RPC readout optimization: miniTRASGO as a path to a single-plane multiplexed timing system

November 19th 2025, Valencia

XVII CPAN Days

C. Soneira-Landín (csoneira@ucm.es), A. Blanco, L.M. Fraile, L. Lopes, J.M. Udías

Table of contents - *A detector story*

- **Introduction**
  Resistive Plate Chambers in miniTRASGO
- **More advanced versions**
  R3B prototype
  Multiplexing: SHIP prototype ← *Current stage!*
- **Next step**
  going for the single plane

Introduction

Resistive Plate Chambers in miniTRASGO

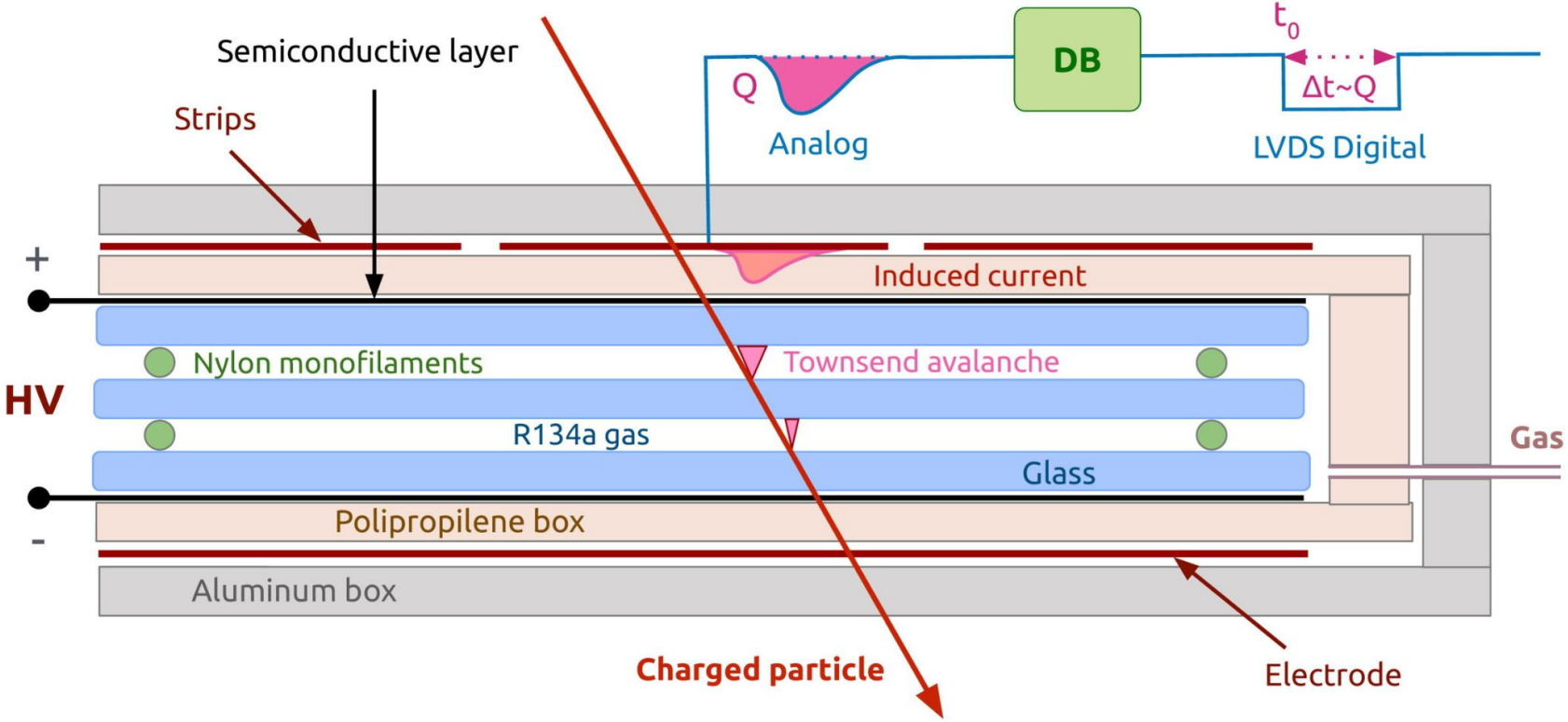
miniTRASGO: RPC-based muon telescope

- 4 parallel 30x30 cm² **Multigap glass Resistive Plate Chambers** (MRPCs)
  - **~400 ps** timing
  - **~3 cm** spatial resolution
- **Gas**: R134a, flux of <1 kg/month

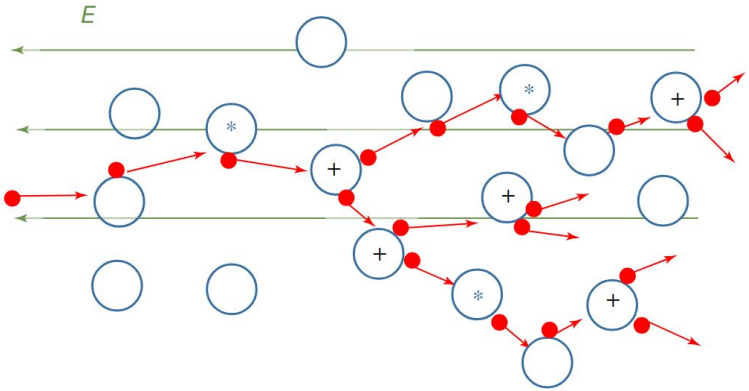
C. Soneira-Landín et al., NIM A, 2025, https://doi.org/10.1016/j.nima.2025.170511
C. Soneira-Landín et al., Adv. Space Res., 2025, https://doi.org/10.1016/j.asr.2025.07.096
C. Soneira-Landín et al., PoS(ICRC2025)1368

Resistive Plate Chamber layout

- Every **Multigap glass RPC** has:
  - **2 gas gaps → 1 mm/gap**
  - **3 glass electrodes → 2 mm/glass**
- **Readout**: *wide* strips (6-9 cm)

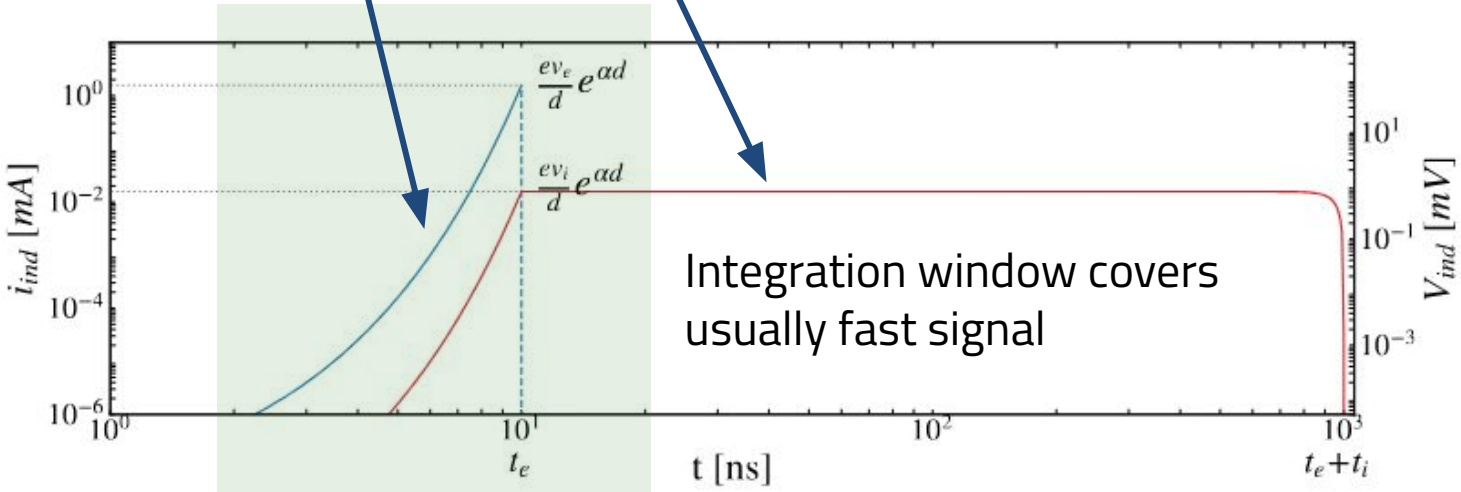


Signal induction in RPCs



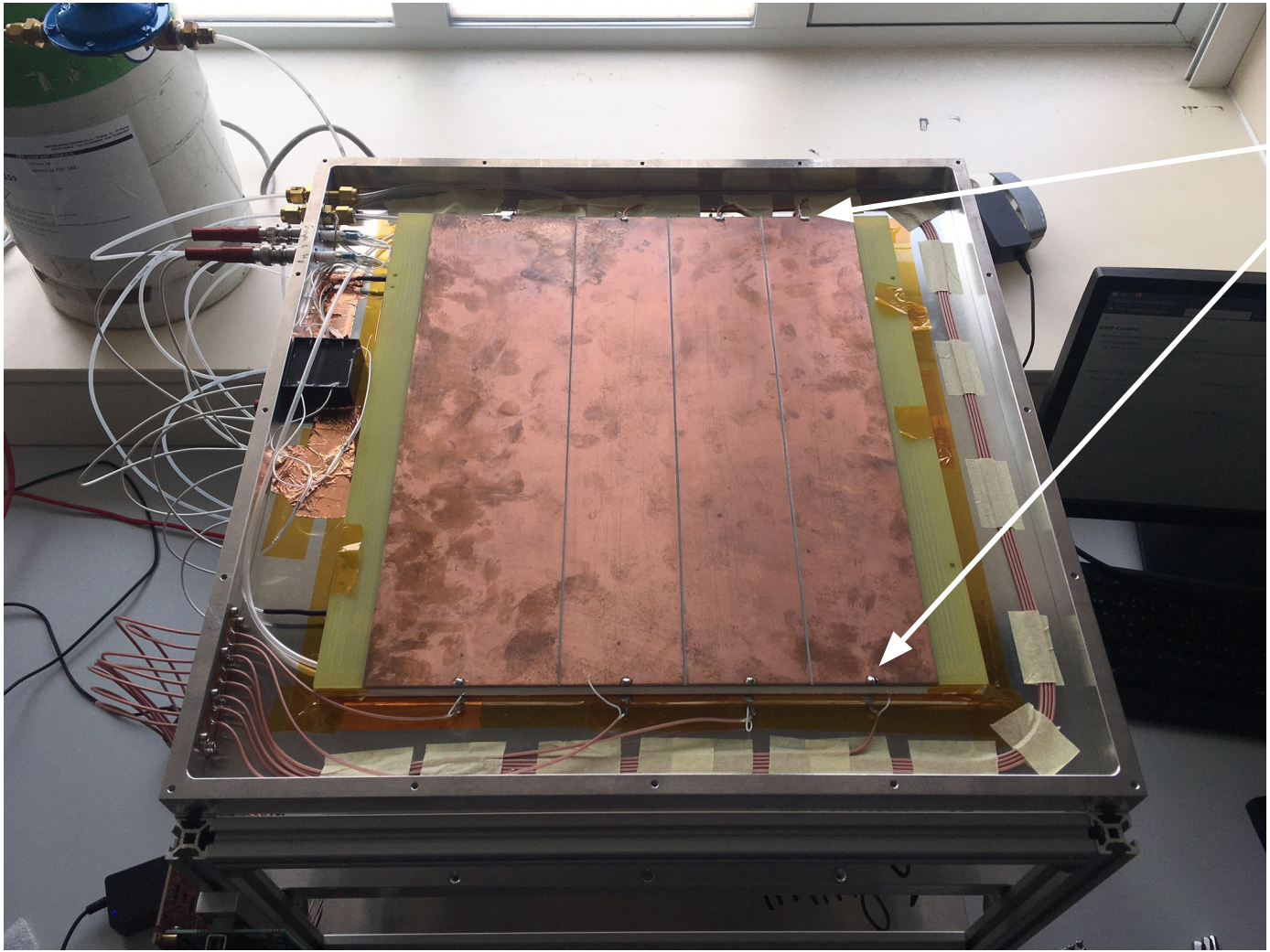
Ionic signal

Electronic signal



Integration window covers usually fast signal

Townsend avalanche (from Abbrescia et al., 2018)

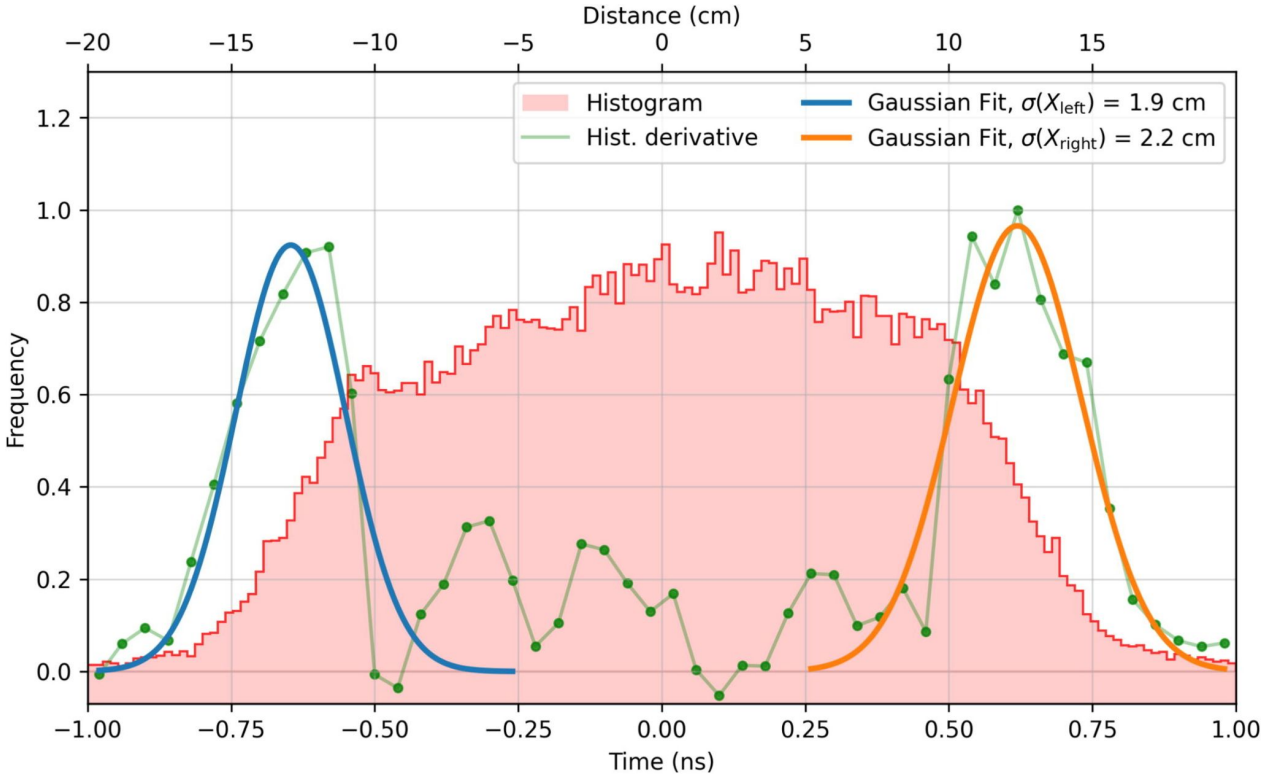


Asymmetric parallel **Cu** strips read in Front and Back (32 channels)

Time and **charge** obtained

Estimated position uncertainty

Using the **time difference** in both sides of the **strip** the position of the event can be determined

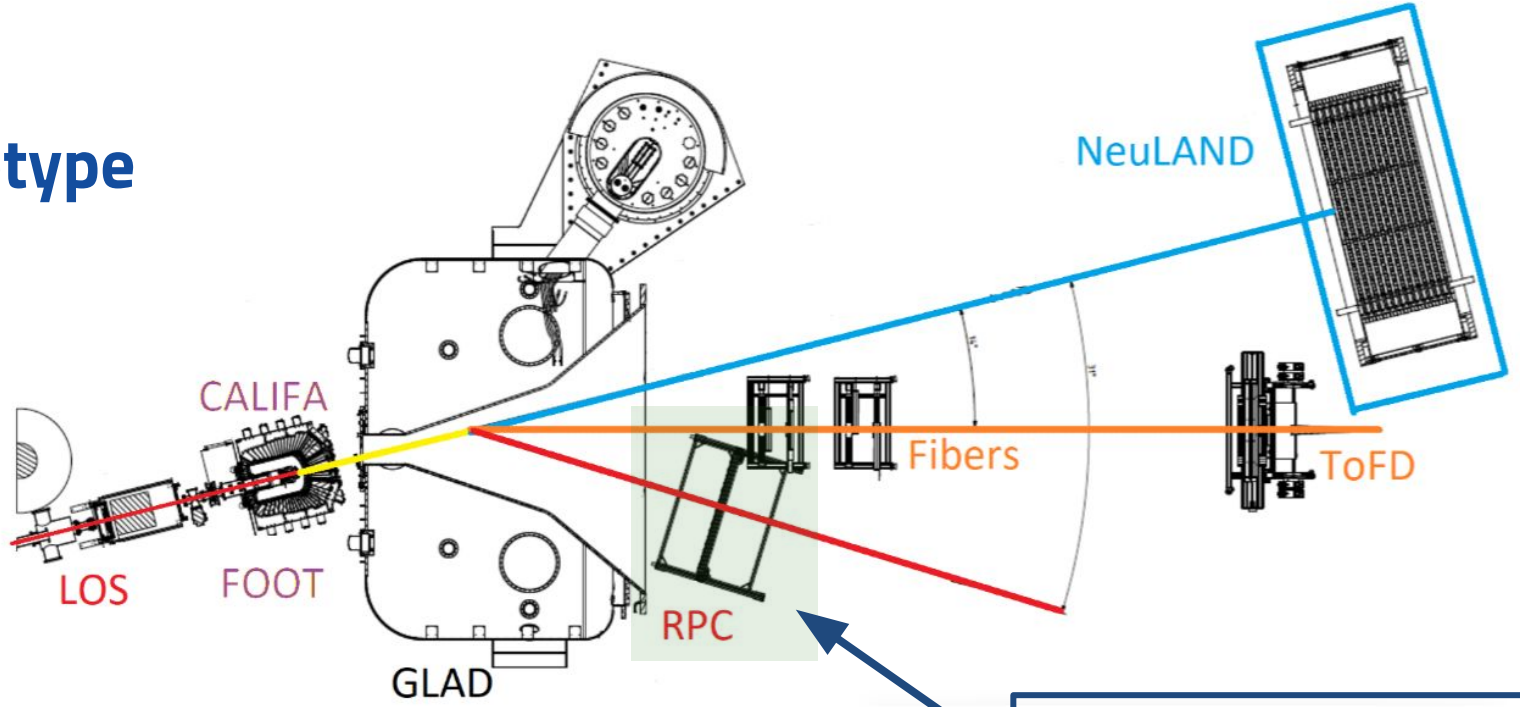


C. Soneira-Landín et al., Adv. Space Res., 2025, https://doi.org/10.1016/j.asr.2025.07.096

More advanced versions

R3B prototype

R3B prototype



2 m²
6 gaps x 2 chambers
3 cm pitch strips

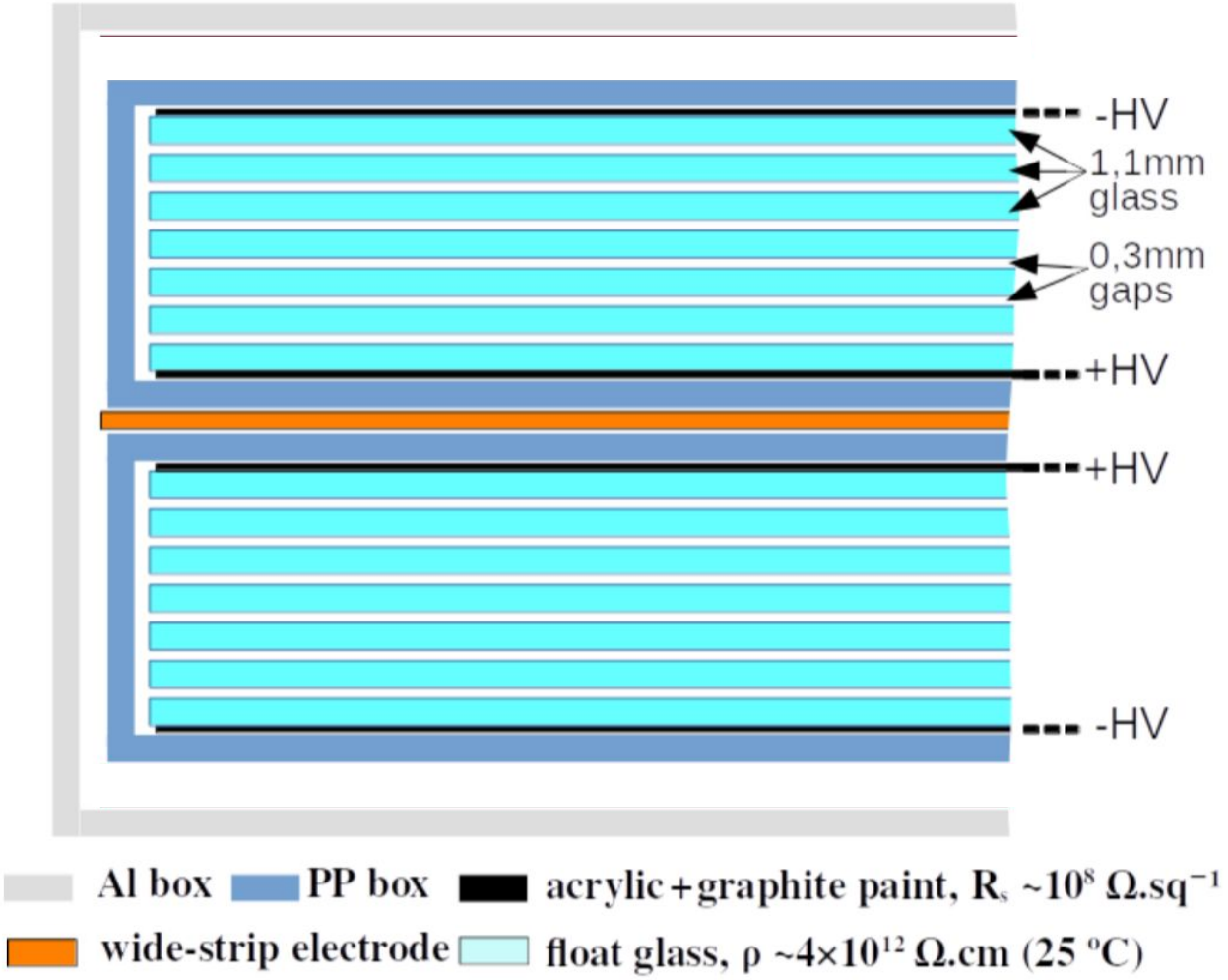
The next step in the detector development is being used in R3B experiment at FAIR

Adapted from M. Xarepe et al., NIM A, 2023, https://doi.org/10.1016/j.nima.2023.168445

R3B prototype layout

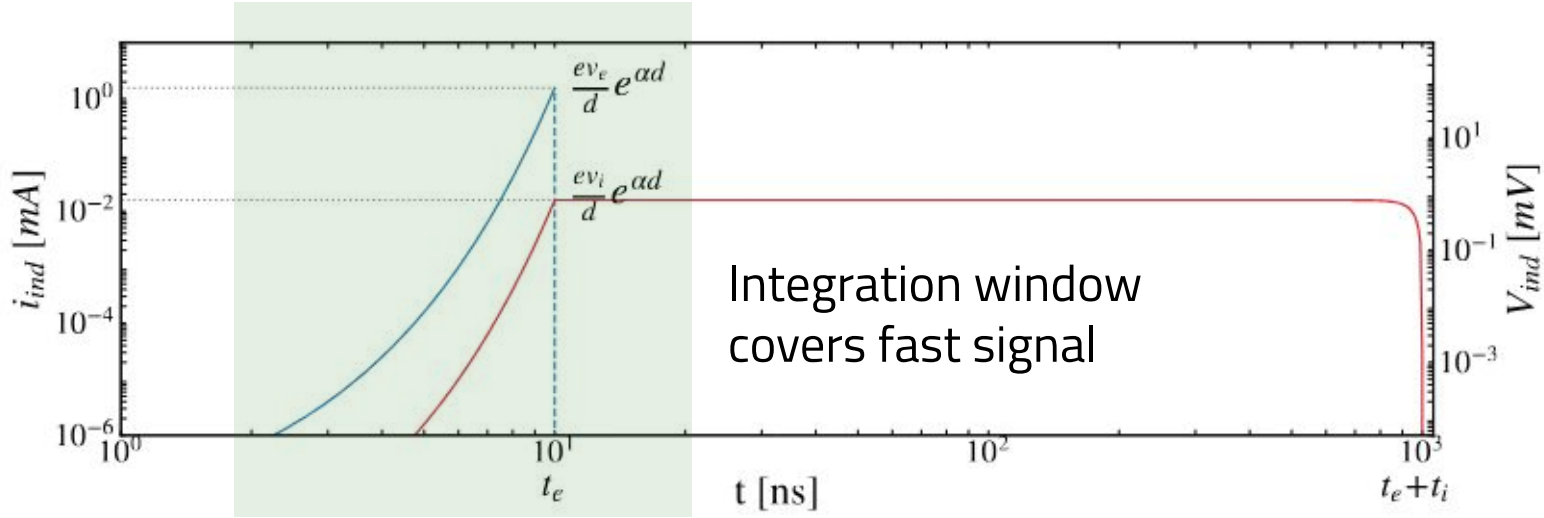
2 multigap RPCs **stacked**

Thick readout strips are in the **middle**



Still measuring the fast signal

→ **Faint** (less efficient) and **ballistic deficit** (losing information)



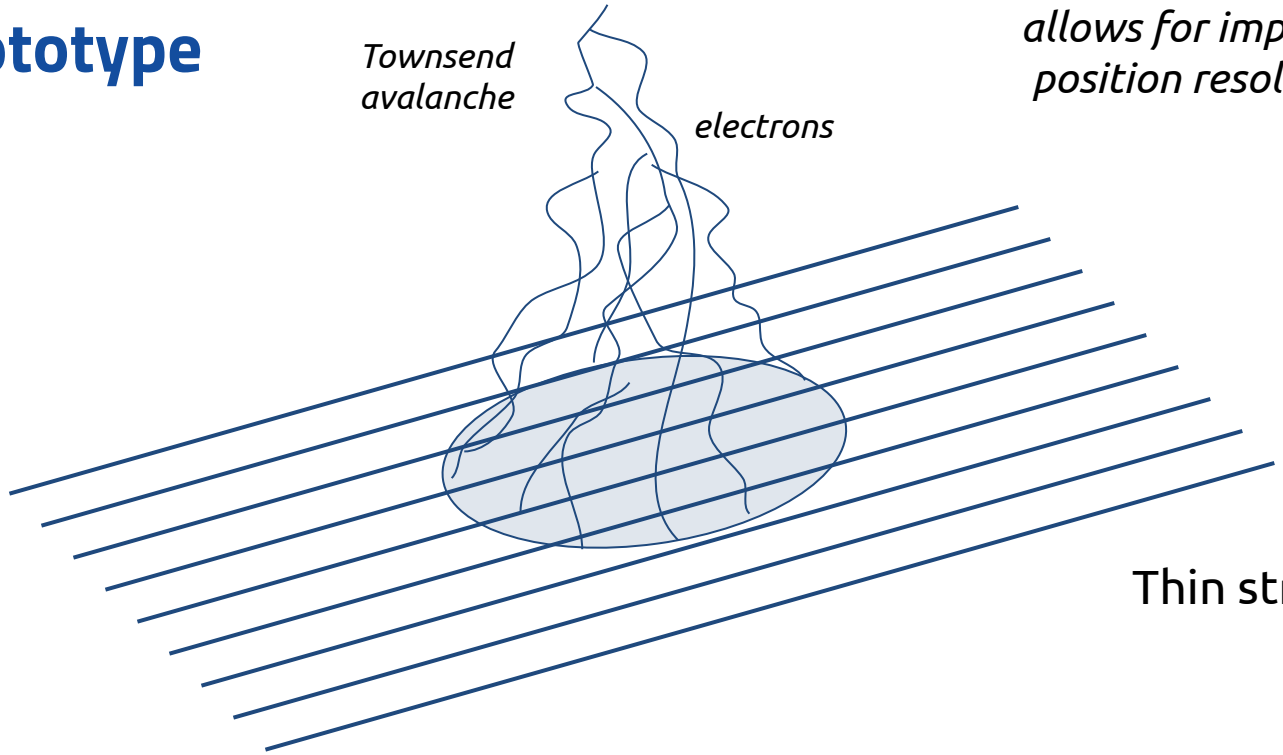
Still, using a double stack allows for **98% efficiency for MIPs**

More advanced versions

Multiplexing: SHIP prototype

SHIP prototype

Charge induction sharing allows for improved position resolution



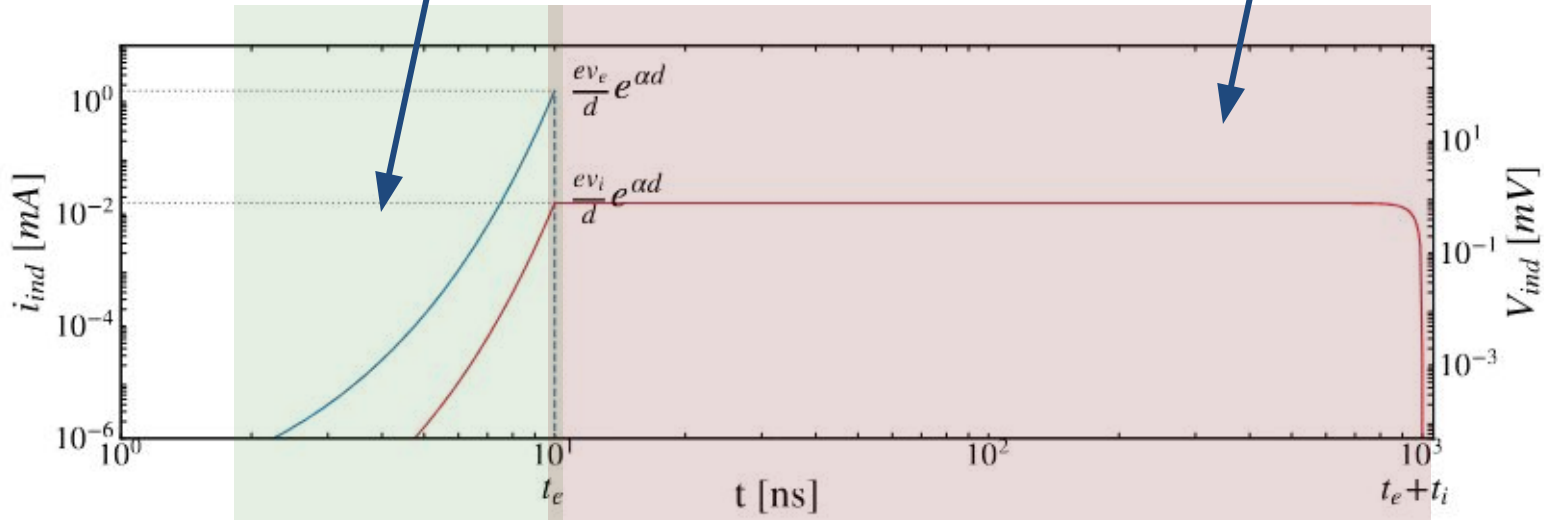
Thin strips

Let's take profit on the long signal

But combining readouts

Thin strips for slow signal → position

Thick strips for fast signal → timing



→ **Robust** (more efficient) and **total charge collection**

Readout electrodes

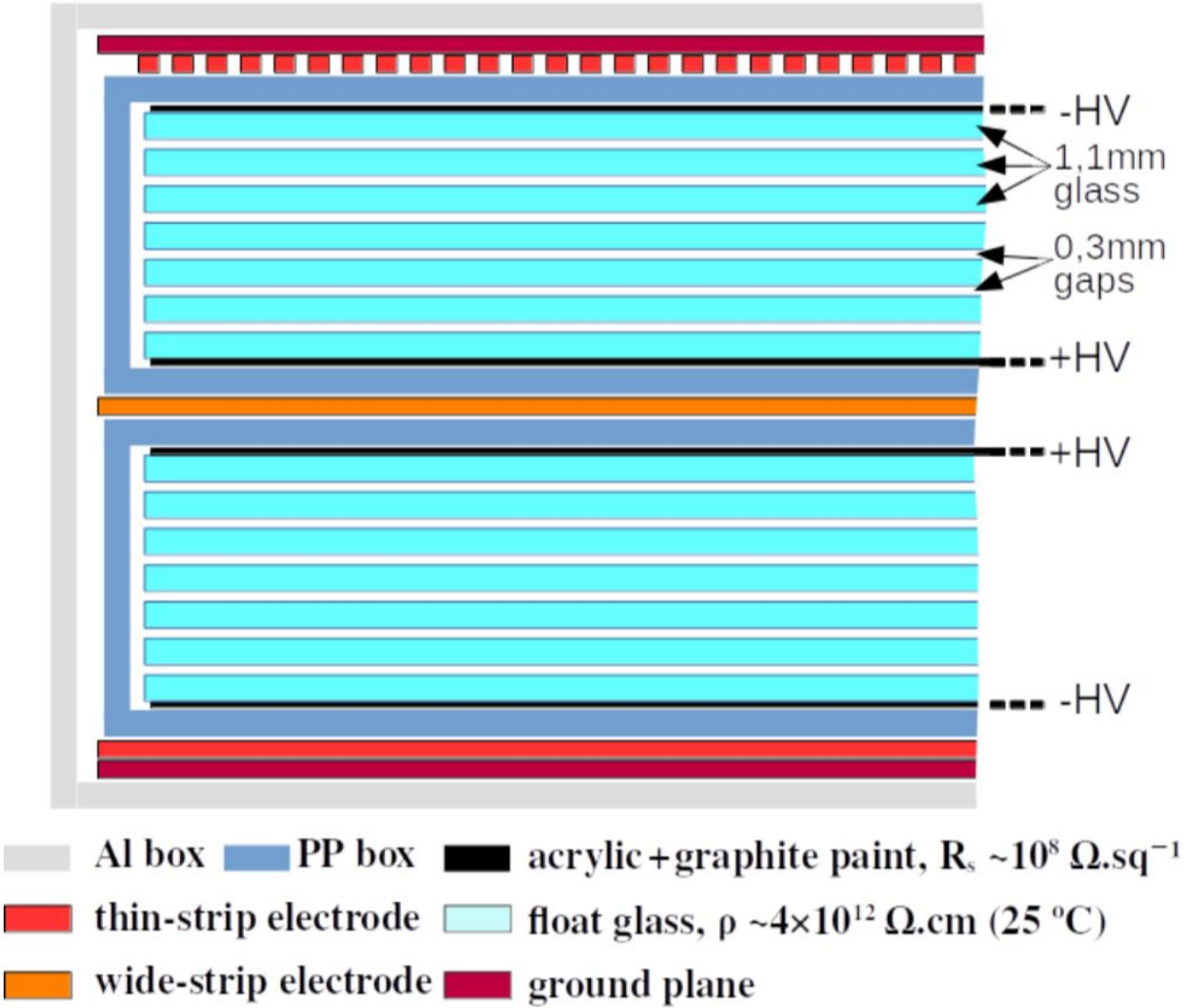
Pitch 61.0 mm
Interstrip 2 mm

Pitch 2.54 mm
Interstrip 1 mm

(a) Thin-strip PCB

(b) Wide-strip PCB

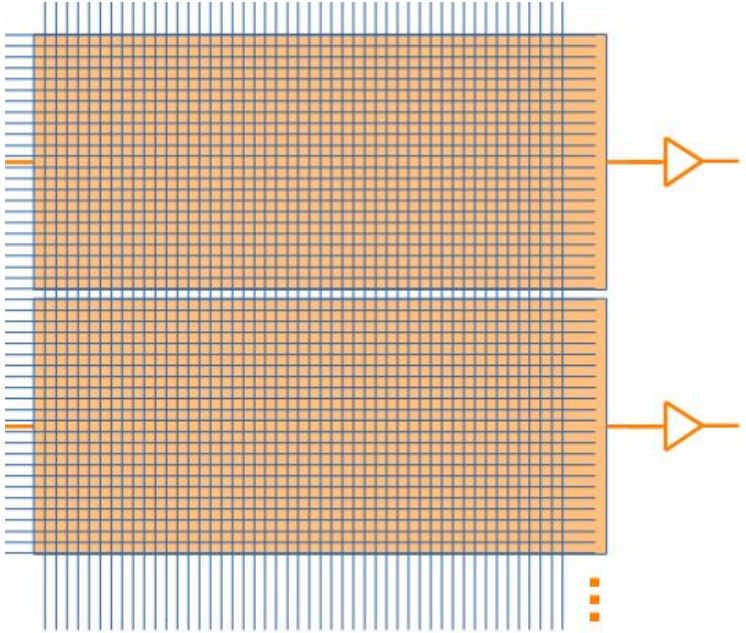
SHIP prototype



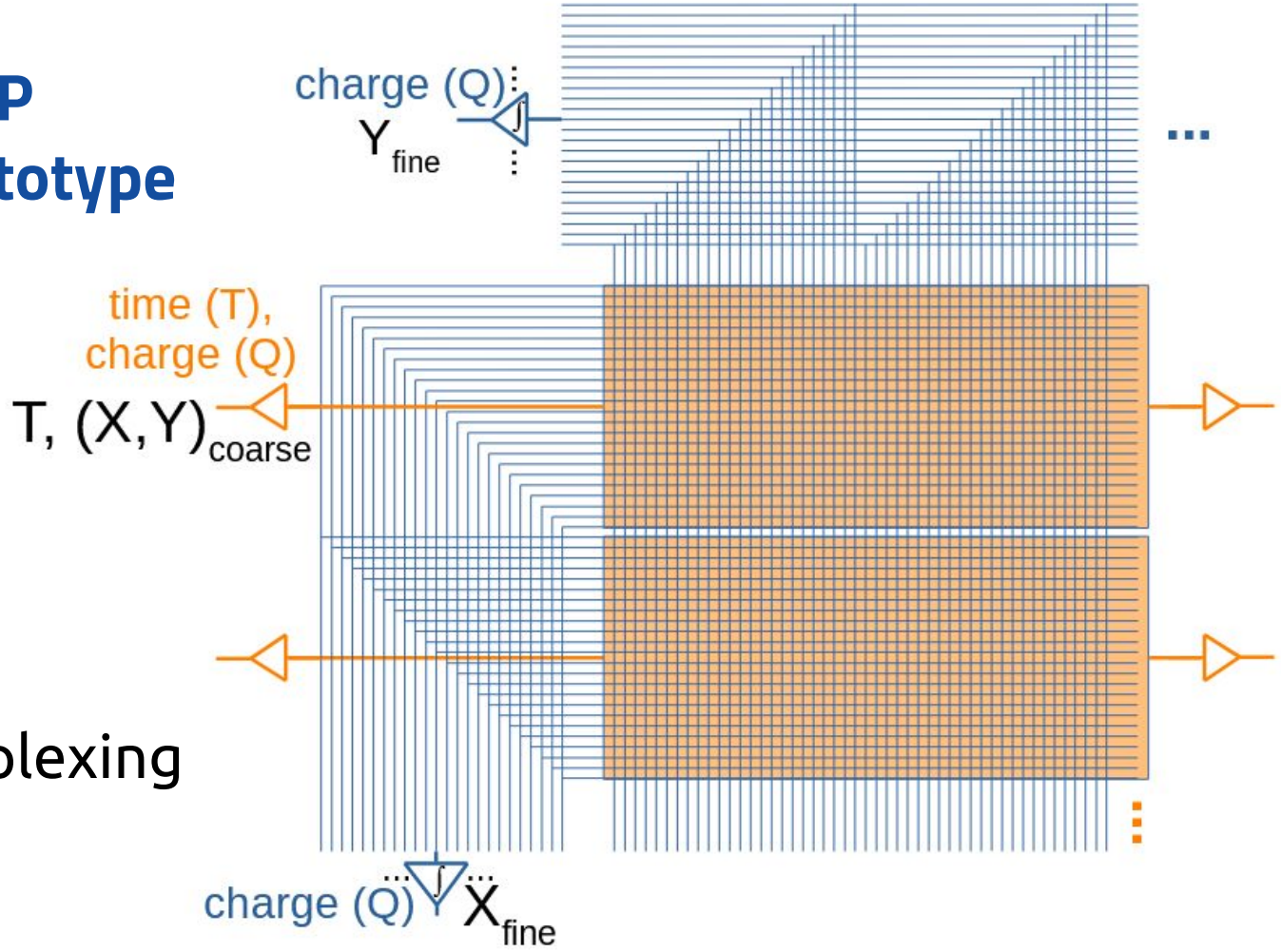
SHIP prototype

But this makes the channel count massive → high cost

Solution?



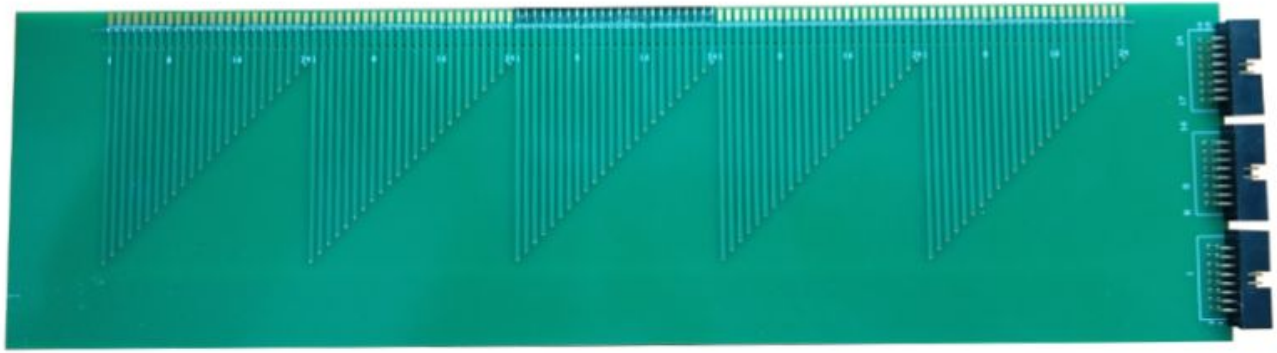
SHIP prototype



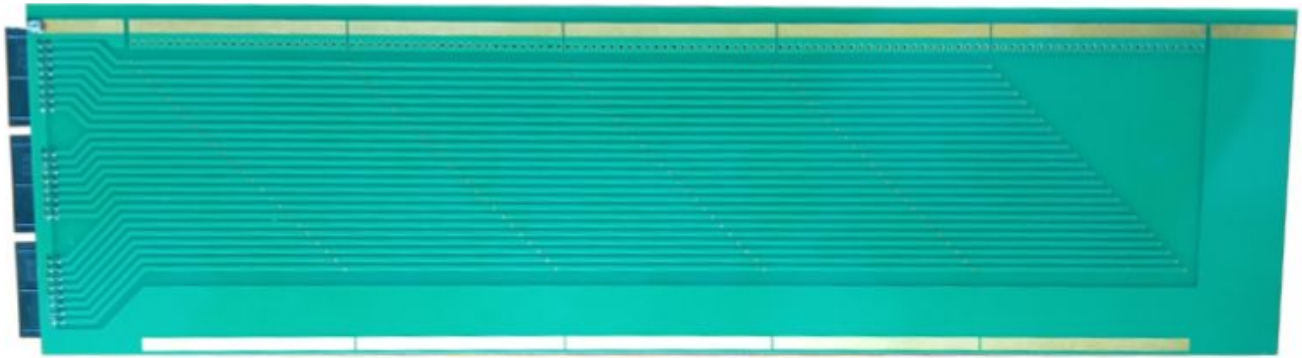
Multiplexing

SHIP prototype

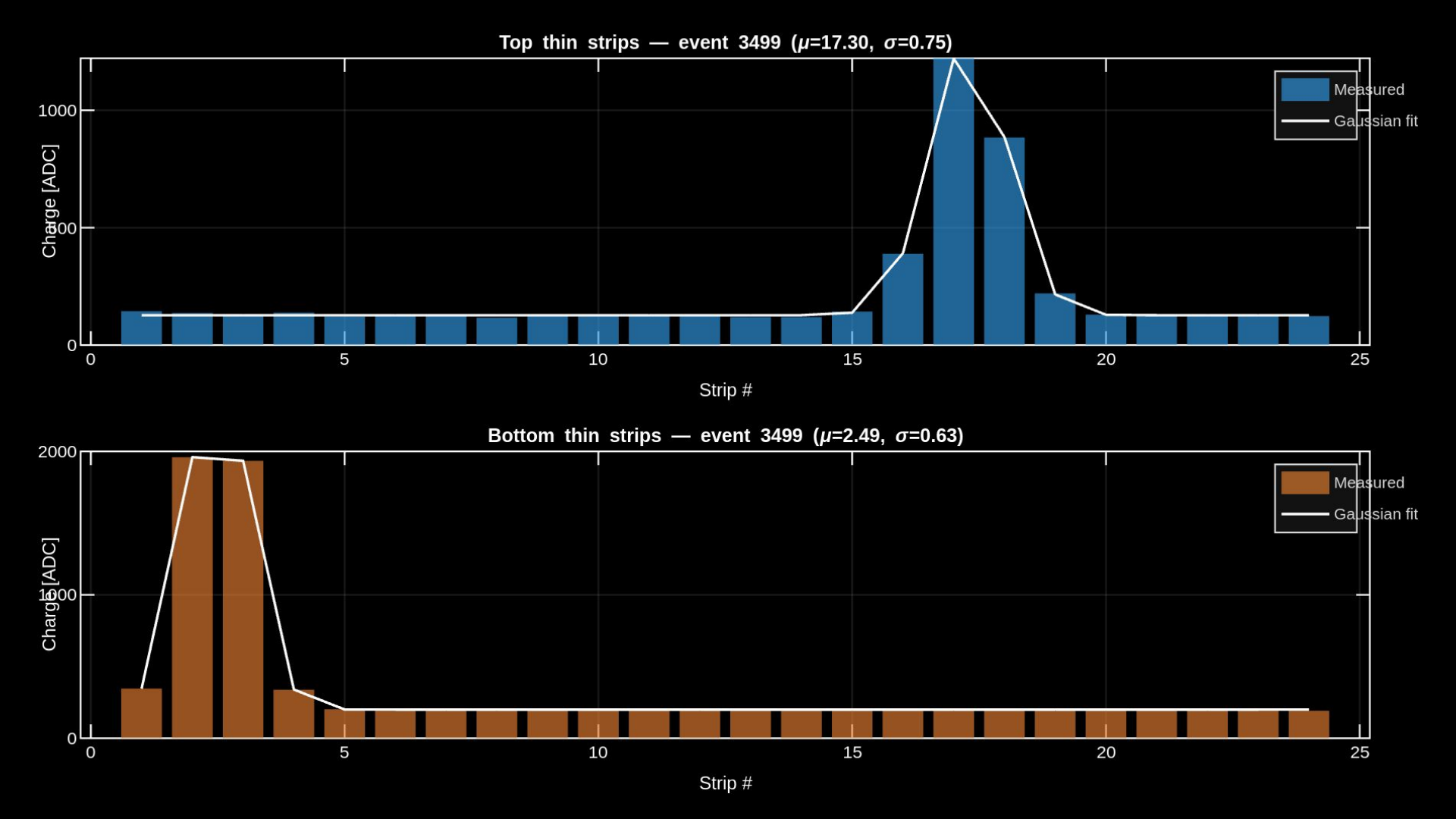
Multiplexing PCB



Front side

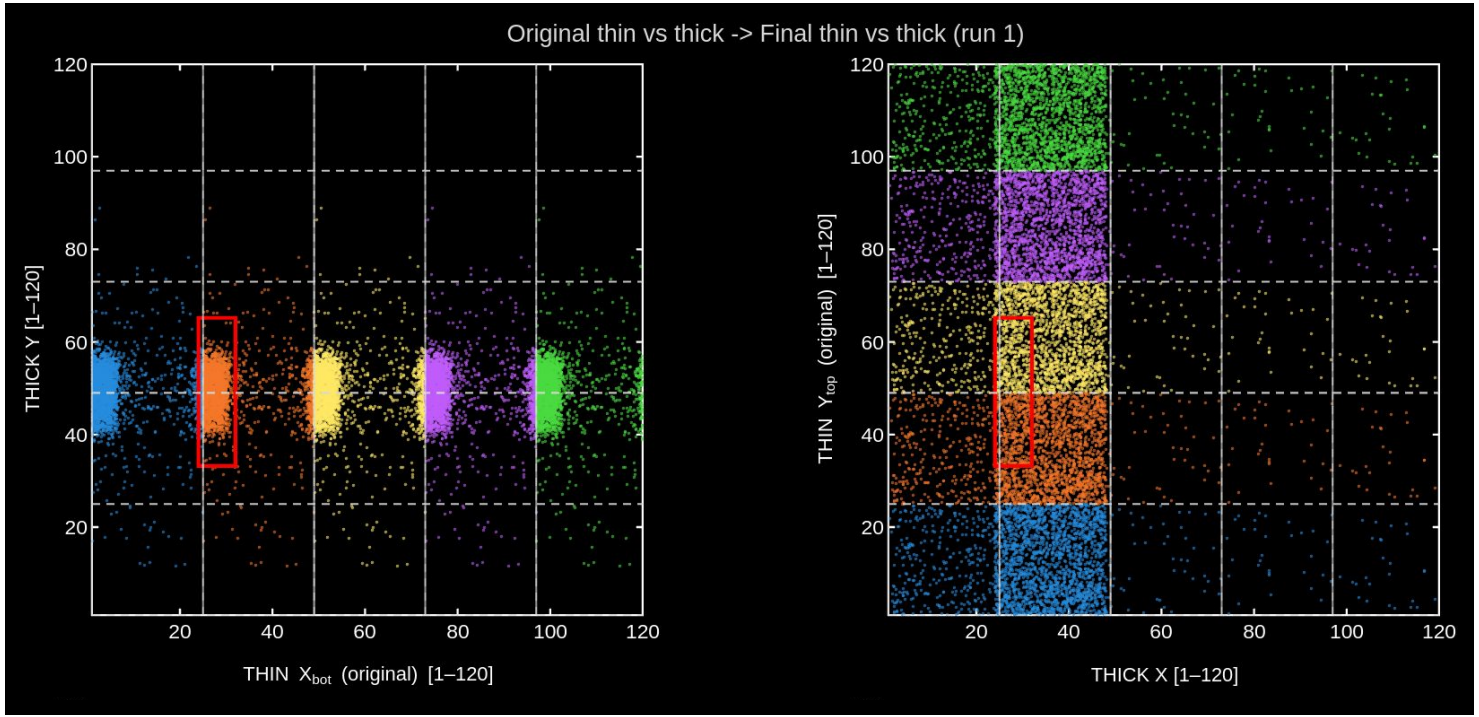


Rear side


Top thin strips — event 3499 (μ=17.30, σ=0.75)
Measured
Gaussian fit
Charge [ADC]
Strip #
Bottom thin strips — event 3499 (μ=2.49, σ=0.63)
Measured
Gaussian fit
Charge [ADC]
Strip #

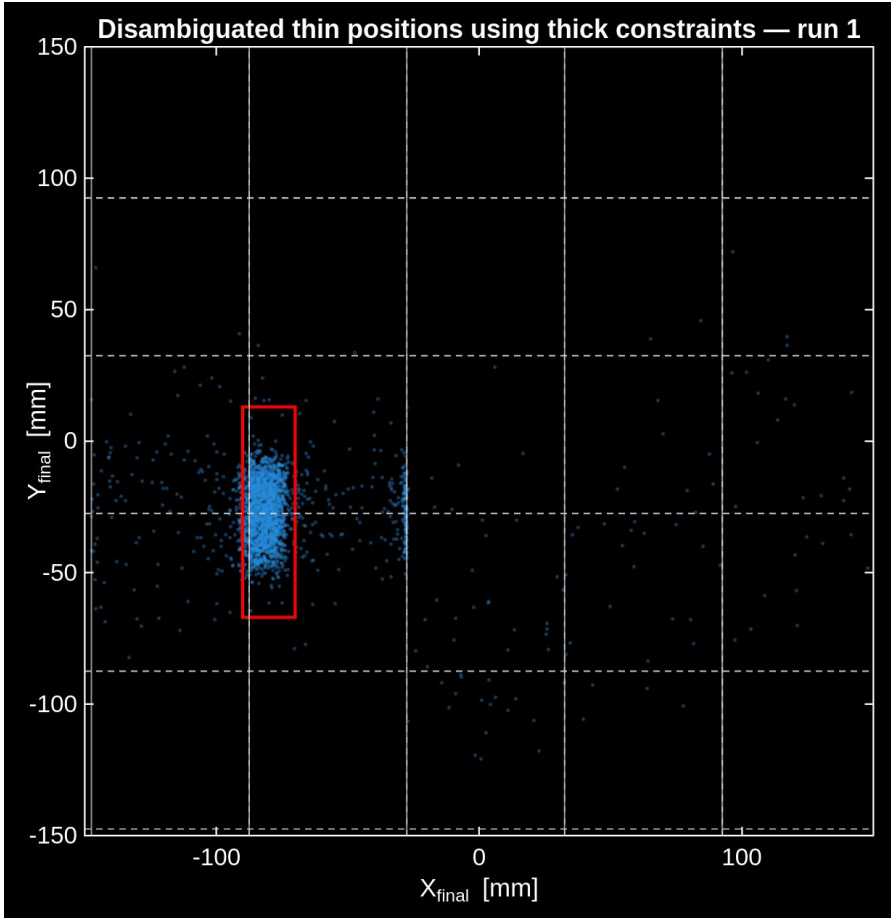
SHIP prototype

Ambiguities can be eliminated by combining information from different detector components



SHIP prototype

Unwrapped positions (preliminary method, yet to be refined)



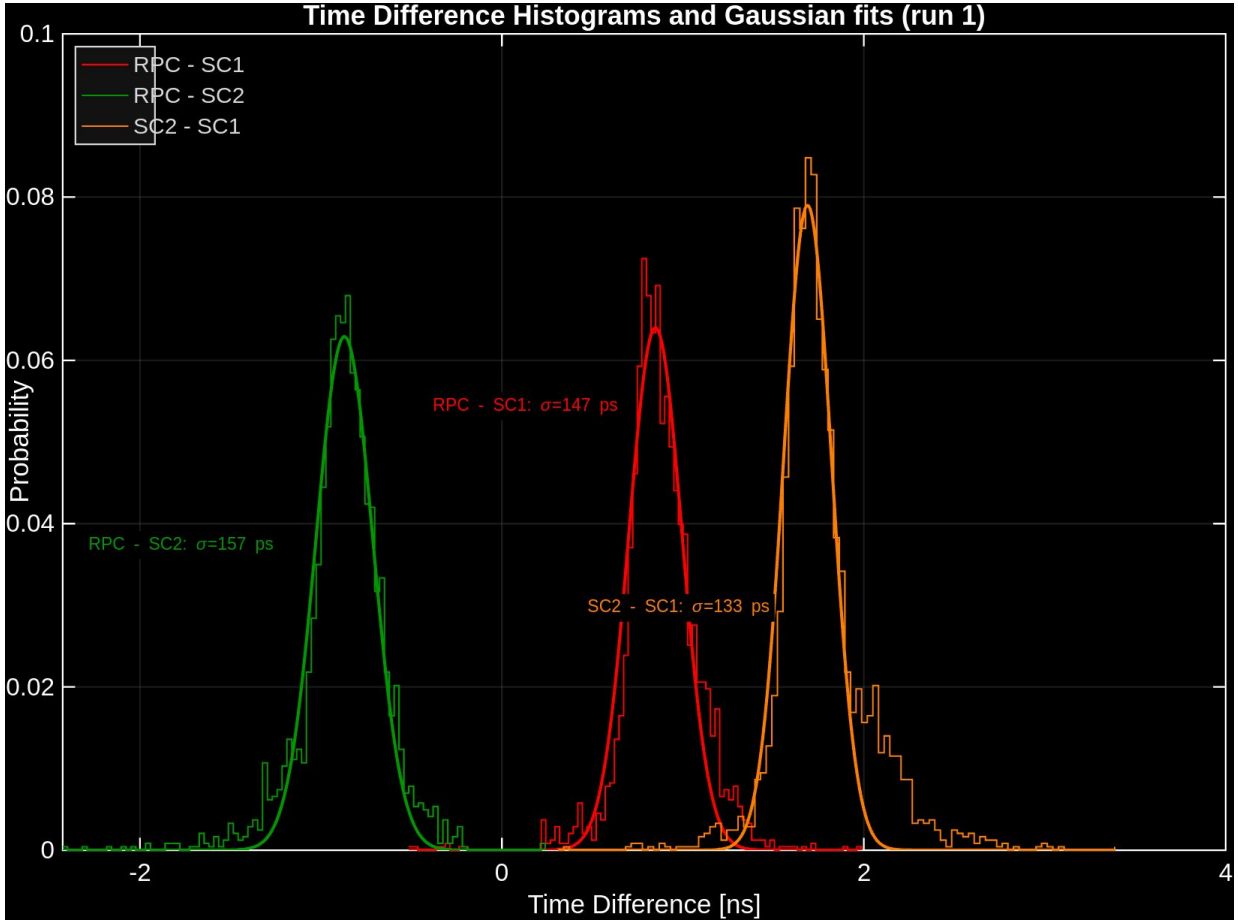
SHIP prototype

Time resolution (preliminary)

$$\begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} \sigma^2_{RPC} \\ \sigma^2_{SC_1} \\ \sigma^2_{SC_2} \end{bmatrix} = \begin{bmatrix} \sigma^2_{RPC\text{-}SC_1} \\ \sigma^2_{RPC\text{-}SC_2} \\ \sigma^2_{SC_1\text{-}SC_2} \end{bmatrix}$$

Time res. (equal-PMT assumption)

- RPC → **119 ps (preliminary)**
- SC → 94 ps

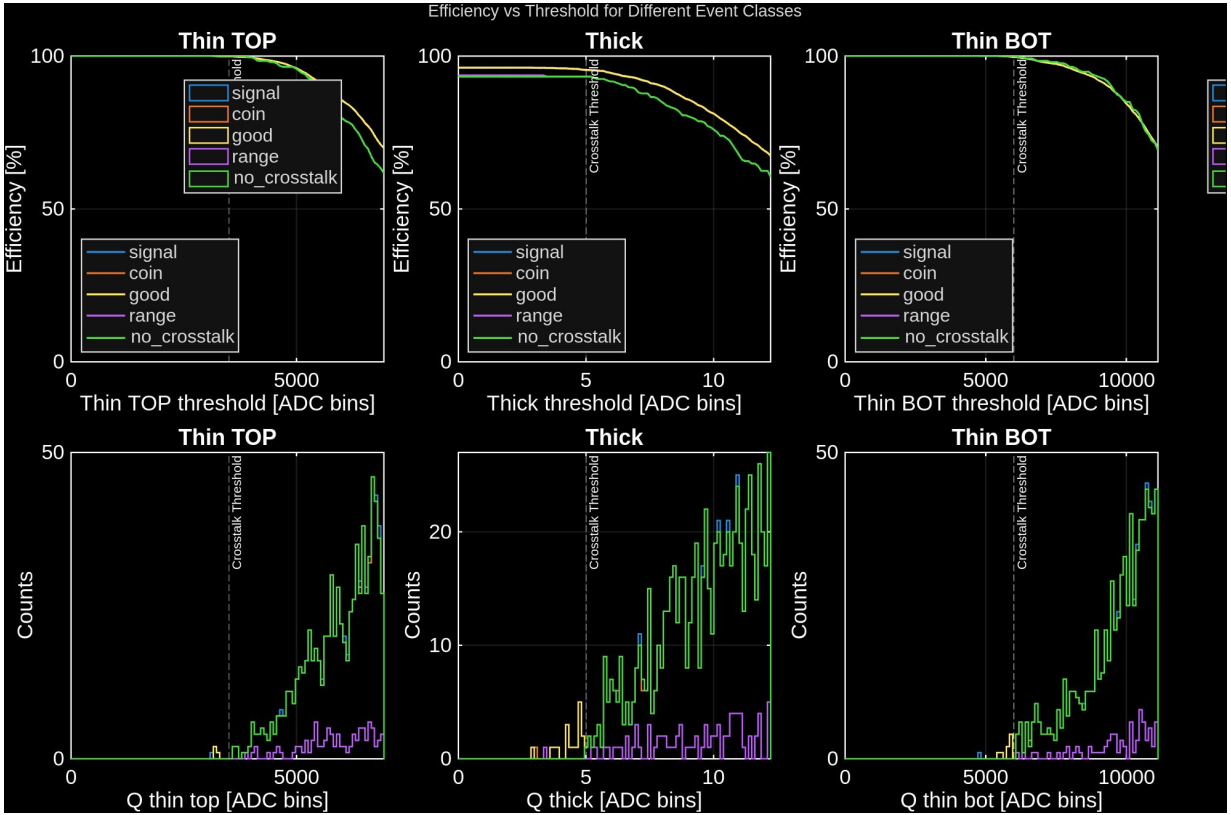


SHIP prototype

Efficiency (preliminary)

Using scintillators as reference

RPC	Efficiency [%]
Thin_top	100.0 (2.8)
Thick_center	96.2 (2.7)
Thin_bottom	100.0 (2.8)



Next step

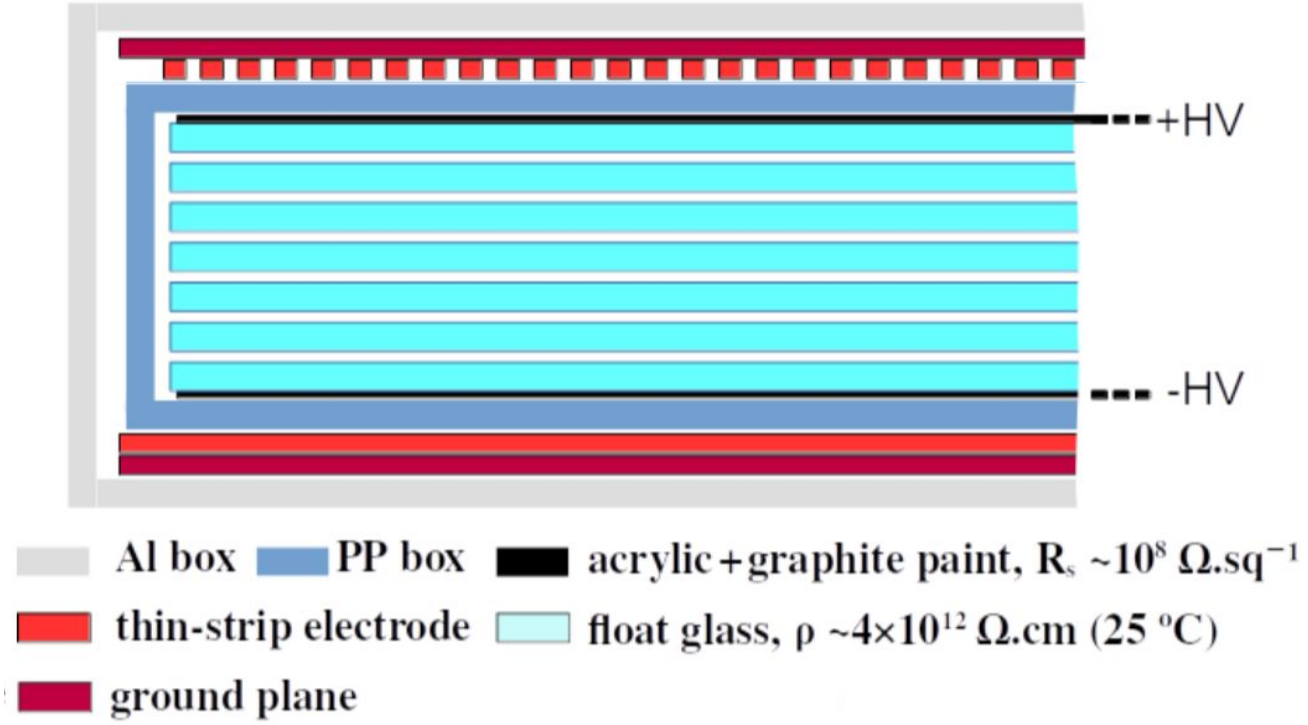
going for the single plane

Single-plane prototype

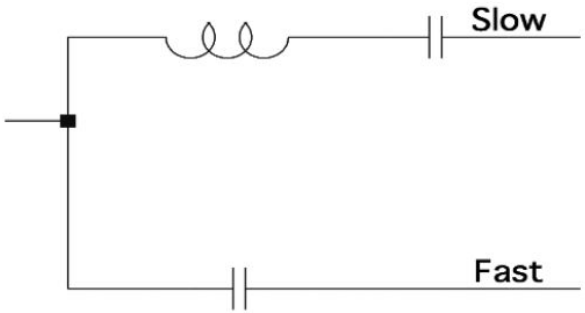
Fewer channels, less electronics, less material

Problem
Which readout for timing, which one for position?

Solution
Both of them!



Single-plane prototype: signal separation



Signal collected fully on thin strips

- Dedicated RC network to split fast and slow components
- Tests (Joana Pinto @ LIP):
  - Emulation of a typical RPC pulse.
  - Capacitors scanned and optimal ratio found
    i. C_fast : C_slow ≈ 1 : 10, with final values 560 pF (fast) and 5.6 nF (slow), avoiding saturation and keeping amplitudes.

→ *Next step is plugging real RPC signals*

Concluding

a summary of the story

Conclusions - *A detector story*

- **miniTRASGO**
  a good workspace for detector characterization
- **R3B prototype**
  → double mRPC read in the middle
- **SHIP prototype**
  → introducing thin strips and multiplexing
- **Single plane**
  → thin strips only and fast/slow filter

We are here.

Thank you!

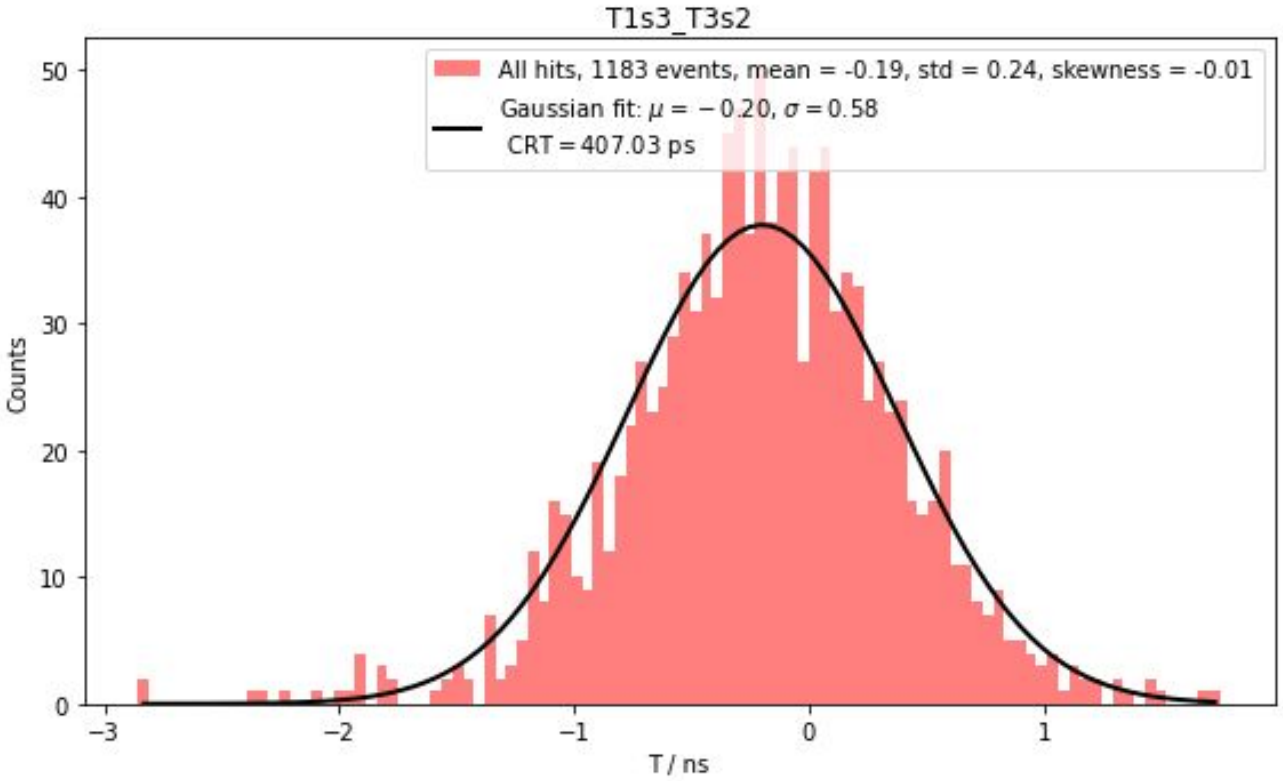
Questions?

RPC readout optimization: miniTRASGO as a path to a single-plane multiplexed timing system

csoneira@ucm.es
C. Soneira-Landín

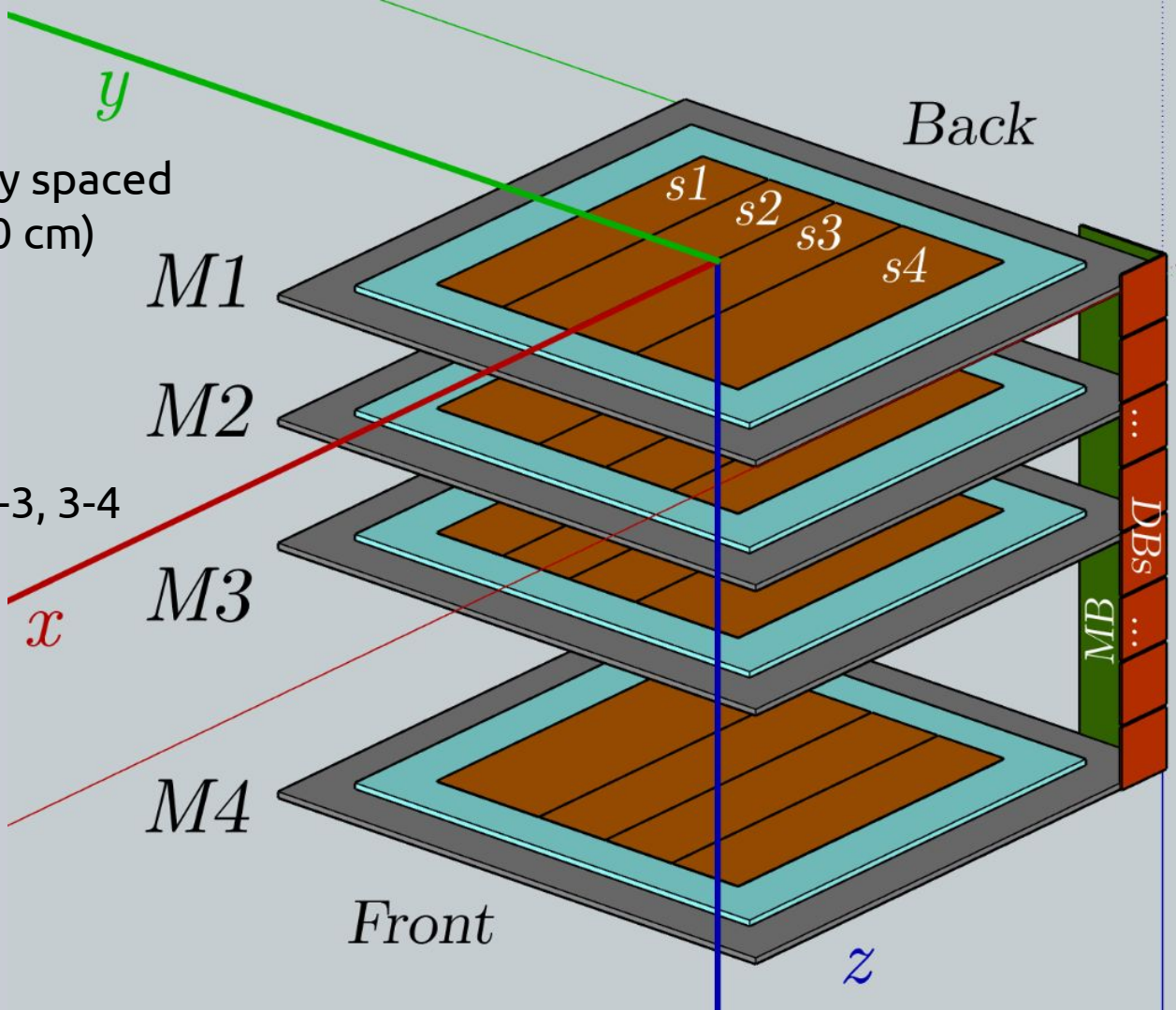
Back-up slides

for those curious


T1s3_T3s2
All hits, 1183 events, mean = -0.19, std = 0.24, skewness = -0.01
Gaussian fit: $\mu = -0.20$, $\sigma = 0.58$
CRT = 407.03 ps
Counts
T / ns
0
10
20
30
40
50
−3
−2
−1
0
1

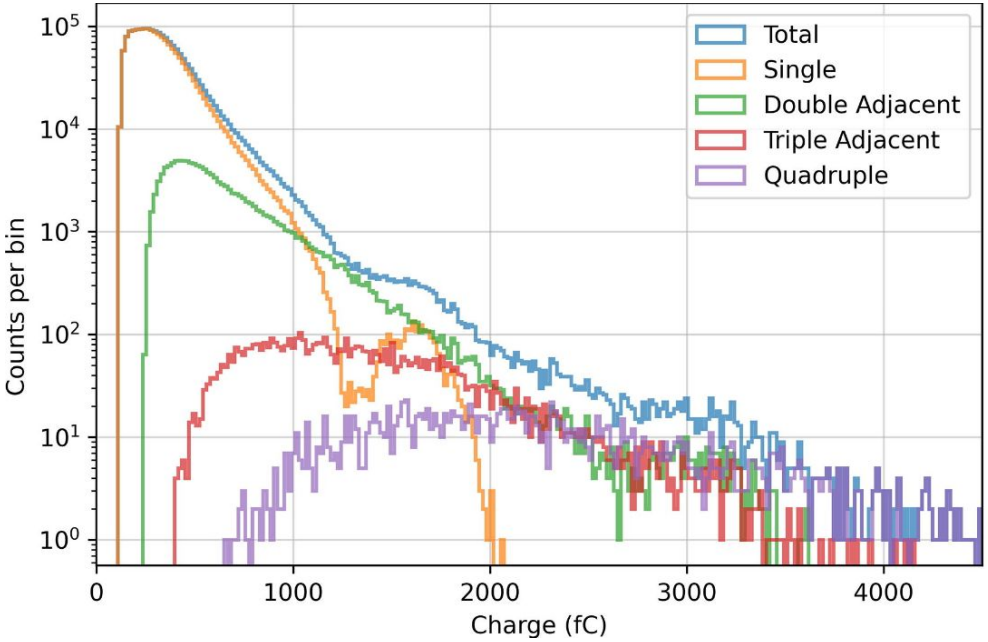
Not evenly spaced
(10 and 20 cm)

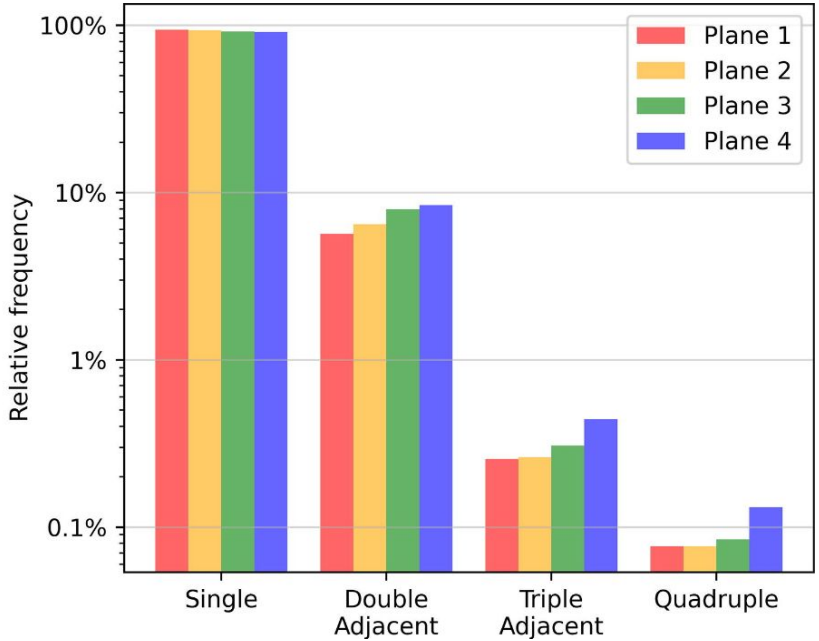
Trigger:
1-2, 1-3, 2-3, 3-4

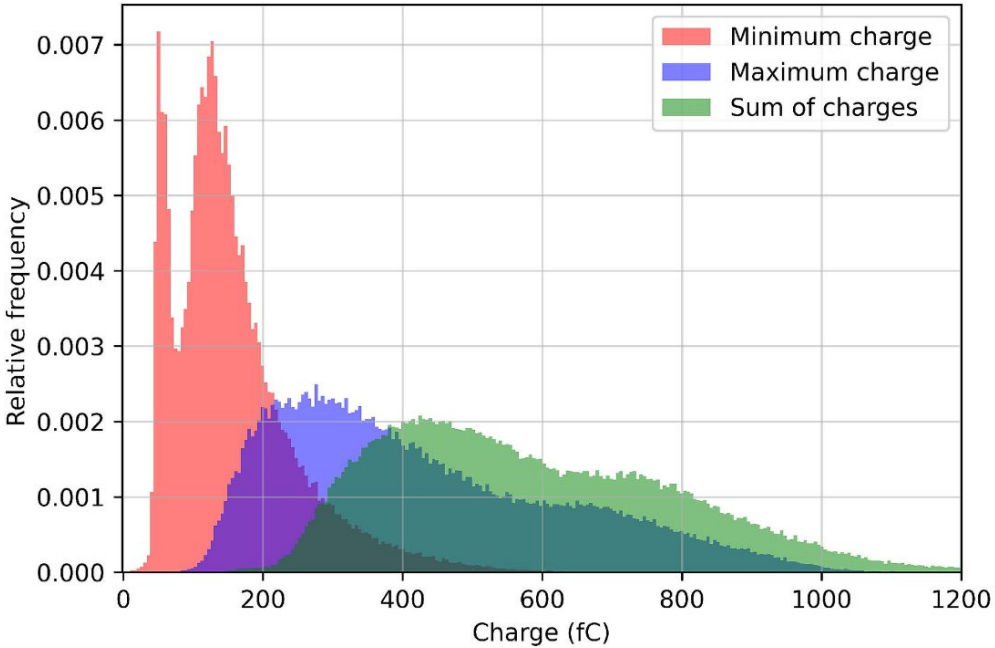


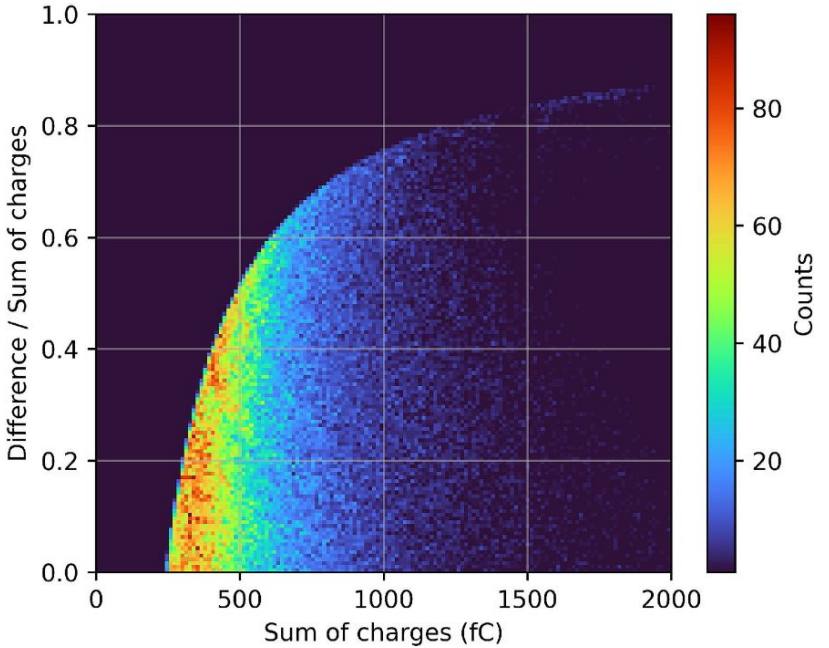
Asymmetric parallel **Cu** strips read in Front and Back

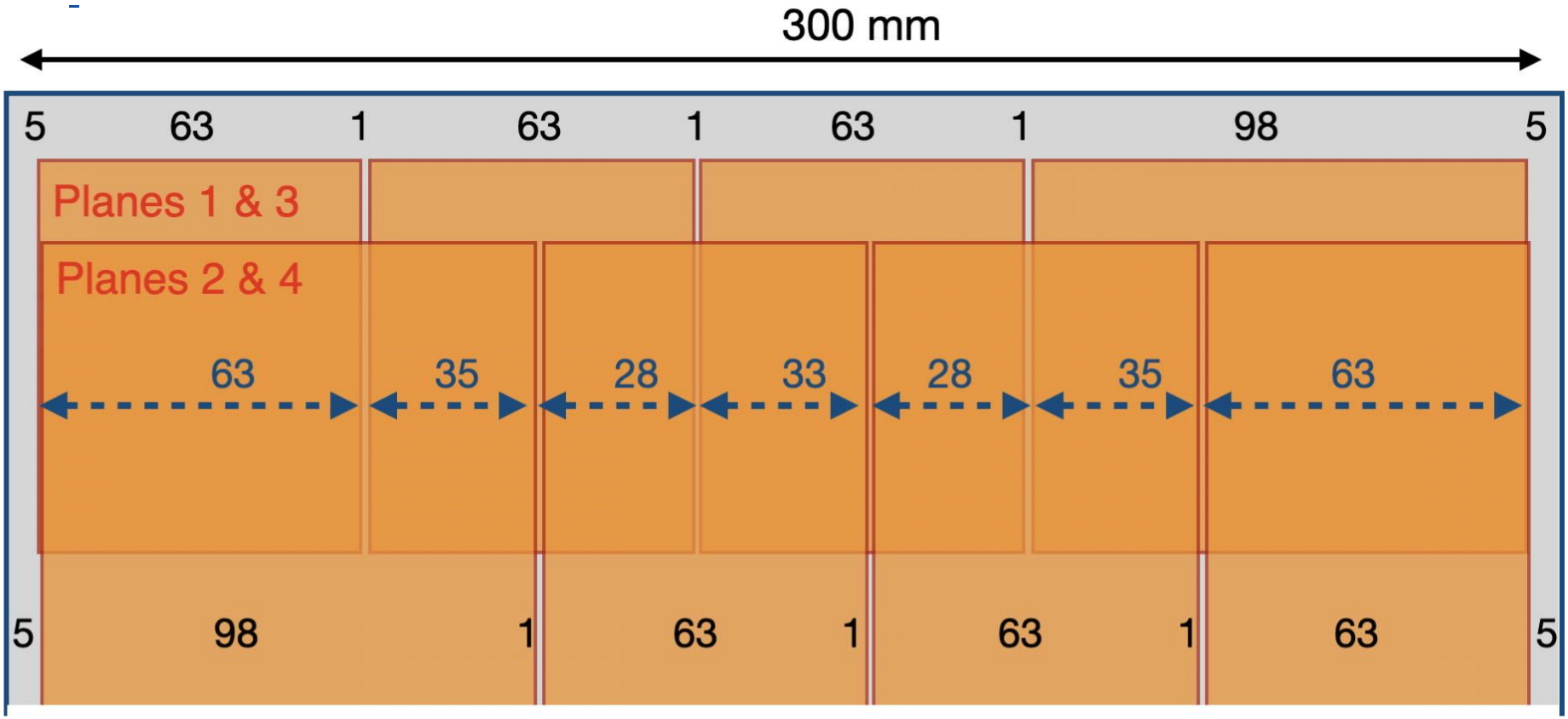
32 channels


Total
Single
Double Adjacent
Triple Adjacent
Quadruple
Counts per bin
Charge (fC)
0
1000
2000
3000
4000


Plane 1
Plane 2
Plane 3
Plane 4
Relative frequency
100%
10%
1%
0.1%
Single
Double Adjacent
Triple Adjacent
Quadruple


Minimum charge
Maximum charge
Sum of charges
Relative frequency
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0
200
400
600
800
1000
1200
Charge (fC)


Difference / Sum of charges
0.0
0.2
0.4
0.6
0.8
1.0
0
500
1000
1500
2000
Sum of charges (fC)
Counts
20
40
60
80


300 mm
5
63
1
63
1
63
1
98
5
Planes 1 & 3
Planes 2 & 4
63
35
28
33
28
35
63
5
98
1
63
1
63
1
63
5

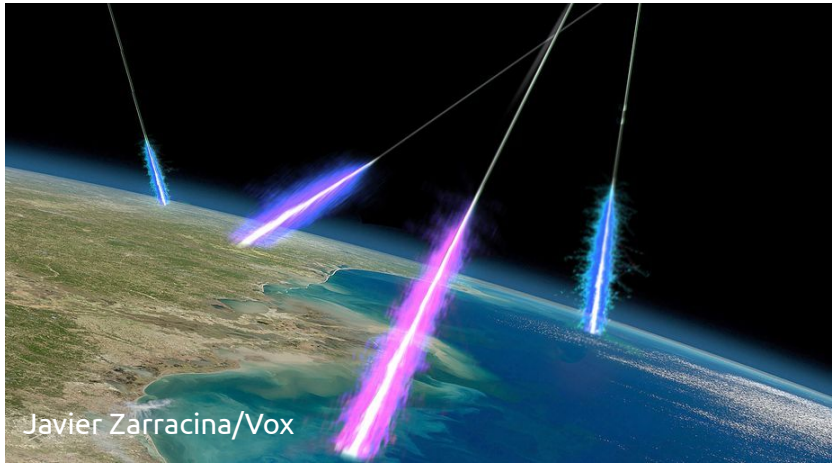
Nuclear reactions in the upper atmosphere

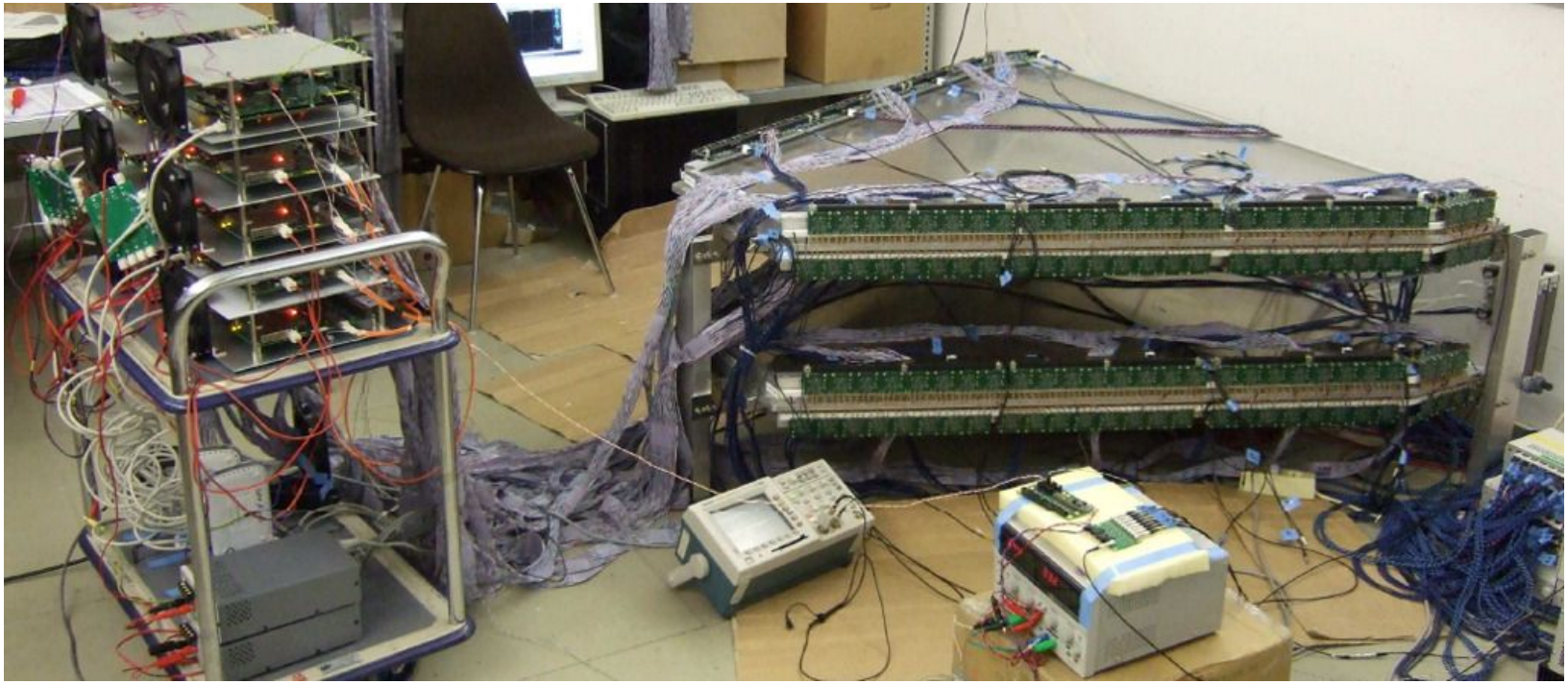
$$p + A \rightarrow p + n + \pi^0 + \pi^{\pm} + \ldots$$

$$\pi^{\pm} + A \rightarrow \pi^0 + \pi^{\pm} + \ldots$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$





HADES Time-of-Flight Wall (commissioning)

- D. Belver et al., *TRASGO: A proposal for a timing RPCs based detector for analyzing cosmic ray air showers*, NIM A, 2012, https://doi.org/10.1016/j.nima.2010.09.173
- A. Blanco et al., *RPC HADES-TOF wall cosmic ray test performance*, NIM A, 2012, https://doi.org/10.1016/j.nima.2010.08.068
- D. Belver et al., *Analysis of the space-time microstructure of cosmic ray air showers using the HADES RPC TOF wall*, JINST, 2012, 10.1088/1748-0221/7/10/P10007

TRAGALDABAS

- A Blanco et al., *TRAGALDABAS: a new RPC based detector for the regular study of cosmic rays*, JINST, 2014, DOI 10.1088/1748-0221/9/09/C09027
- I. Riádigos et al., *Revisiting the limits of atmospheric temperature retrieval from cosmic-ray measurements*. Earth and Space Science, 2022, https://doi.org/10.1029/2021EA001982
- I. Riádigos et al., *Atmospheric temperature effect in secondary cosmic rays observed with a 2 m² ground-based tRPC detector*. Earth and Space Science, 2020, https://doi.org/10.1029/2020EA001131

- Logicmelt, *Stratos DS – Stratospheric temperature prediction using artificial intelligence*, Logicmelt – Use Cases, 2025, https://logicmelt.com/en/use-cases_eng/stratos-ds-prediction-of-the-stratosphere-temperature/
- NAC-Intercom, *Project STRATOS – Ground Station for Continuous Monitoring of the Stratosphere Temperature through Cosmic Ray Directional Flow*, NAC-Intercom – Projects, 2025, https://www.nac-inter.com/en/content/30-project-stratos

STRATOS

TRISTAN

- J.P. Saraiva, et al., *The TRISTAN detector—2018–2019 latitude survey of cosmic rays. Journal of Instrumentation*, JINST, 2020, https://doi.org/10.1088/1748-0221/15/09/C09024

miniTRASGO network

Warsaw 🇵🇱

Madrid 🇪🇸

Puebla 🇲🇽

Monterrey 🇲🇽

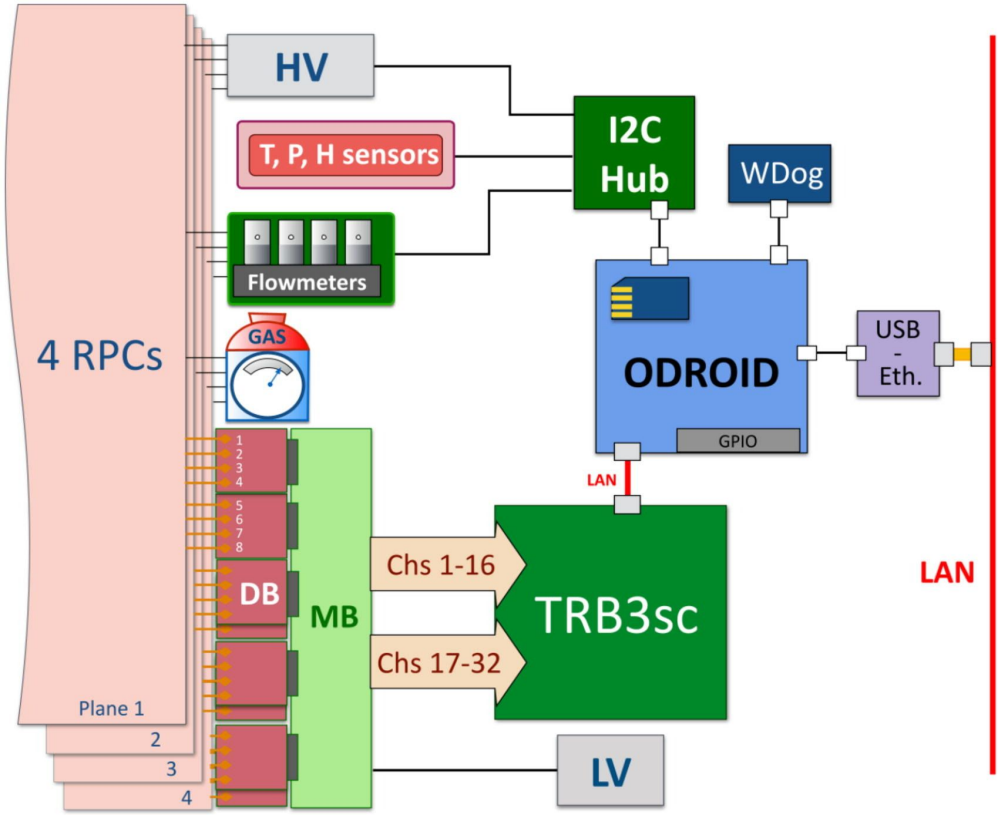
Compact and autonomous

Only three connections:

- **Power** (standard plug)
- **Gas** bottle (15 kg)
- **Ethernet** (not required)

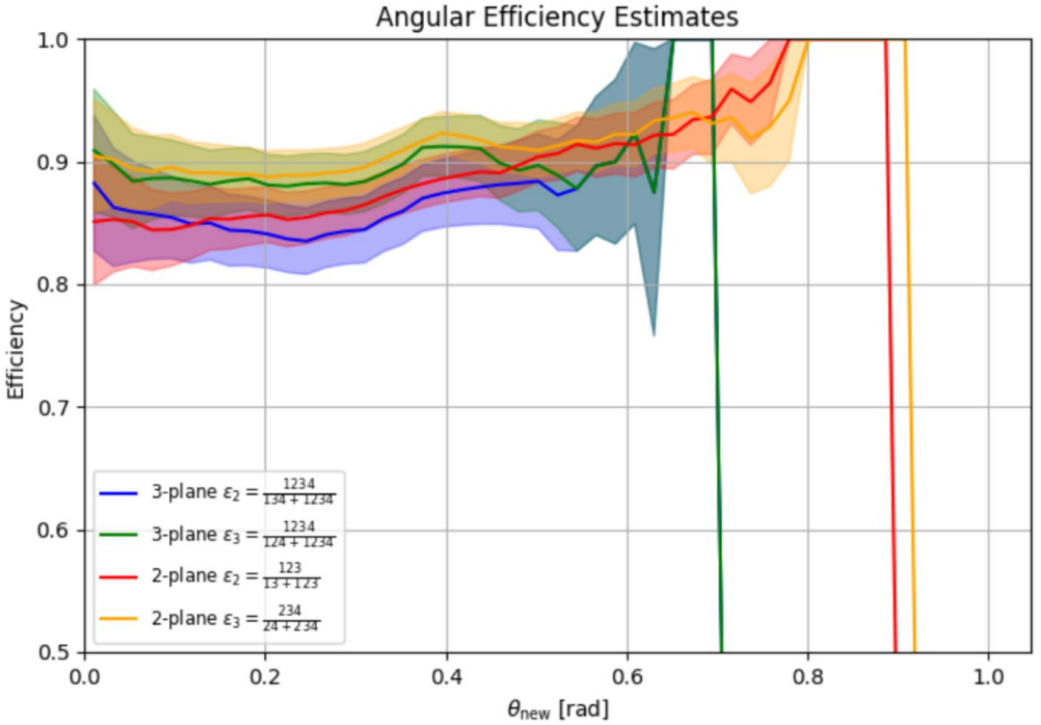
Includes:

- environment sensors, flowmeters, DAQ and a PC for data analysis and storage



Efficiency vs. incident zenith muon angle

Oblique tracks spend more time in the active volume

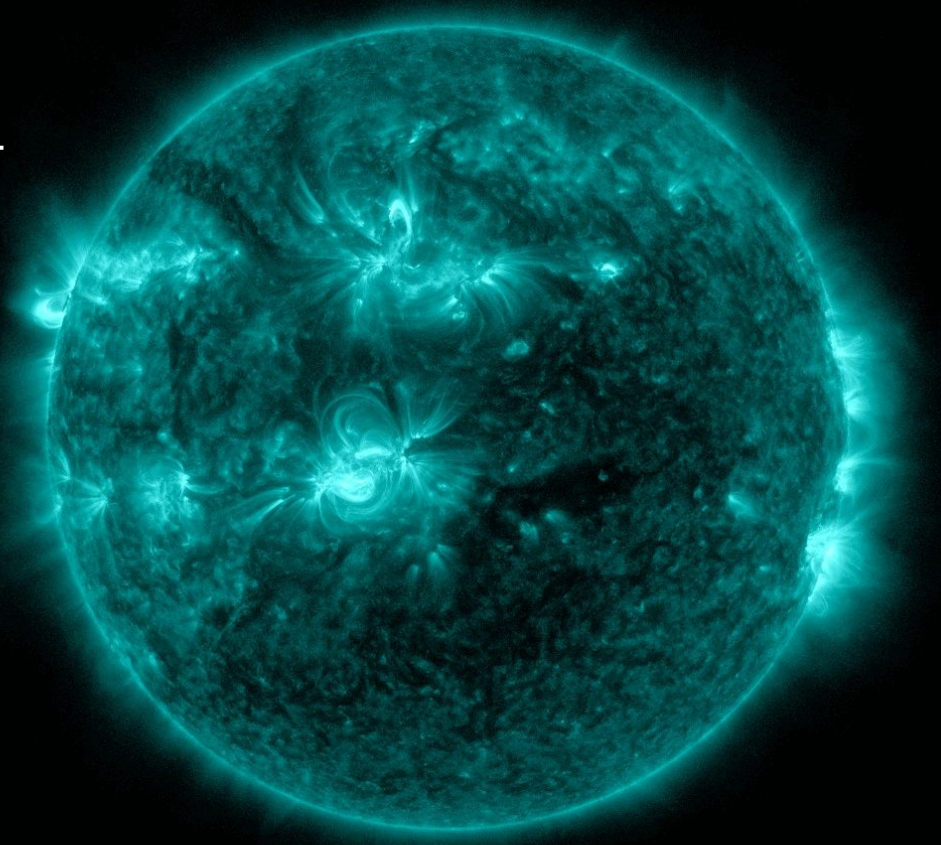


Forbush Decrease

On March 2024

Two Sunspots exploded in tandem on March 23rd 2024 (03:30 CET)

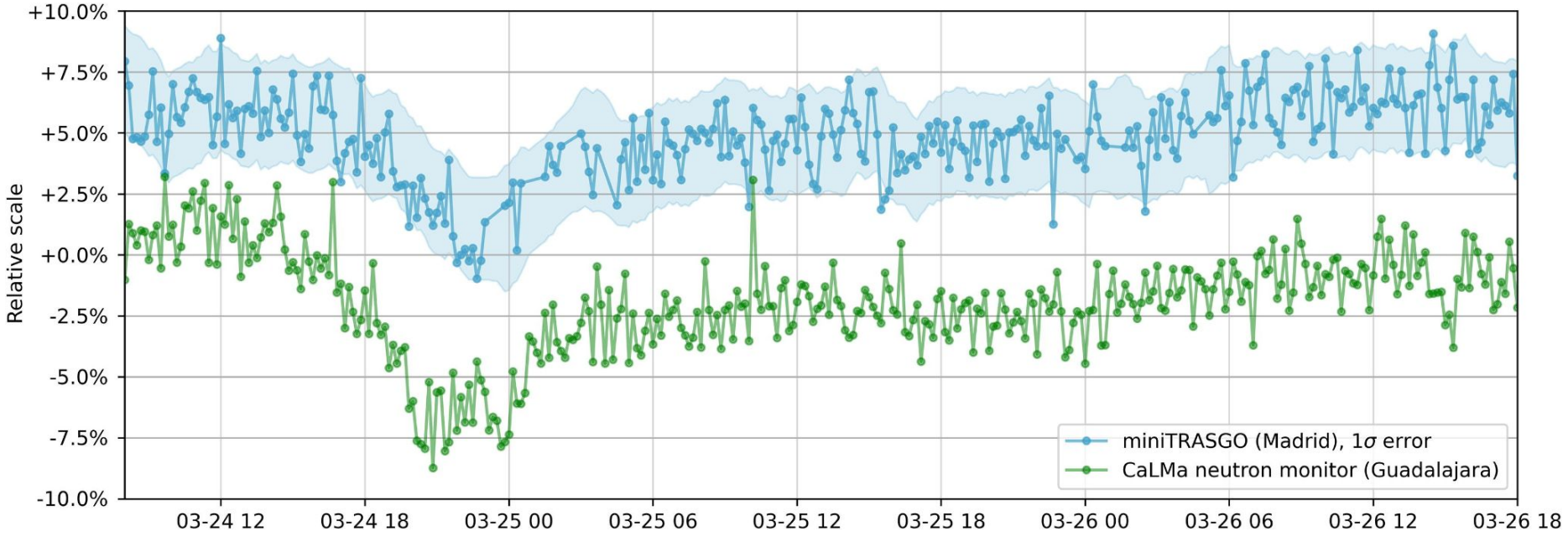
8 hours later…



From Solar Dynamics Observatory, NASA

Eff. and pressure corrected rate

→ the Forbush Decrease can be seen



Measure: time and charge in F and B per strip

Time sum → Incidence time
Time diff → Position
Charge sum → Total charge
Charge diff → Monitor