Performance of diamond timing detectors after collecting 2.5 fb^{-1}

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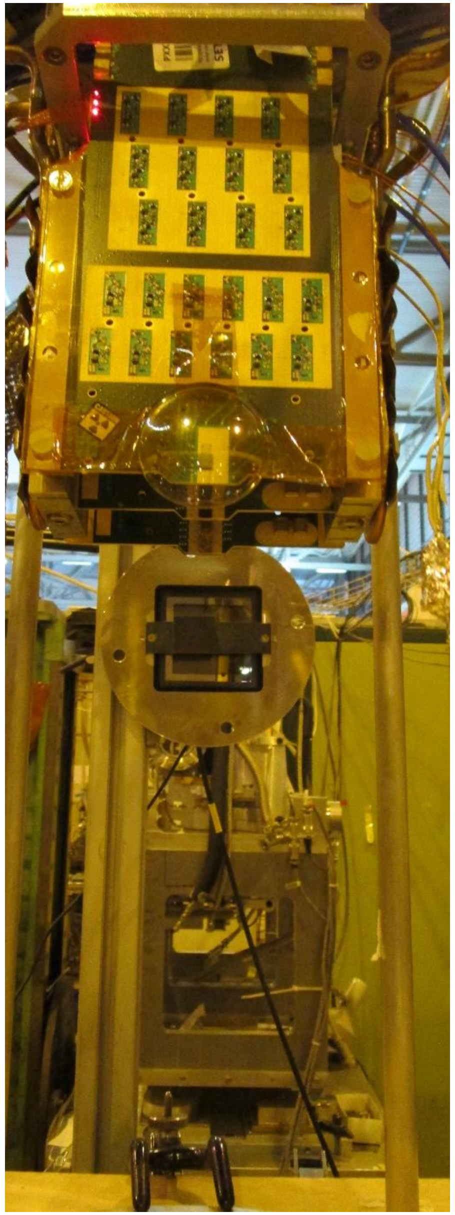
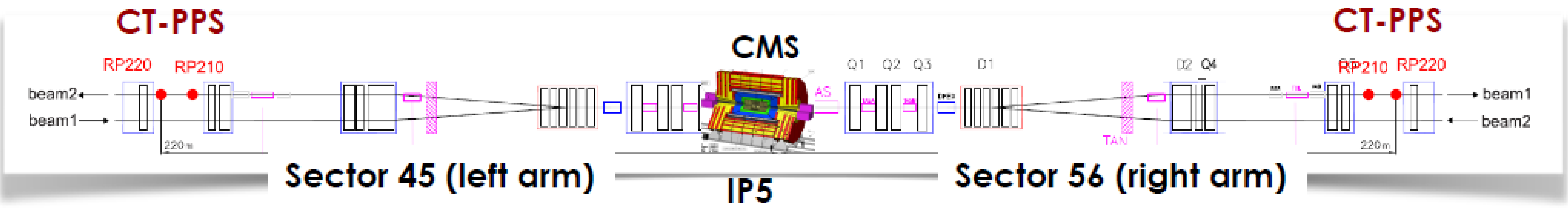
Overview

- ✓ Diamond as time of flight detector
- ✓ Double diamond
- ✓ Set-up at the test beam
- ✓ Results



Motivation: CMS-TOTEM Precision Proton Spectrometer (CT-PPS)



Measures forward protons, joint project between CMS and TOTEM

In each arm:

2 stations of tracking detectors: Precise measurement of proton trajectory

1 timing station: Time-of-Flight of proton

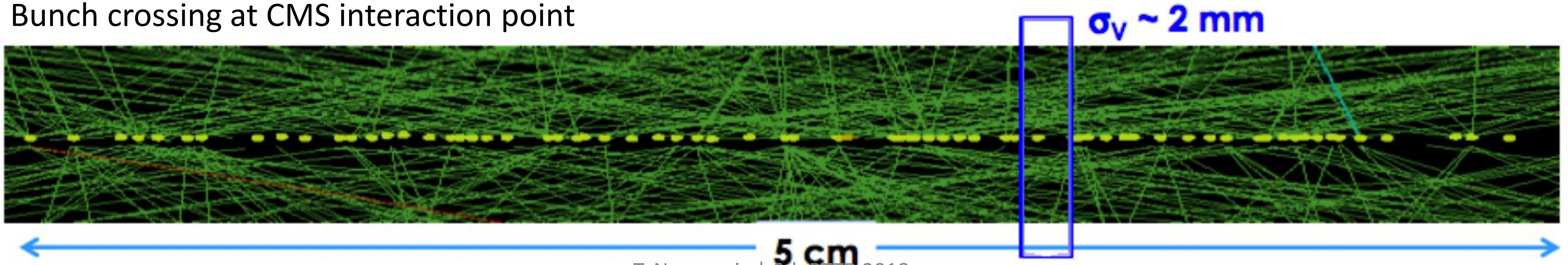
Vertex measurement by timing eg.: σ_t=10ps → σ_v=2mm

Needed time resolution depends on magnitude of **pile-up,**

Depending on beam optics needed resolution ranging from 10ps to 50ps

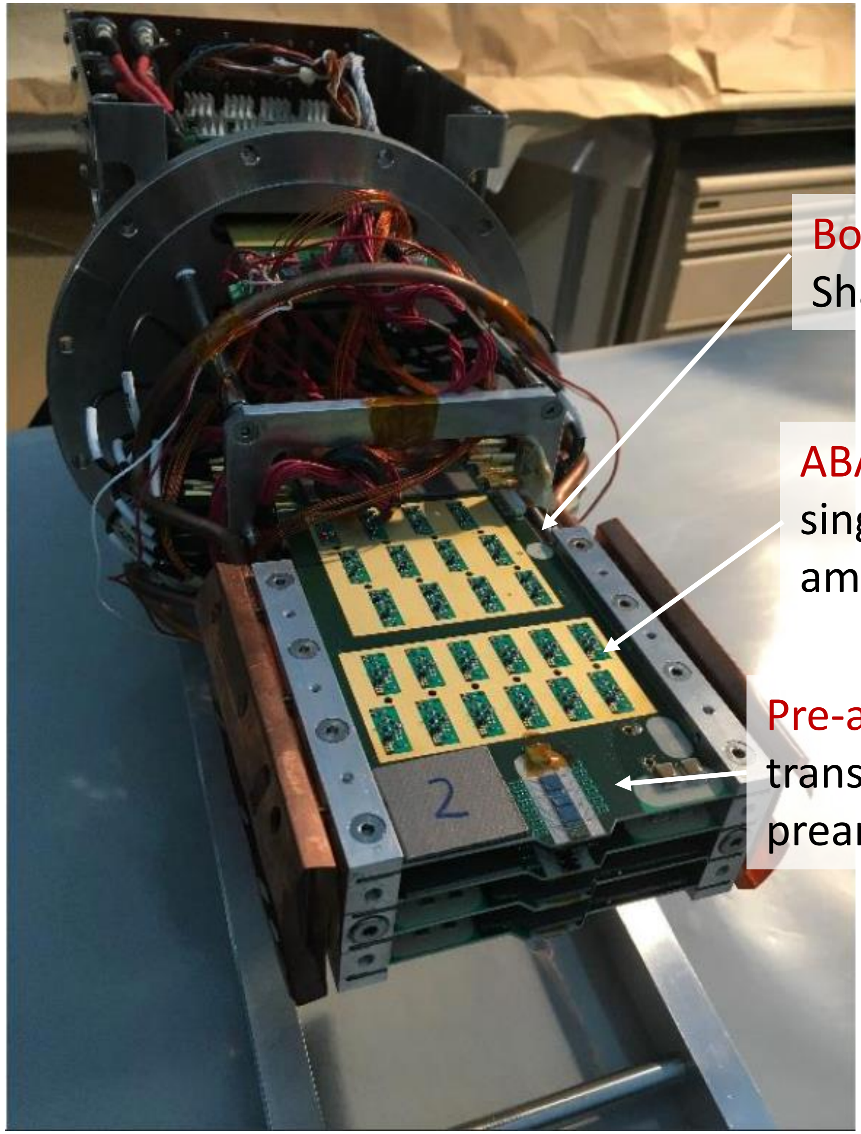
Note: Requirements for time precision are for detector package. Current timing detector package consists of 4 planes.

Bunch crossing at CMS interaction point



[LHCC-2014-021; TOTEM-TDR-003; CMS-TDR-13]

CT-PPS Timing detectors



Booster
Shaping amplifier

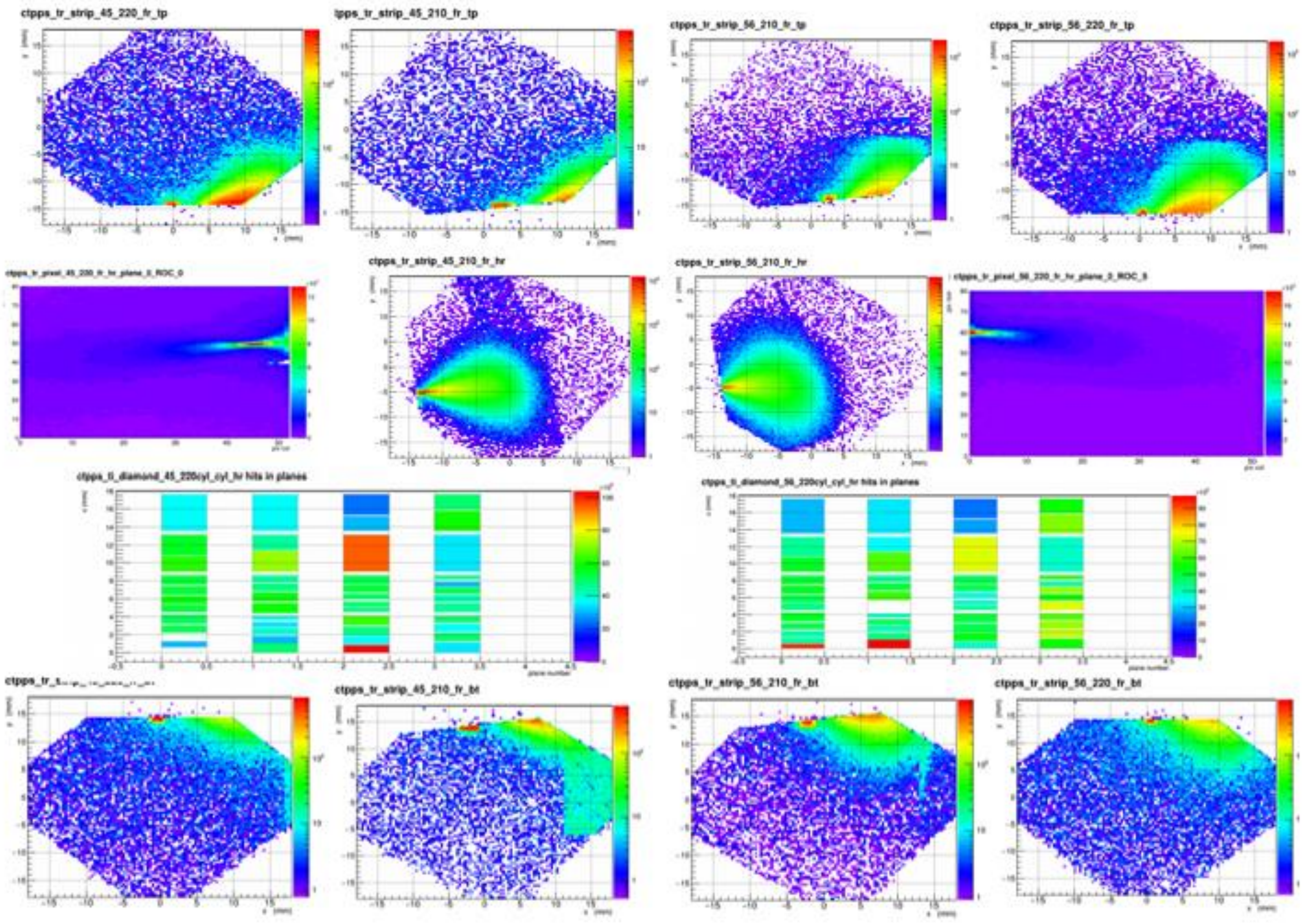
ABA
single stage voltage amplifier

Pre-amp
transconductance preamplifier

- ✓ First installation in June 2016: 4 Diamond planes
- ✓ The detectors collect 2.5 fb^{-1} of data and spend some time inserted without taking data
- ✓ One plane replaced with Ultra-Fast Silicon Detectors (UFSD) during the LHC technical stop from Dec 2016 to Apr 2017
- ✓ One of the removed planes (labelled in this presentation as IP5) taken to beam test at CERN SPS Northern Experimental area (beamline H8) May 2017
- ✓ It was also characterized with radiation sources in Helsinki Institute of Physics Novemeber 2017

CT-PPS Timing detectors

- ✓ Working well
- ✓ Hitmaps of installed detectors at the LHC

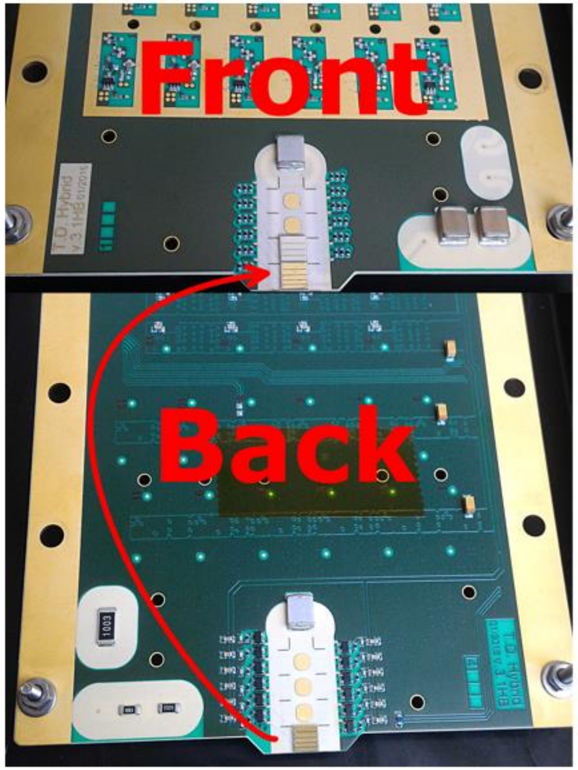


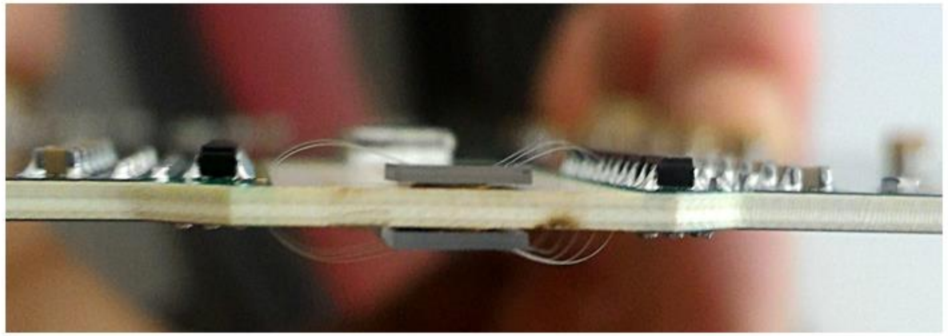
Hitmaps from Nicola Minafra: ”CT-PPS timing and pixel detector status”
https://indico.cern.ch/event/673941/contributions/2793163/

Double layer diamond detectors

Borrowed slide from talk in 5th BTTB by Tommaso Isidori: ***Timing Performance of a Double Layer Diamond Detector*** https://indico.desy.de/indico/event/16161/session/8/contribution/33

New Prototypes: “Double Diamond”





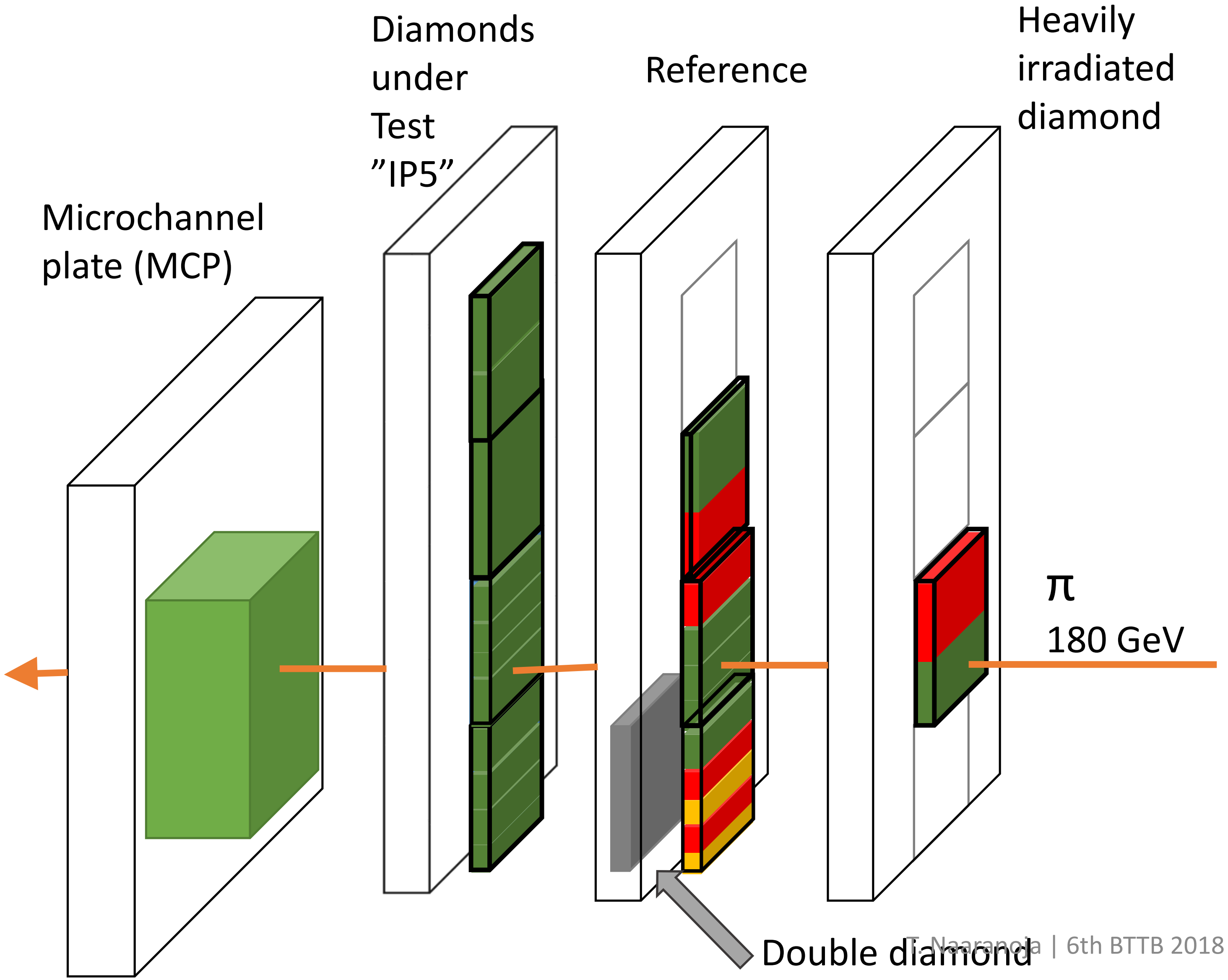
*The DD signal is **compared with a signal obtained from a single scCVD diamond of twice the area** (pixel area 1.02 x 4.2 mm^2), and therefore its capacitance is within 10% equal to the one of the double arrangement, with a pixel of 0.55 x 4.2 mm^2.*

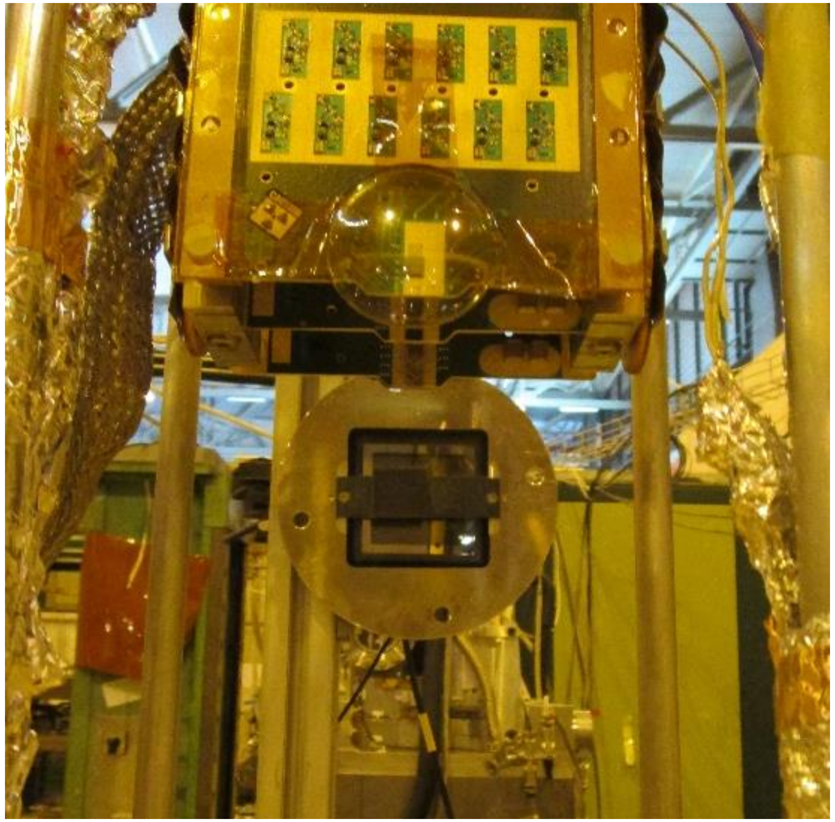
Diamonds have small dielectric constant and small capacitance (0.1 pF/mm^2) ...

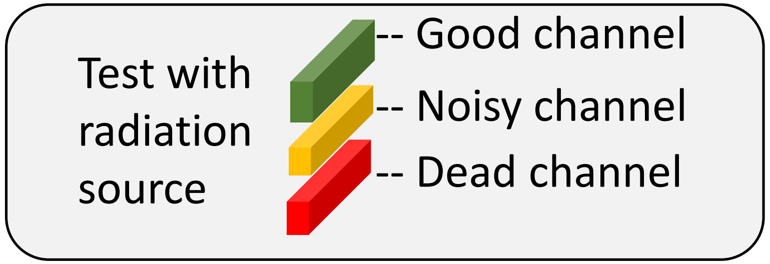
... More than one diamond sensors can be connected in parallel to one amplifier without degradation of the timing performance !!

See also:
Timing Performance of a Double Layer Diamond Detector, 2017 JINST 12 P03026, https://doi.org/10.1088/1748-0221/12/03/P03026

Set-up at SPS Northern experimental area





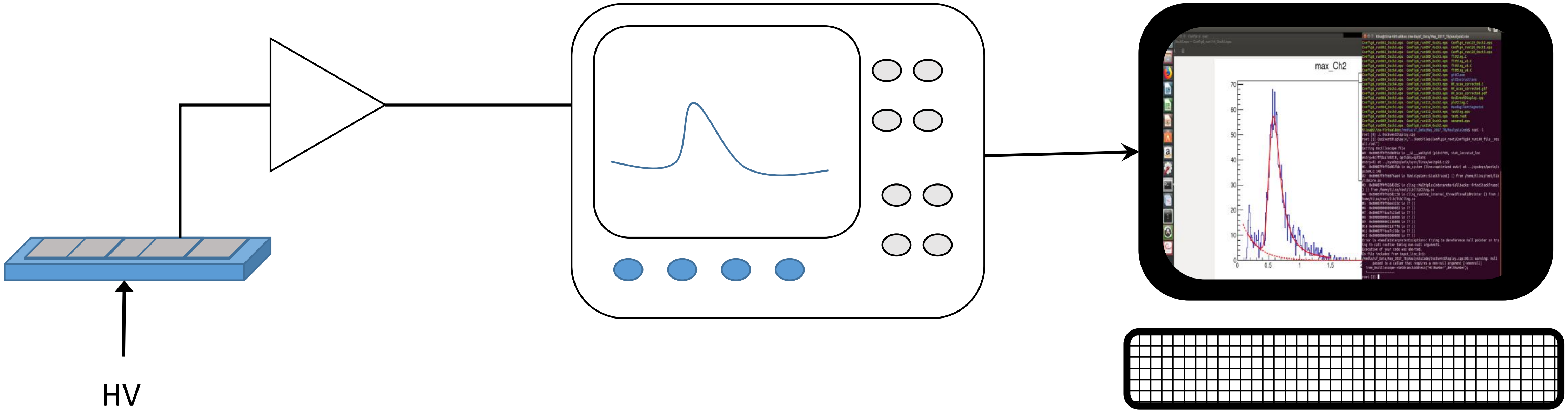


Set-up at SPS Northern experimental area

- ✓ Sensor mounted on TOTEM hybrid [2] as it was installed
- ✓ Three stage amplification chain

- ✓ Signal readout with fast oscilloscope (Agilent DSO9254A)

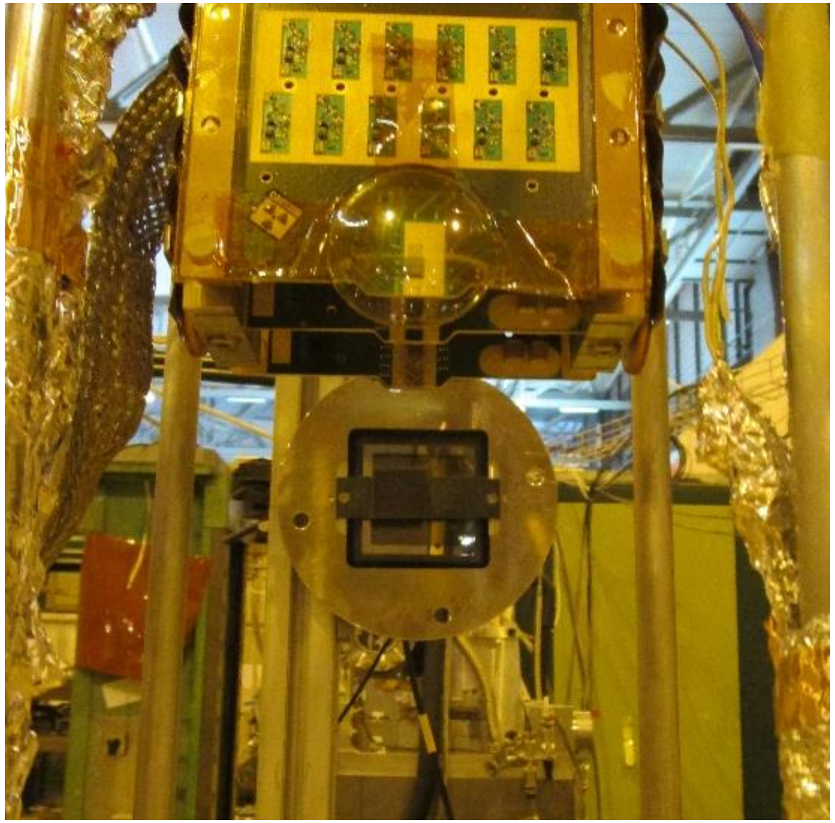
- ✓ Signal processed offline using ROOT



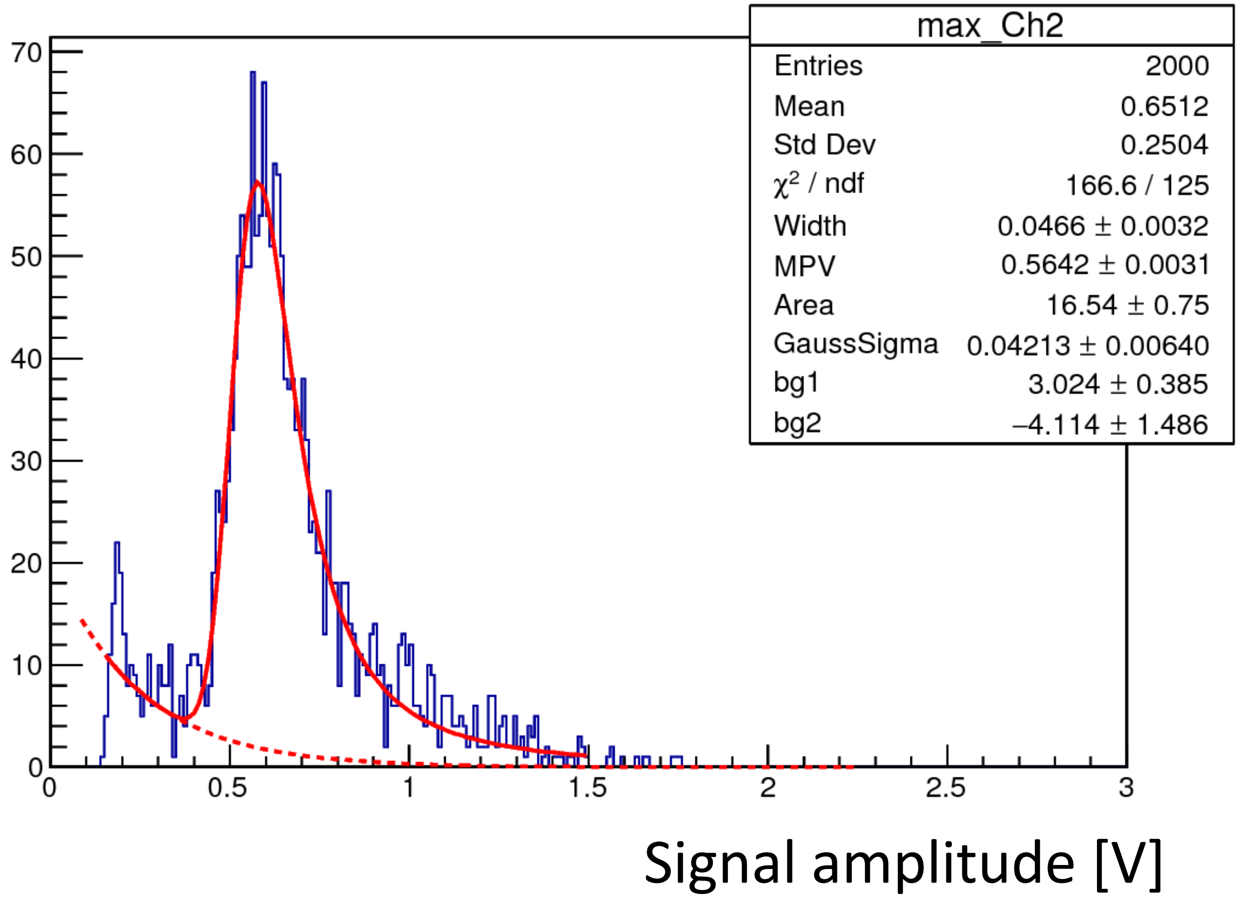
[2] 2017 JINST 12 P03007

Workflow

- ✓ Test each channel with Sr-90
- ✓ Test full DAQ & DQM
- ✓ LV-scan (optimized for Signal to noise ratio (SNR) and MIP signal amplitude Most Probable Value (MPV))
- ✓ HV-scan (low end)
- ✓ MIP spectrum on each channel
- ✓ Coincidence with MCP as timing reference



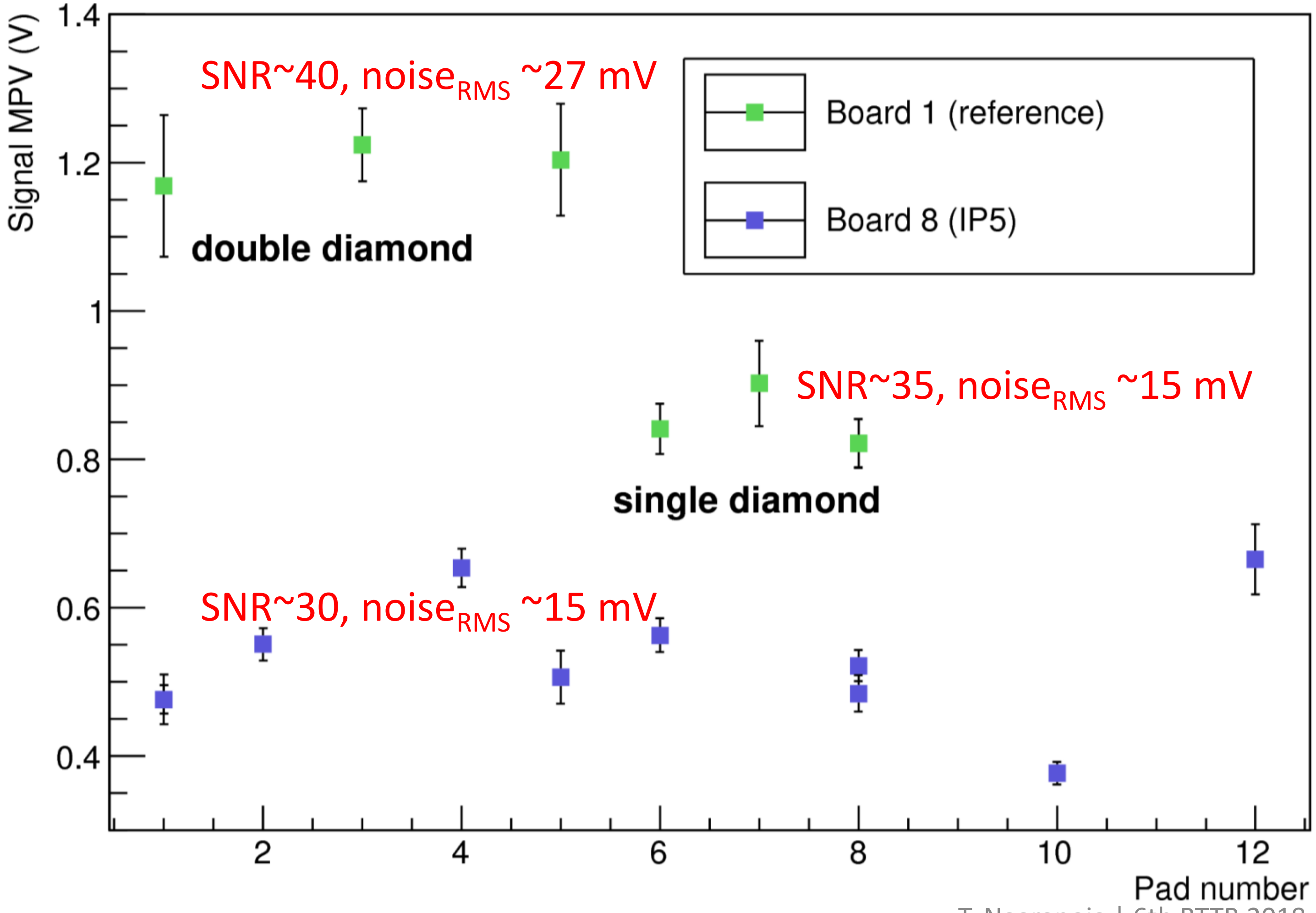
Minimum Ionizing Particle (MIP) spectrum



- ✓ MIP signal amplitude spectrum fitted with
  - ✓ Exponential background
  - ✓ Signal: Landau convoluted with Gaussian
- ✓ For channels without coincidence with reference, background was significant

MIP spectrum

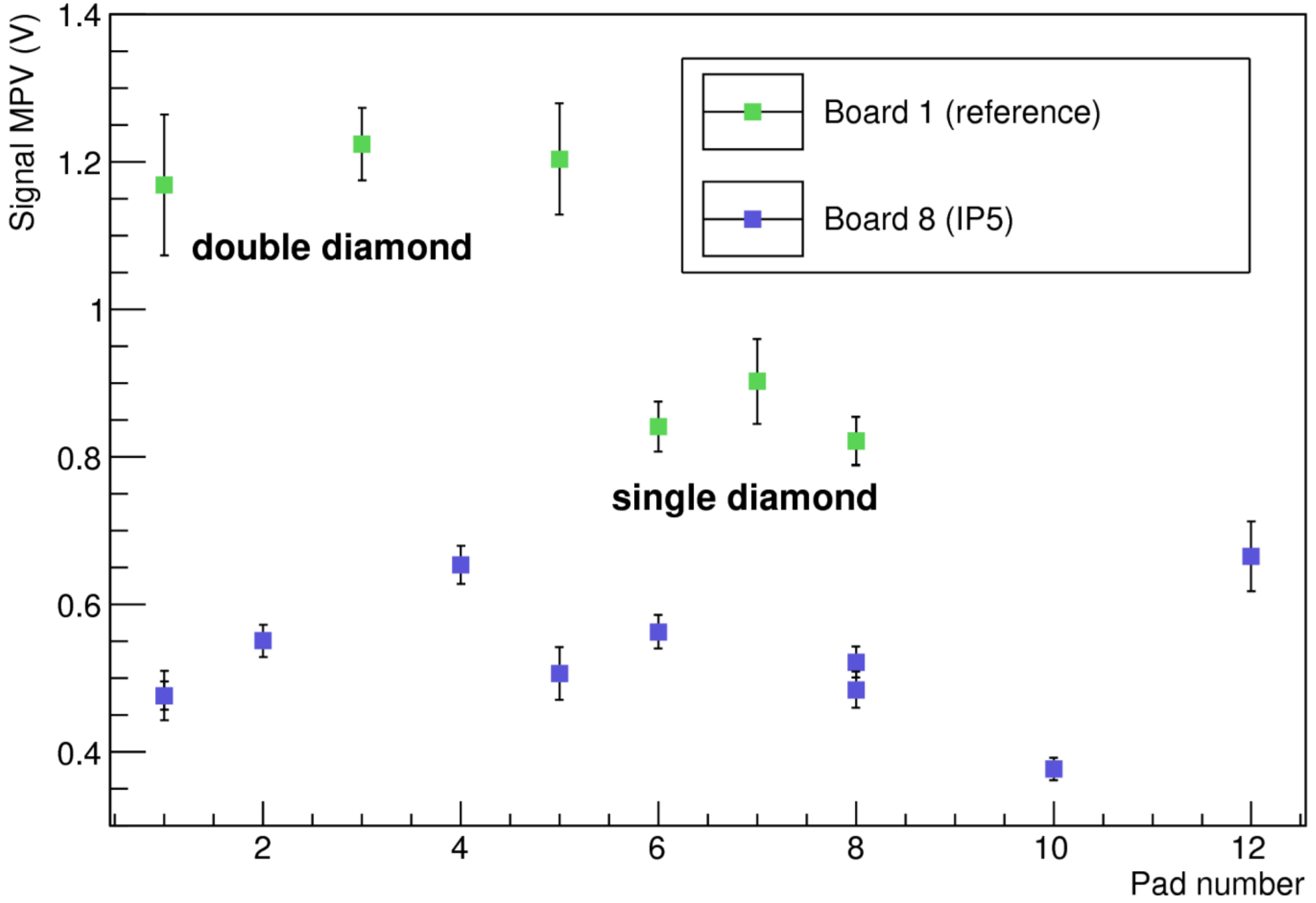
Disclaimer: Direct comparison of signal amplitude to reference is problematic!
- ✓ Strong dependence on amplifier settings
- ✓ SNR ratio also depends on environment, electronics and settings



- ✓ Signal amplitude (Most probable value in Landau fit) varies from 0.4 V to 0.7 V
- ✓ Boards were checked before installation, with typical signal to noise ratio SNR=40…50
- ✓ For double diamond expected same noise as for normal diamond
- ✓ Reference board had broken electronics on one channel, which injected noise to other channels
  - ✓ Might affect signal height
  - ✓ Either double diamond signal should be higher or single diamond lower [3]
- ✓ Maximum signal around pad 4. Is the structure in signal height significant?

MIP spectrum

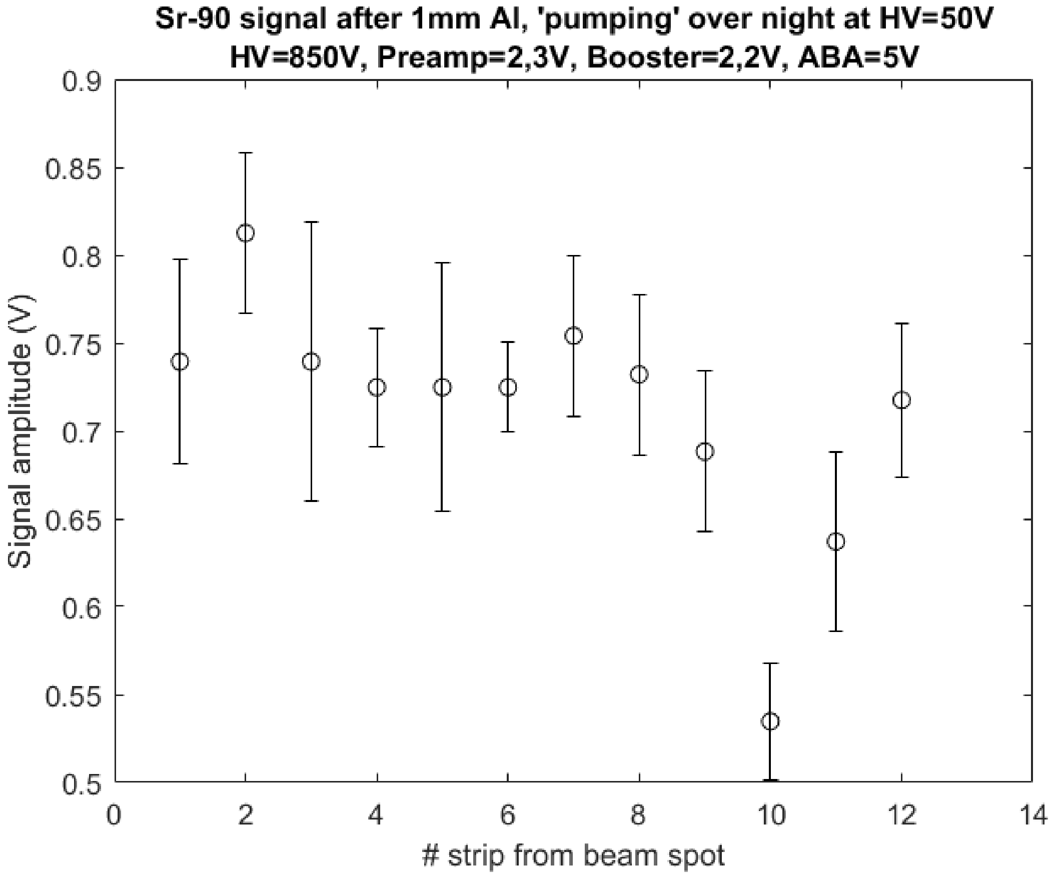
180GeV π MIP at beam test



Disclaimer: Direct comparison of signal amplitude to reference should be avoided!

- ✓ Strong dependence on amplifier settings

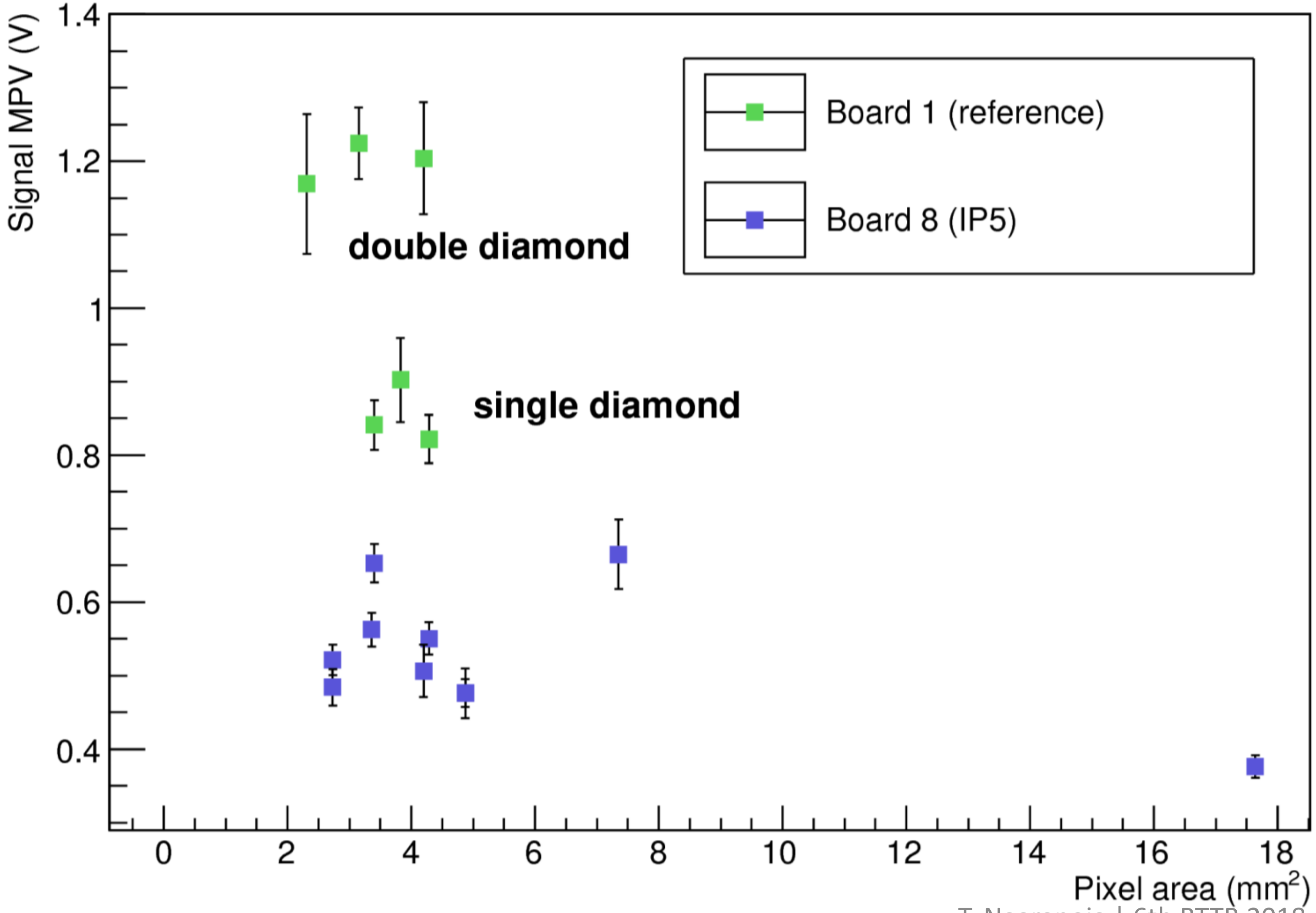
~2 MeV β at lab (almost MIP)



NB! In laboratory diamonds were ”primed” overnight with the source

MIP spectrum

Disclaimer: Direct comparison of signal amplitude to reference should be avoided!
- ✓ Strong dependence on amplifier settings



- ✓ Pad 10 largest pixel on the board
  - ✓ reduced signal amplitude due to pixel size
- ✓ Difference between reference and IP5 probably due to differences in the electronics

Conclusions

- ✓ The board removed from IP5 working properly
- ✓ Reference detectors had problems with noisy channels
- ✓ Differences could be explained by differences in the electronics
- ✓ Strange features in signal amplitude versus location not significant
  - ✓ Explained by random fluctuations and pixel size
- ✓ Continue with efforts to extract time resolution
- ✓ In future beam tests: estimation of efficiency (requires tracking)

Acknowledgements

Thank you for your attention!

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- Thanks for funding:
  - Magnus Ehrnrooth foundation
  - AIDA-2020 Transnational Access programme (Horizon 2020)

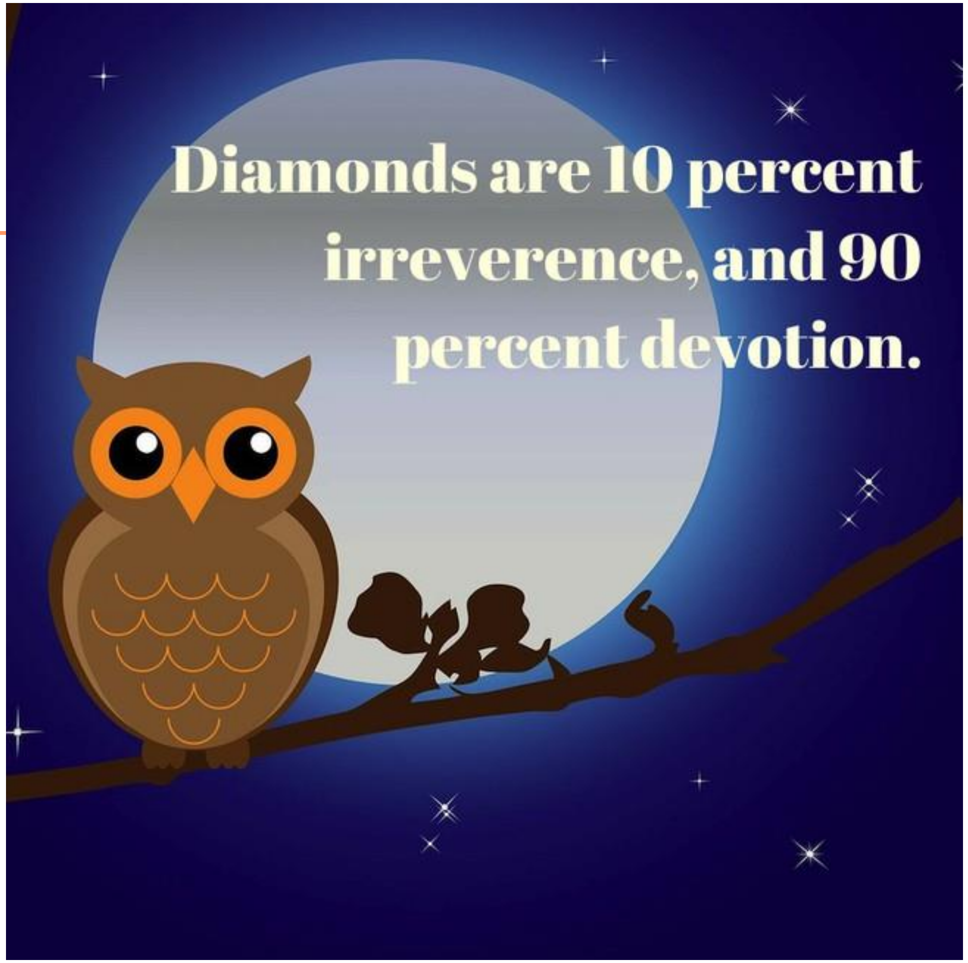


Image source: inspirobot.me

References

[1] TDR for CT-PPS:
LHCC-2014-021; TOTEM-TDR-003; CMS-TDR-13, https://cds.cern.ch/record/1753795

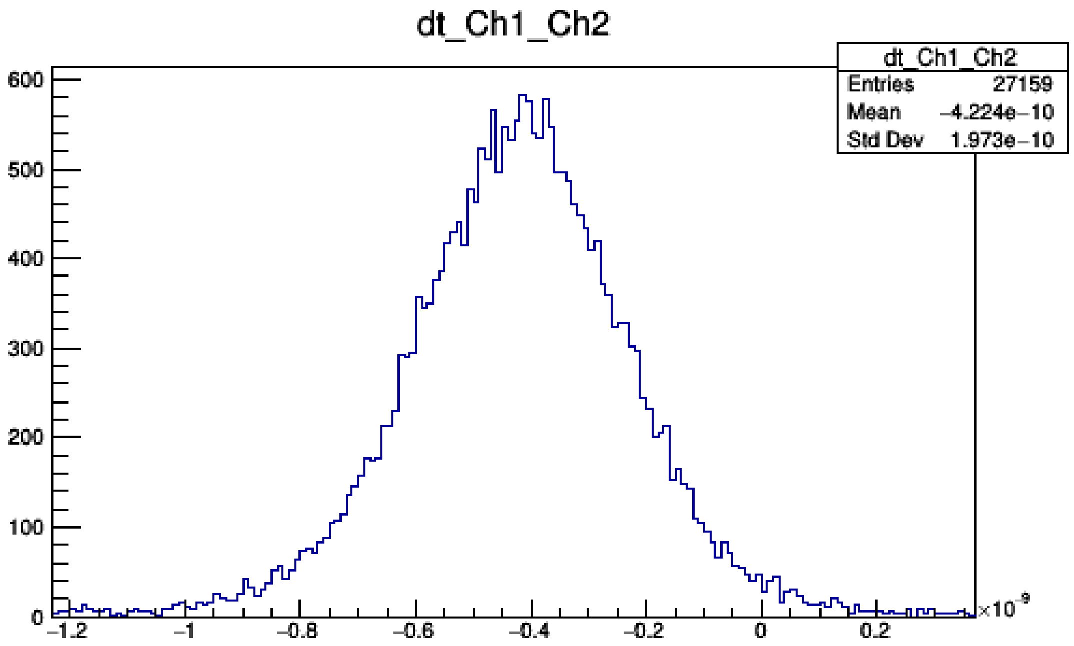
[2] Diamond detectors for the TOTEM timing upgrade:
2017 JINST 12 P03007, https://doi.org/10.1088/1748-0221/12/03/P03007

[3] Double diamonds :
2017 JINST 12 P03026, https://doi.org/10.1088/1748-0221/12/03/P03026

Backup

Time resolution

- MCP data lost in data analysis
- Data taken with coincidence required for IP5 & reference & MCP
- Available distribution of difference of arrival time to investigated diamond (IP5) and reference
- Standard deviation = 197ps
  - If assumed identical time resolution for reference and IP5: 140ps, which is far from the expected 80ps
- Is problem with reference, IP5 or set-up in general?
- Much more analysis needed



Polarization with alpha source

- Polarization (uneven accumulation of space charge) often observed with irradiated diamonds
- Best visible with alpha source
- Signal compared when the state let to stabilize (and diamond become polarized) and when polarization prevented by alternating HV (10s HV off, 5s stabilizing, 20s measuring)
- No strong polarization observed
- on channels closes to beam 8±2% signal loss explained by polarization