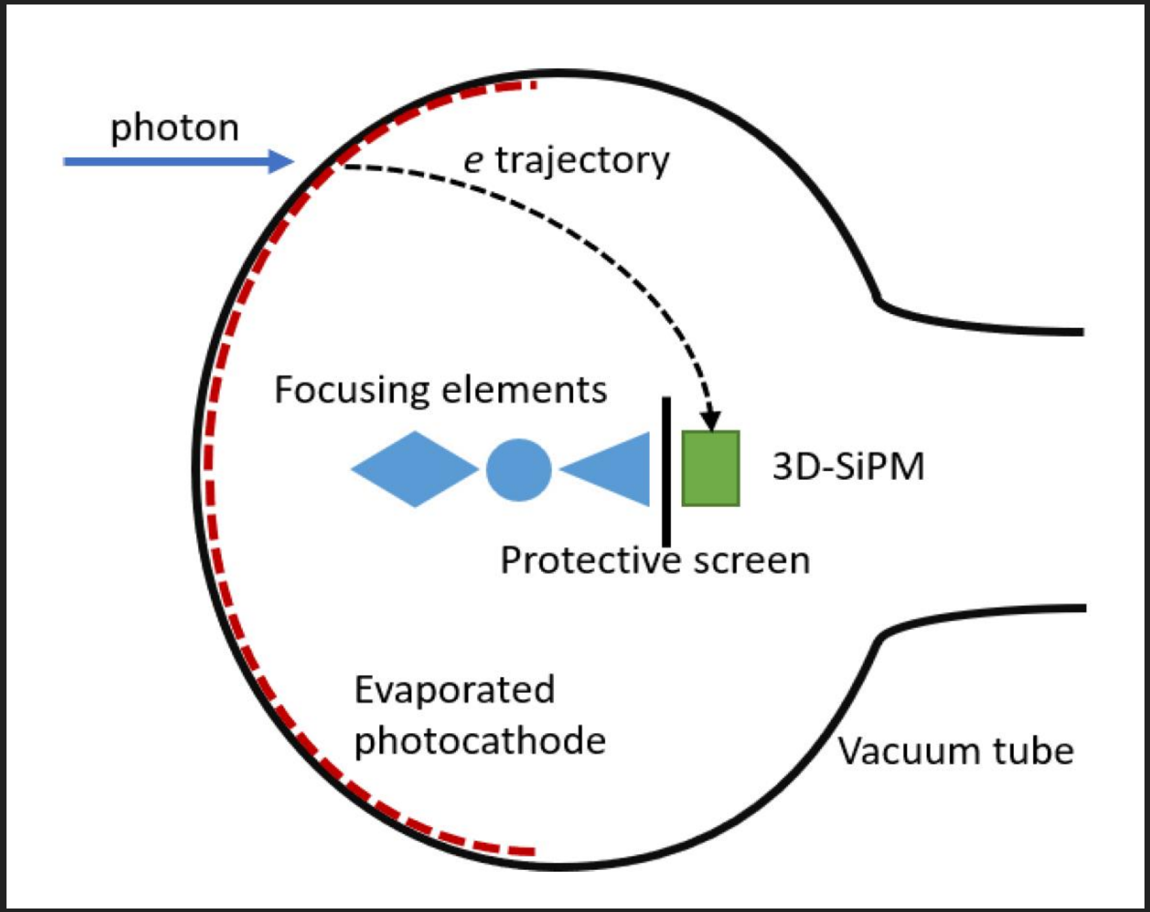


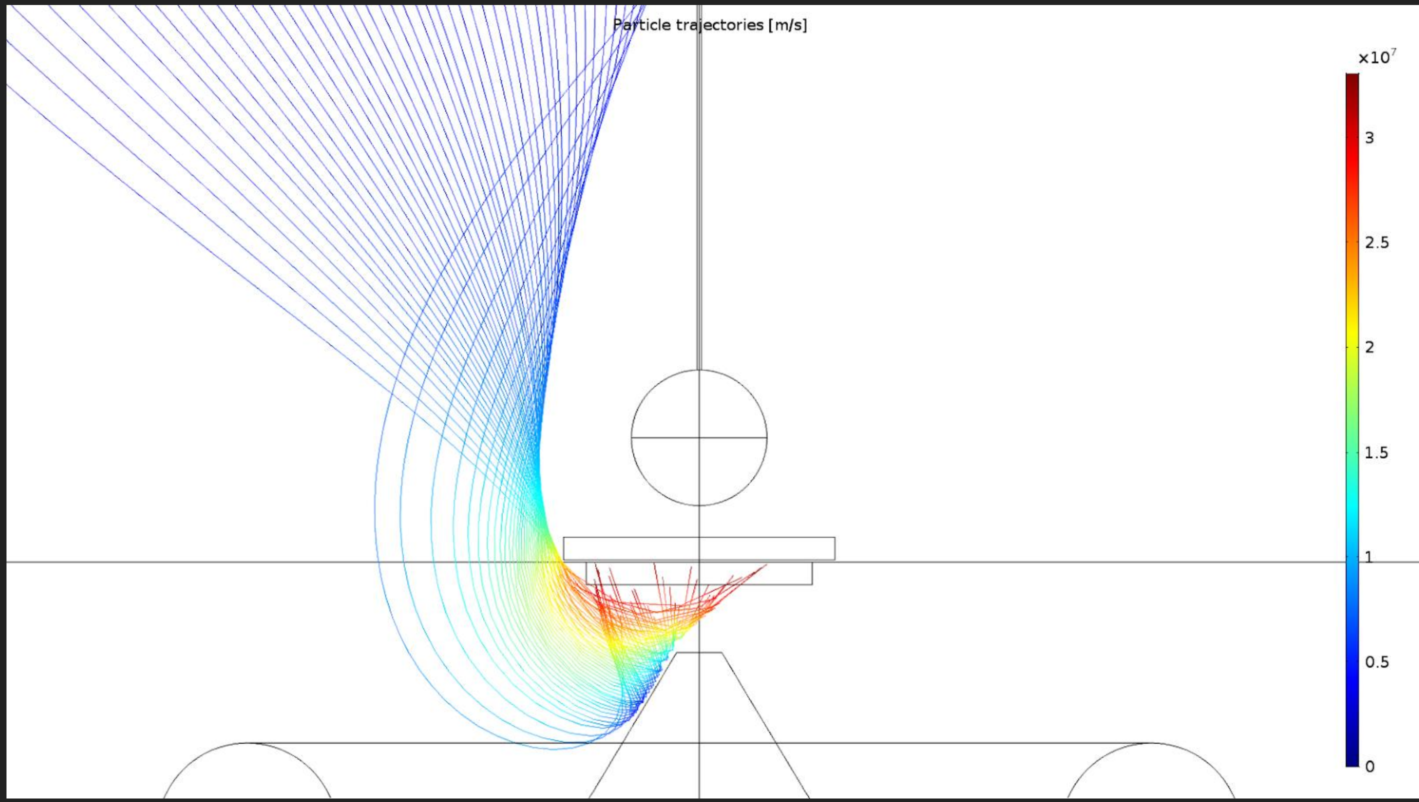
TRIUMF

U.ALBERTA ELECTRIC FIELD

- Isolate gain stage







LETS BUILD A LARGE AREA PHOTON TO BIT CONVERTER IN CANADA

- Design and build dedicated single electron avalanche diode array
- Integrated in Sherbrooke's 3D integrated scheme
  - Tailor CMOS chip for this purpose
- Test gain stage using dedicated setup
- Collaborate with PMT manufacturer for delivering a final product