SiPM4MIP
Direct detection of charged particles with SiPMs

Towards an R&D collaboration for PD and PID (DRD4)
Community Meeting
CERN, 16-17 May 2023

P. Antonioli – INFN Bologna
(full authors /institutions list in next slide)

Research context: exploring SiPM as sensors for the ALICE 3 outer timing layer

F. Carnesecchi[1*], ‡B. Sabiu[2], S. Strazzi[2], §G. Vignola[3], N. Agrawal[2], A. Alici[2], P. Antonioli[3], S. Arcelli[2], F. Bellini[2], D. Cavazza[3], L. Cifarelli[2], M. Colocci[2], S. Durando[4], F. Ercolessi[2], A. Ficorella[5], C. Fraticelli[2], M. Garbini[6,3], M. Giacalone[2], A. Gola[5], D. Hatzifotiadou[3], N. Jacazio[2], A. Margotti[3], G. Malfattore[2], R. Nania[3], F. Noferini[3], G. Paternoster[5], O. Pinazza[3], R. Preghenella[3], R. Rath[3], R. Ricci[7], L. Rignanese[3], G. Romanenko[2], N. Rubini[2], E. Scapparone[3], G. Scioli[2] and A. Zichichi[2]

[1]CERN, Esplanade des Particules 1, Geneva, 1211 Geneva 23, Switzerland.
[2]Dipartimento di Fisica e Astronomia "A. Righi", University of Bologna, viale Carlo Berti Pichat 6/2, Bologna, 40127, Italy.
[3]Sezione di Bologna, Istituto Nazionale di Fisica Nucleare, viale Carlo Berti Pichat 6/2, Bologna, 40127, Italy.
[4]Dipartimento di elettronica e telecomunicazioni, Politecnico di Torino, Corso Duca degli Abruzzi, 24, Torino, 10129, Italy.
[5]Fondazione Bruno Kessler, Via Sommarive, 18, Povo, 38123, Italy.
[6] Museo Storico della Fisica e Centro Studi Enrico Fermi, Via Panisperna 89 A, Roma, 10129, Italy.
[7]Dipartmento di Fisica , University of Salerno, Via Giovanni Paolo II, 132, Salerno, 84084, Italy.

References

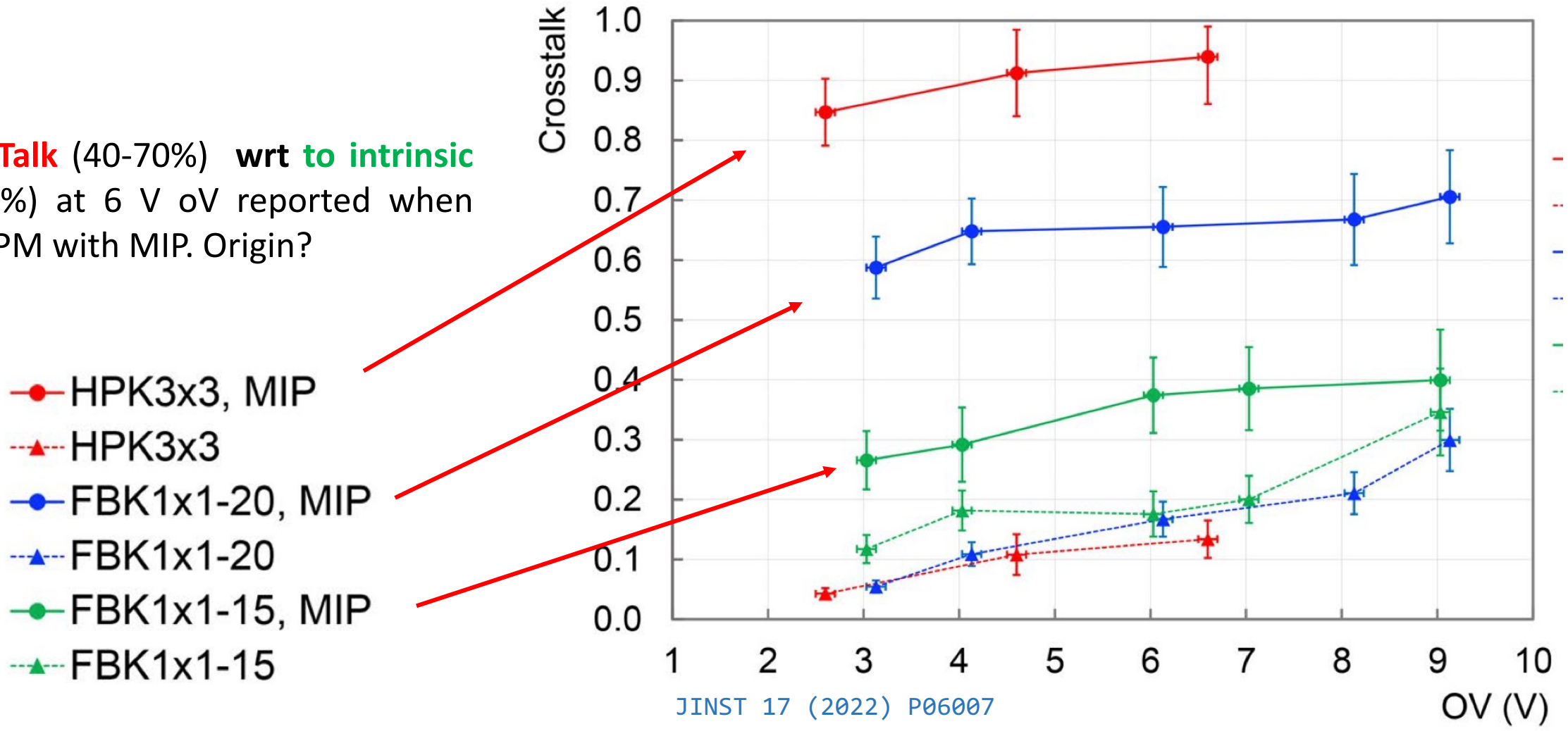
- F. Carnesecchi, et al., JINST 17 (2022) P06007 **1**
- F. Carnesecchi, et al., EPJ+ 138 (2023) 337 **2**
- Results shown as preliminary in this talk (Nov 2022 test beam) → expected to be on arXiv this week **3**

Special credits to F. Carnesecchi, R. Nania and B. Sabiu for providing key material preparing these slides!
[Bianca's UniBo Master Thesis: https://amslaurea.unibo.it/28756/]

What happens when MIP goes through a SiPM?

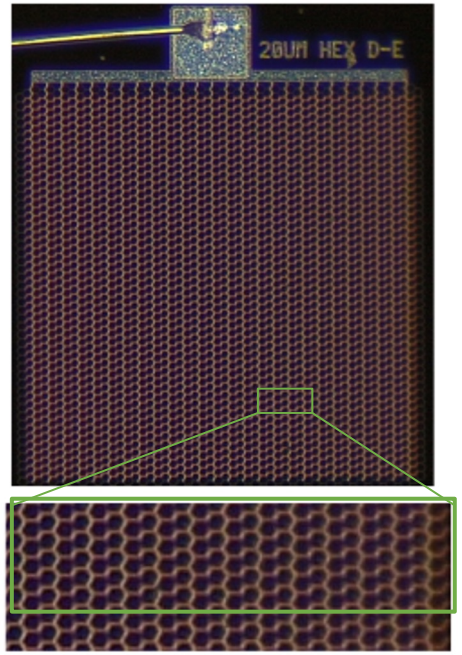
1

higher CrossTalk (40-70%) **wrt to intrinsic noise** (10-15%) at 6 V oV reported when irradiating SiPM with MIP. Origin?

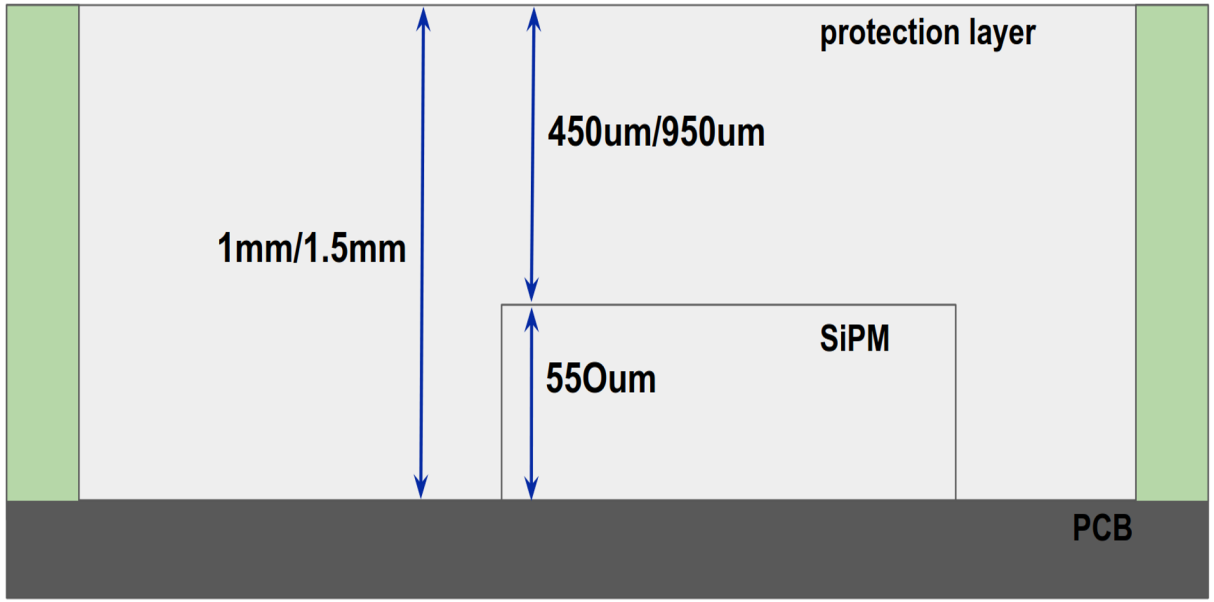


Cherenkov effect in the protection layer or process inside the bulk?

Testing the role played by the protective layer

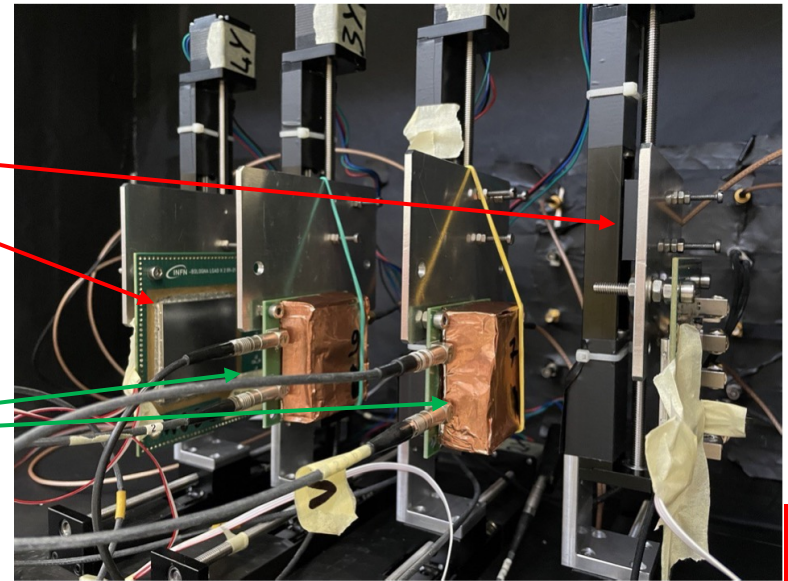


Active area	1x1 mm²
Pixel pitch	20um
#SPADs	2444
Fill Factor	72%
V breakdown	33.0±0.1 V



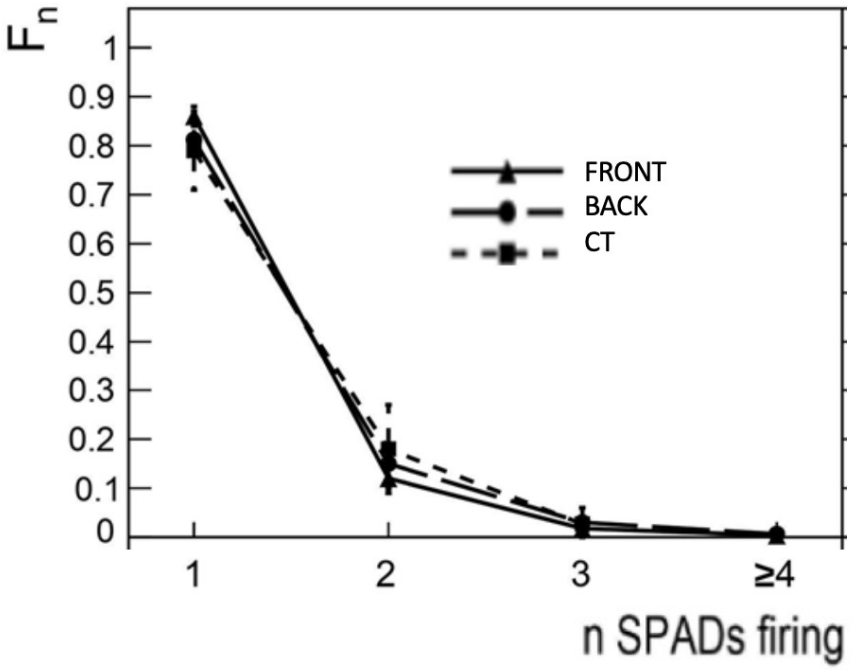
During last test beam tested FBK NUV-HD-RH SiPM:

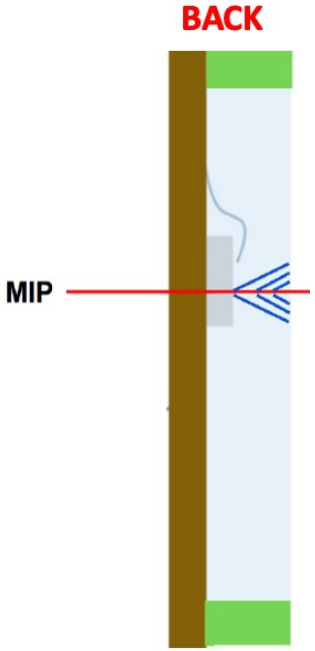
- Si Resin 1 mm (**SR1**)
- Si Resin 1.5 mm (**SR15**)
- Epoxy Resin 1 mm (**ER1**)
- Without resin (**W/O R**)



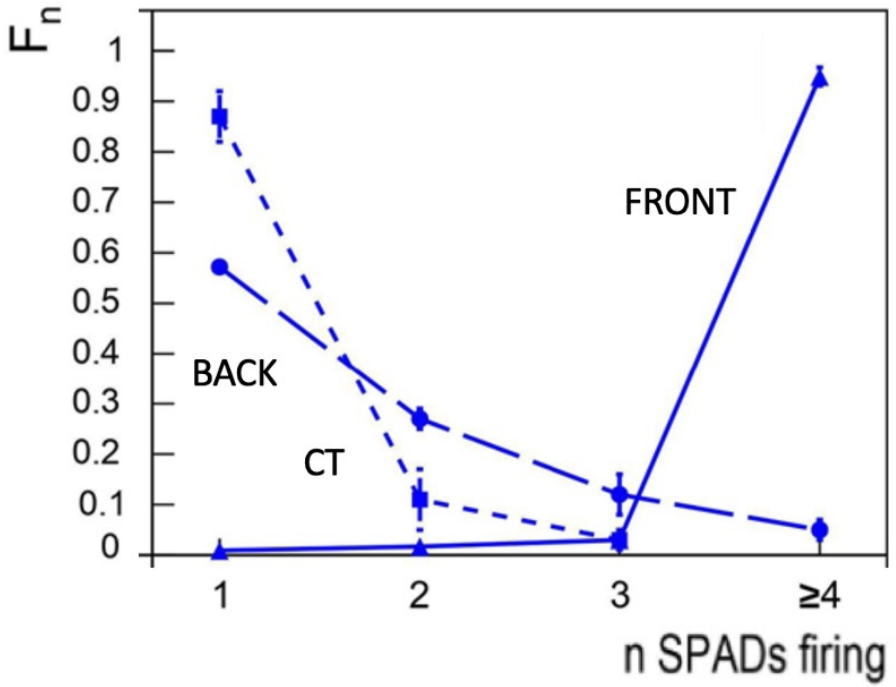
In the bulk or in the layer?

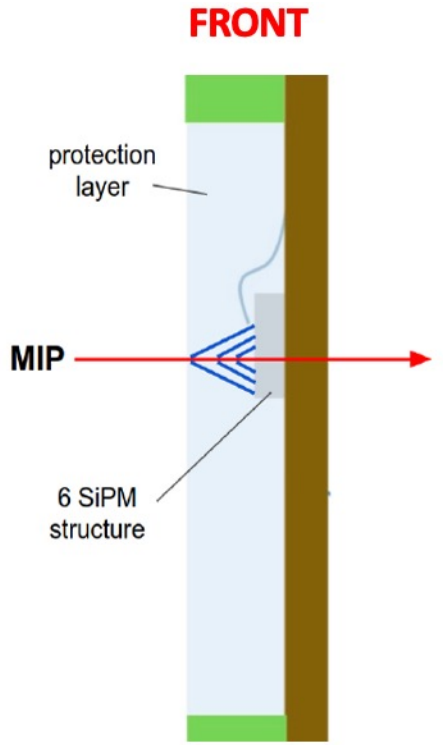
Without protection layer





With protection layer





EPJ+ 138 (2023) 337

2

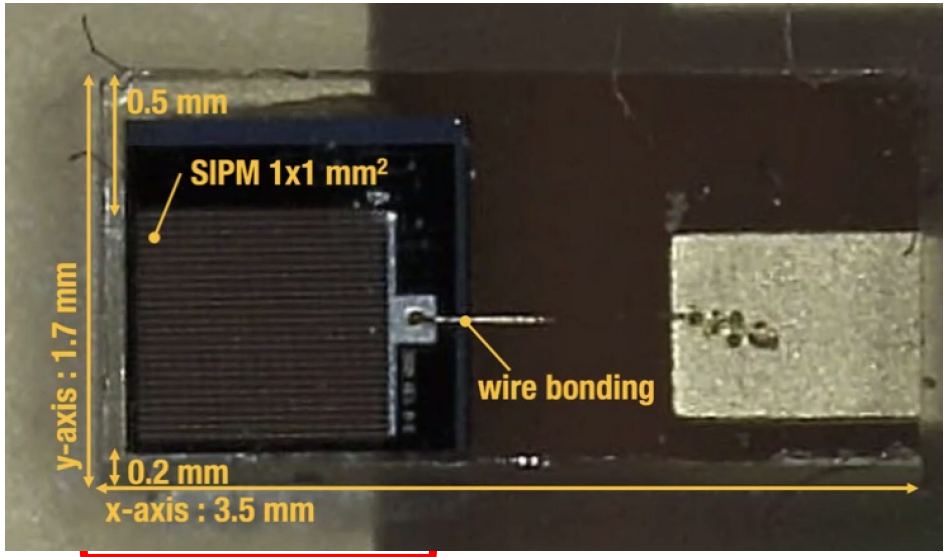
$$F_n = \frac{\text{events with n SPADs firing}}{\text{events with} \geq 1 \text{ SPADs firing}}$$

Cherenkov effect in the protection layer

Protection layer signal study: position scan

Last test beam results (November 2022) @CERN - PS

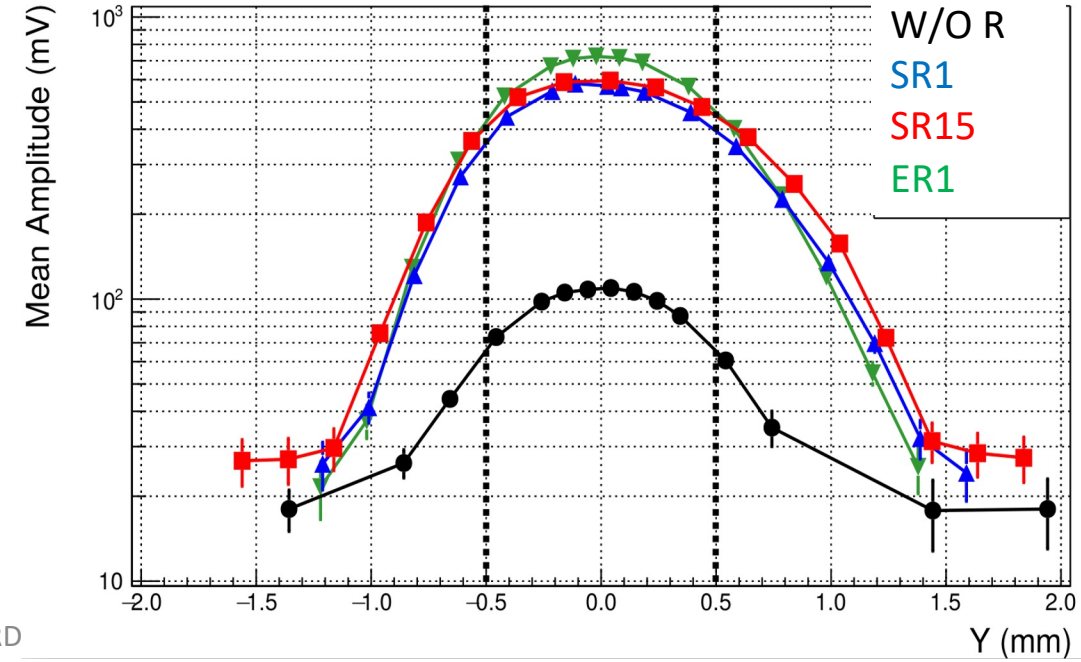
- 10 um precision of micropositioners
- DAQ based on Lecroy Wave-Runner 9404M-MS
- 3V oV with 10 GeV beam

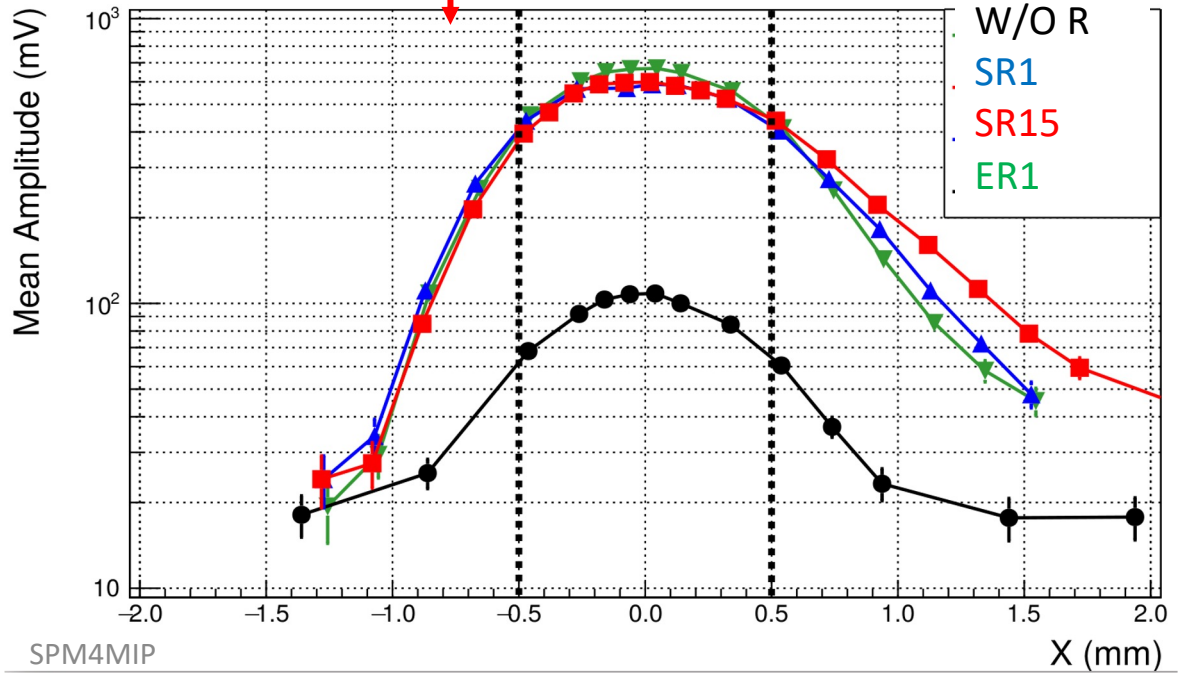


Y-scan

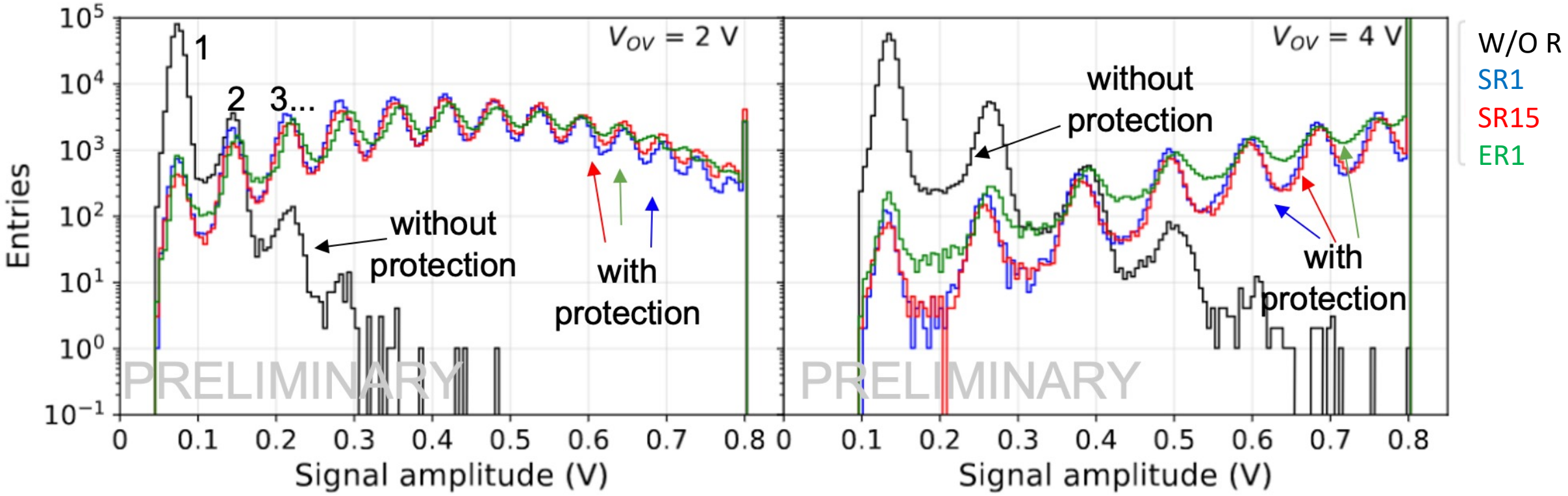
X-scan

average signal much higher with resin than w/o!





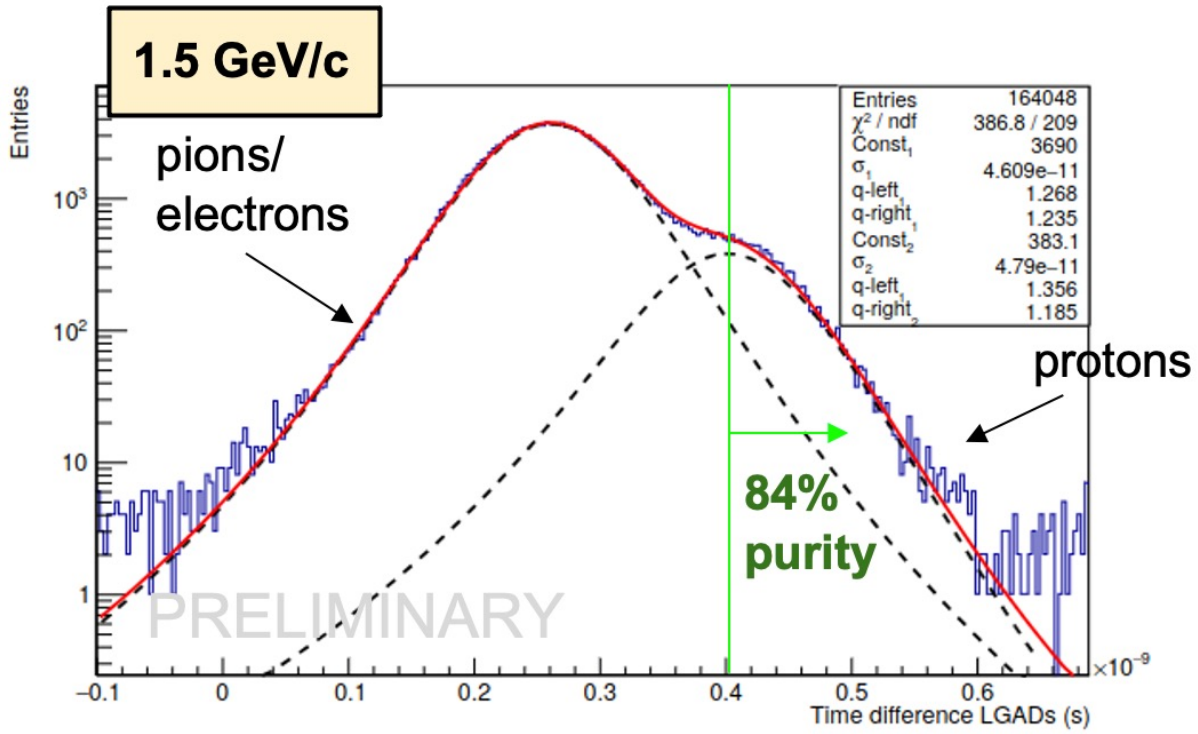
Photoelectrons counting

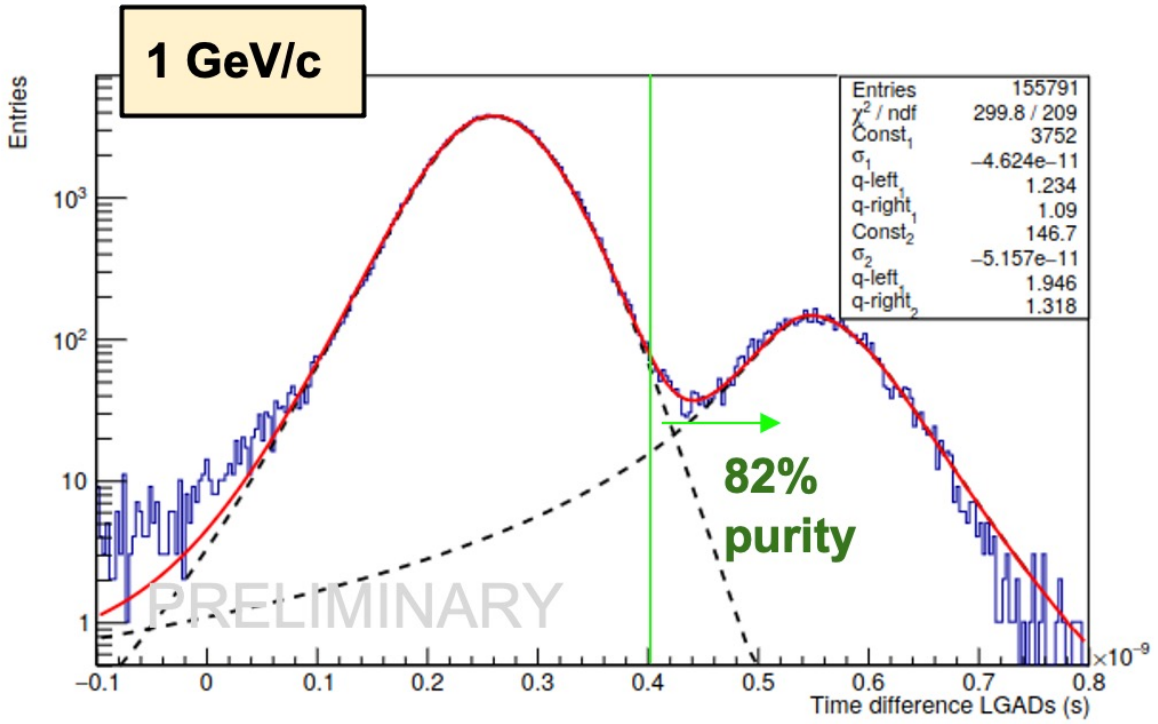


selection at maximum amplitude position

- **W/O R** mainly **1 SPAD** events with some CT up to 4-5 SPADS
- With **protection layer** majority of **multi SPADs events**
- **high efficiency of SiPM with resin:** more than **99%** of event with ≥3 SPADs firing at 2 V oV

Chekenkov effect: energy dependence (I)



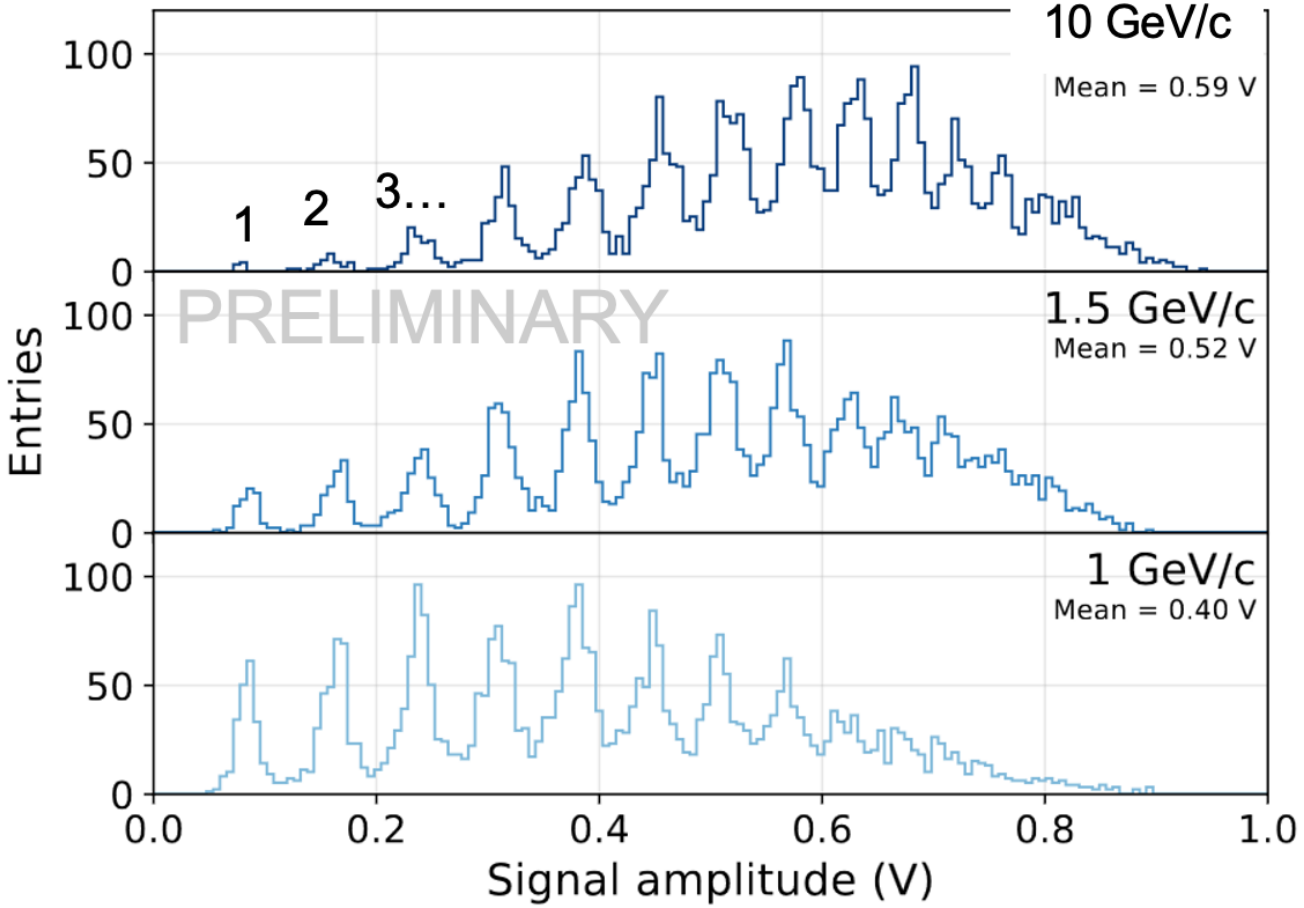


- selection based on timing provided by two LGADs (24 cm time-of-flight)
- timing allows selection of protons

Cherenkov effect: energy dependence (II)

3 V oV

SR1 amplitude



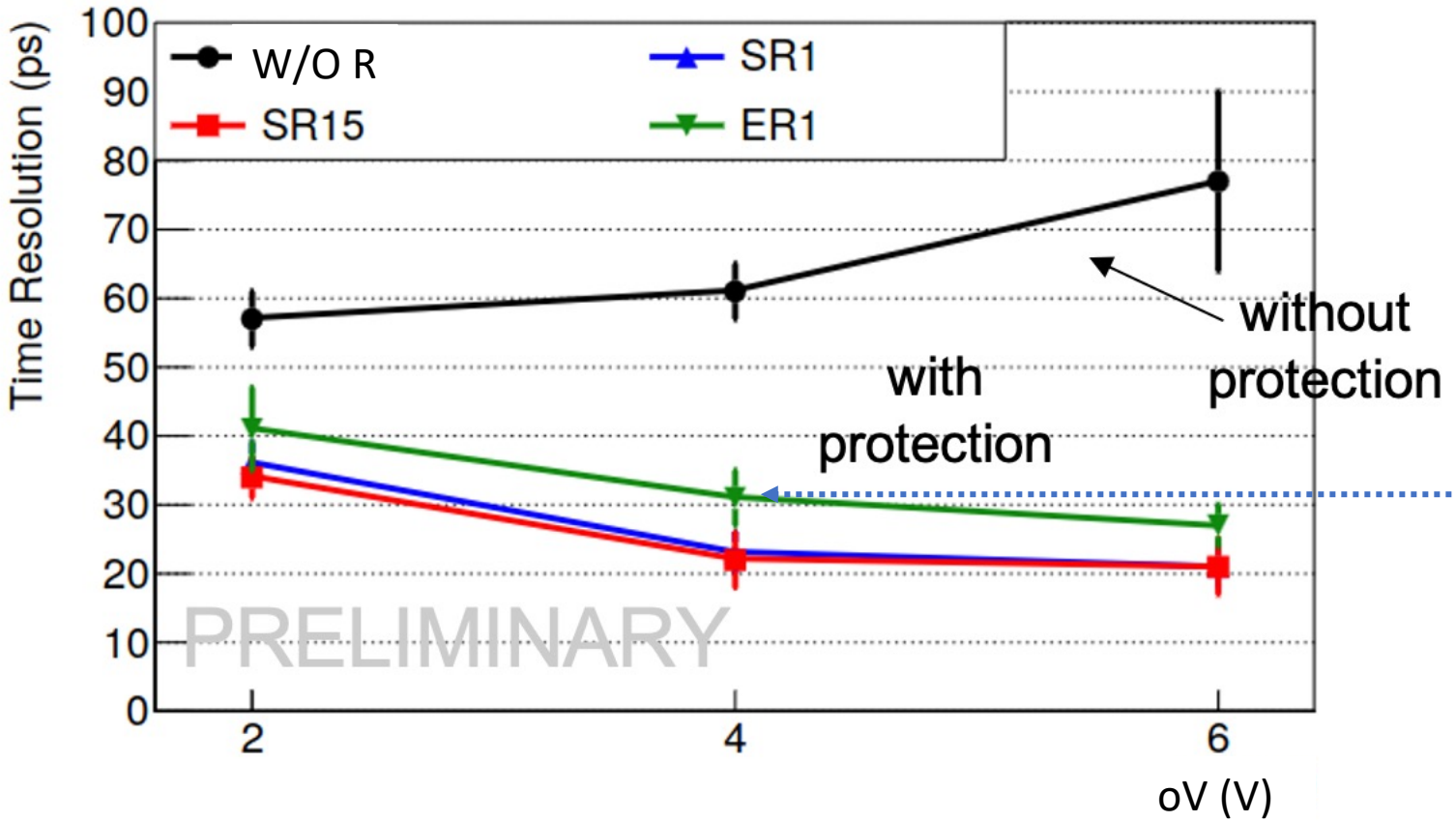
larger **ENERGY**

larger **N SPADs**

Cherenkov threshold ~500 MeV/c

decreasing number of photelectrons/nSPAD broadly in agreement with energy dependence expectations

Time resolution (I)



- 50% CFD LGAD
- 0.5 nphe fixed threshold SIPM

$$\sigma_{SiPM} = \sqrt{\sigma_{fit}^2 - \sigma_{LGAD}^2}$$

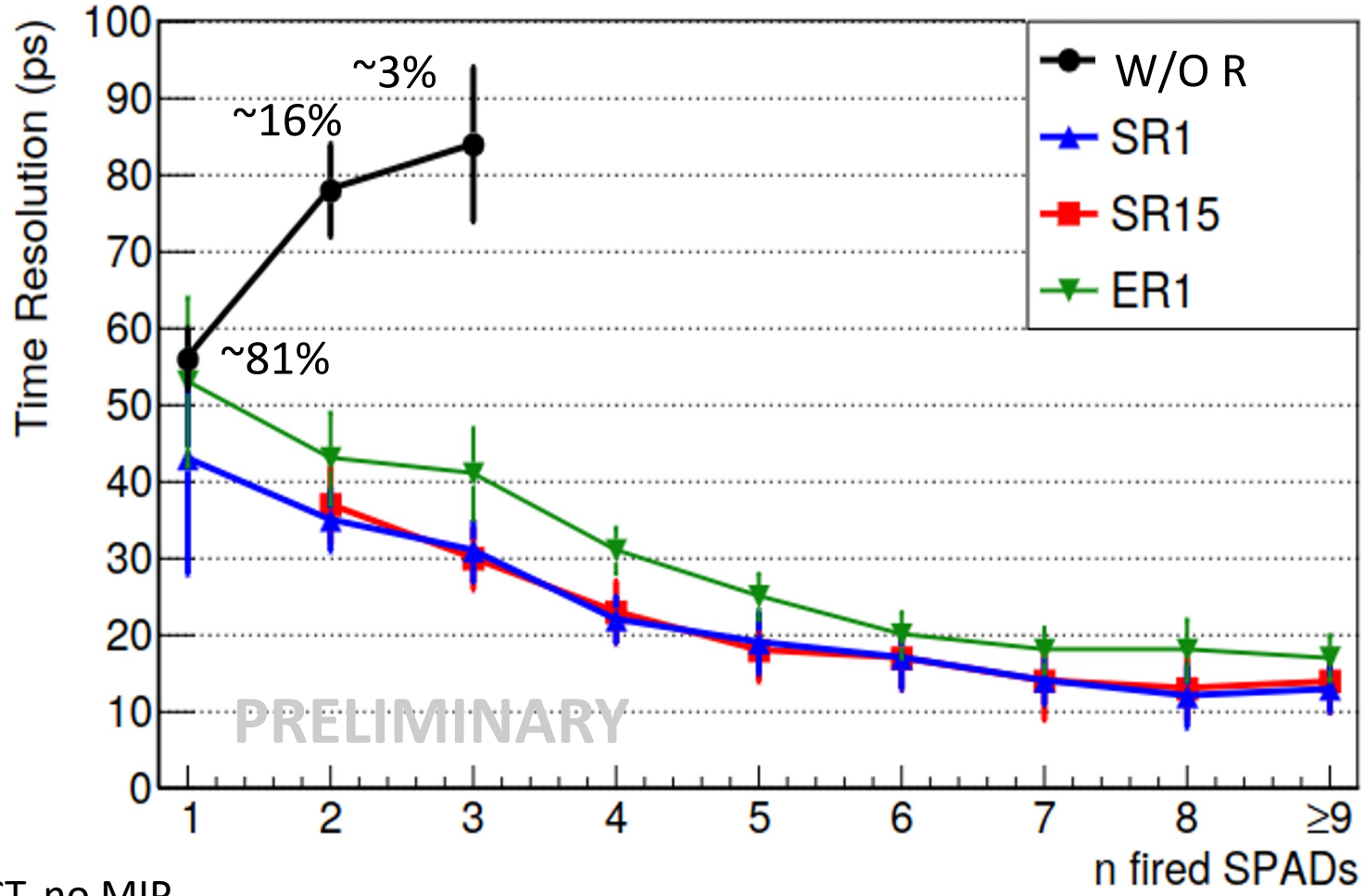
with $\sigma_{LGAD} \simeq$ 30 ps (*)

exploiting Cherenkov radiation in the protection layer at > 4 V oV timing performance O(20-30) ps!

different behaviour vs oV with or without protection layer

(*) F. Carnesecchi et al, EPJ+ 138 (2023) 99

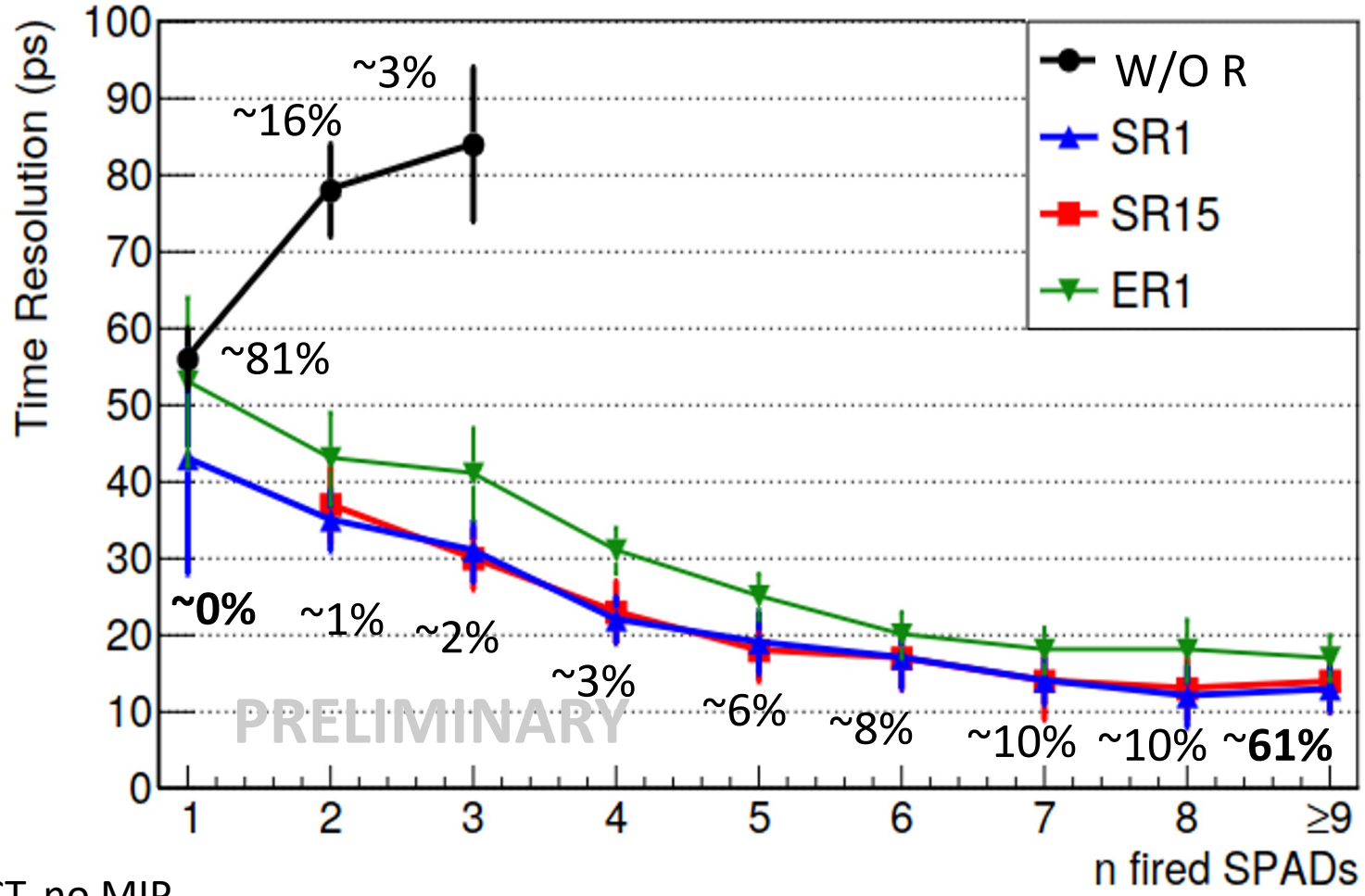
Time resolution (II)



4 V oV

W/O R: signal is due to CT, no MIP
time resolution improves with nSPAD

Time resolution (III)



4 V oV

W/O R: signal is due to CT, no MIP
time resoltuion improves with nSPAD
15-20 ps resolution for nSPAD>=6 (where there is > 90% of events!)

3

time resolution **below 20 ps**

Conclusions and DRD4 outlook

Exploiting Cherenkov radiation produced in the protection layer, SiPM can be used as an **effective** charged particle detectors.

High potential for high precision timing, SiPM-based trackers, TOF and TOF*+RICH detectors, applications in different fields

R&D future directions

- better quantify the number of photons vs different resin thickness/material
- optimize SPAD dimension for timing performances
- follow the developments of new SiPMs more radiation tolerant (back side illuminated for example)
- develop FE electronics easily matched to the SiPM, for precise time measurements (@next test-beam picoTDC+LIROC)

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} DRD4 sounds as a natural networking/collaboration space. Willing to contribute!

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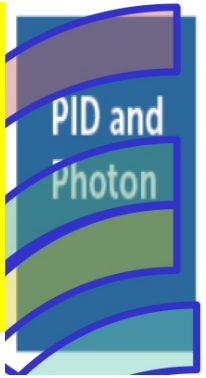
Despite SIPM4MIP detects MIP (using a tiny Cherenkov radiator at the end!), this research work fully aligned with DRDT 4.1, 4.3, 4.4 goals!



DRDT 4.1 Enhance the timing resolution and spectral range of photon detectors

DRDT 4.2 Develop photosensors for extreme environments

DRDT 4.3 Develop RICH and imaging detectors with low mass and high resolution timing

DRDT 4.4 Develop compact high performance time-of-flight detectors