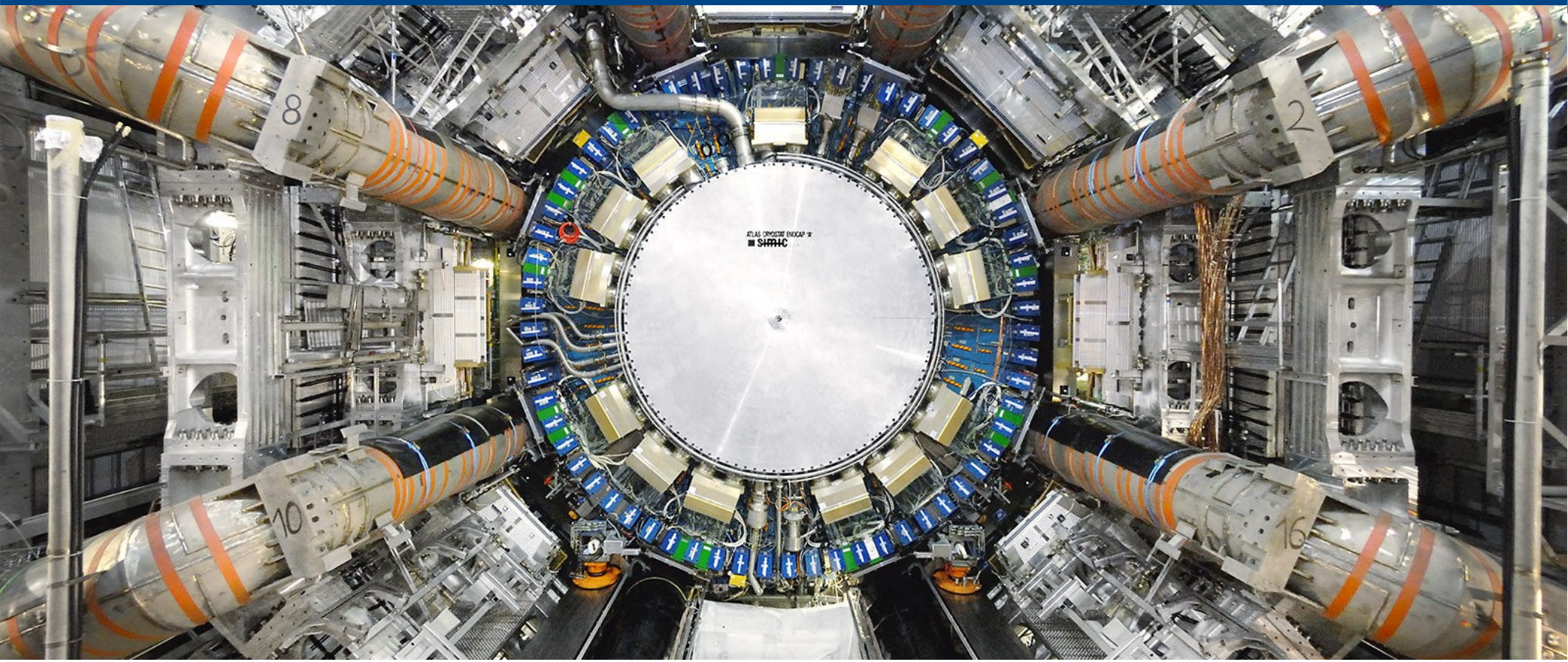
Study on the performance of thin-gap RPCs for ATLAS muon spectrometer upgrade



Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Catriona Bruce

MPP Munich

Oliver Kortner, Hubert Kroha

20.3.18

MAX-PLANCK-GESELLSCHAFT

Muon trigger for HL-LHC

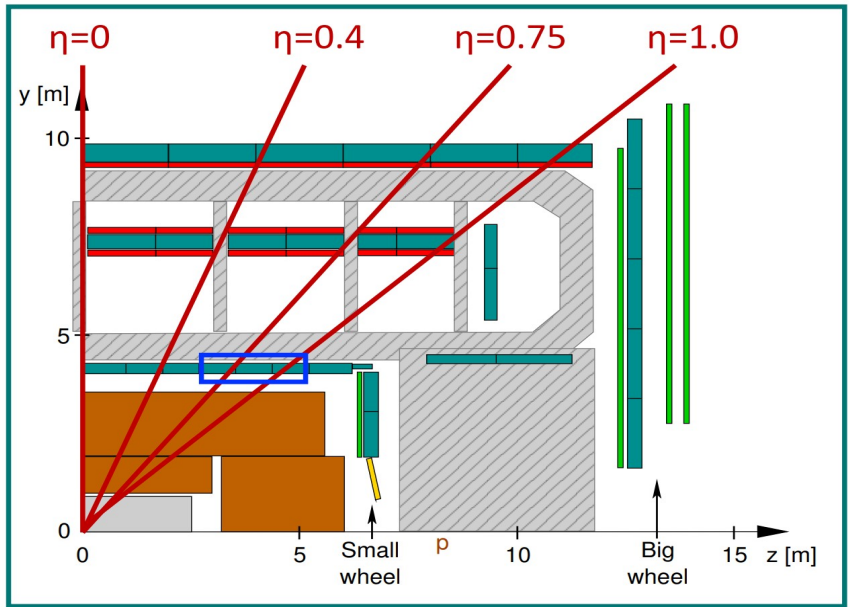
Eventually, will need to replace current RPCs...

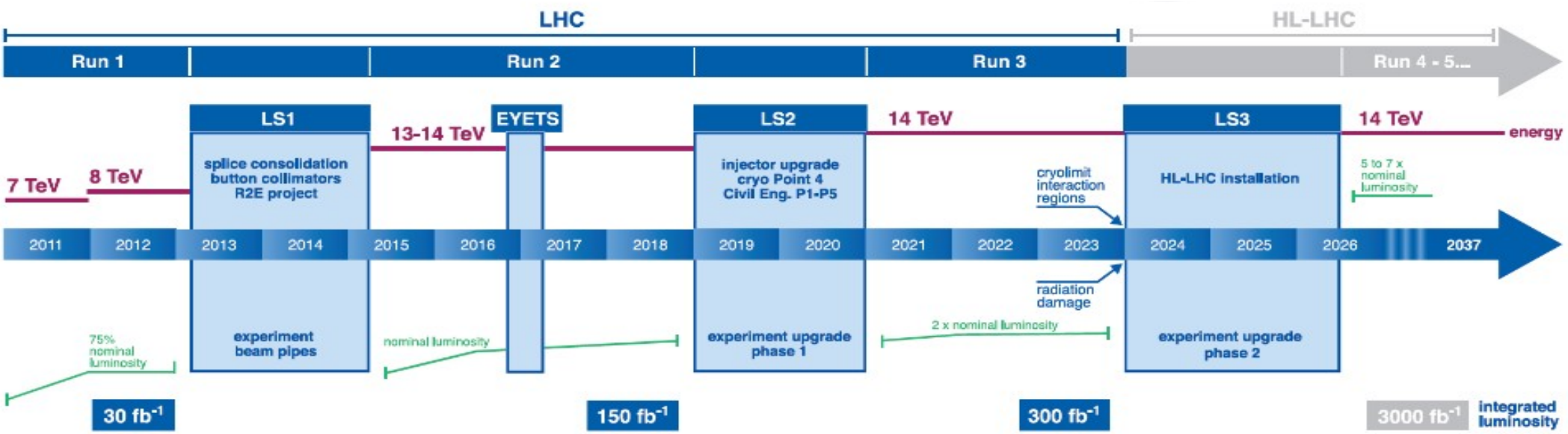
- Lifetime 100kHz/cm^2 for 10 years
- Rates in HL-LHC will increase sevenfold

In the meantime, we can extend their lifespan...

- Increase number of layers
- Fill the blind spots
- New coincidence requirements

  → **each RPC has less work**





The BI project

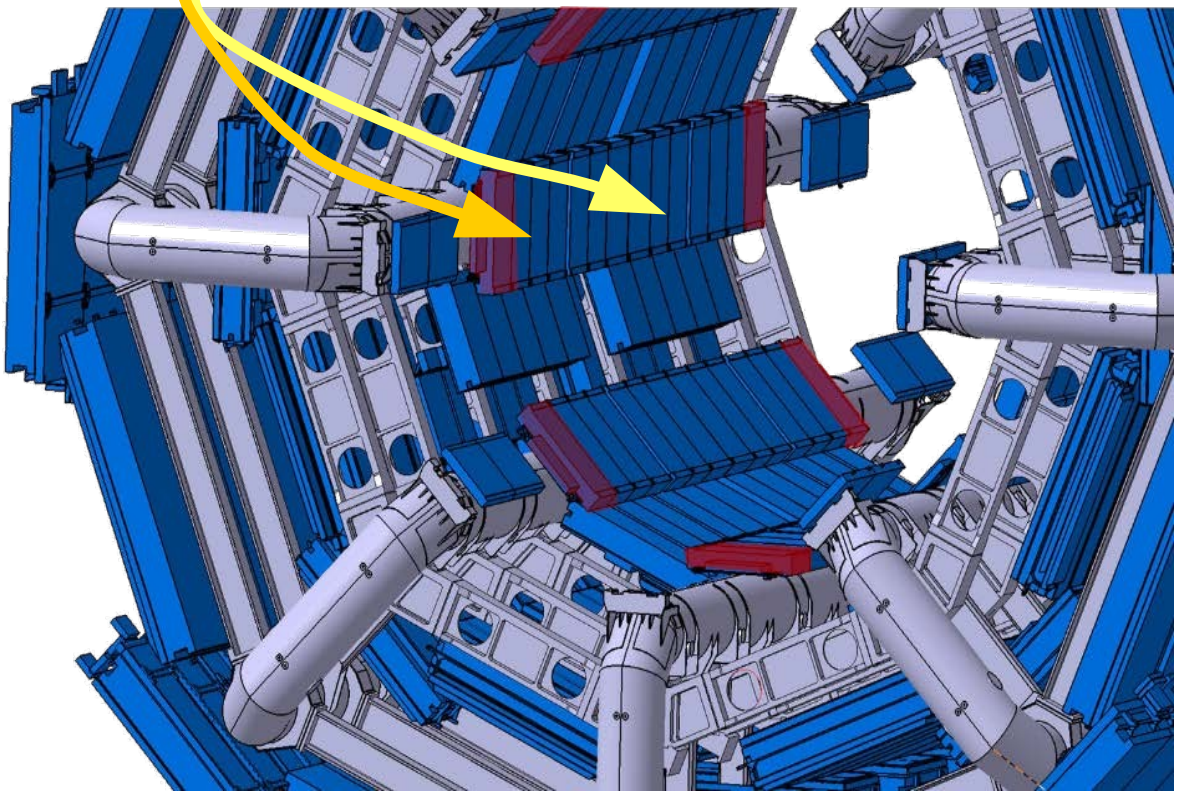
INFN/University of Roma Tor Vergata, Rome, and MPP, Munich

...and mitigate aging by reducing workload.

2024-26: 96 new sMDT-RPCs (1410 m^2)

2019-20: 16 new sMDT-RPCs (150 m^2)

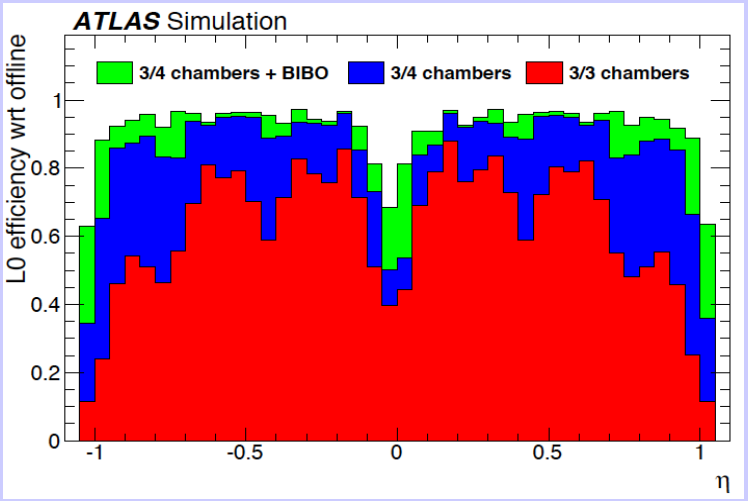
↳ Require only 2/4 coincidence from BM RPCs



BENEFITS

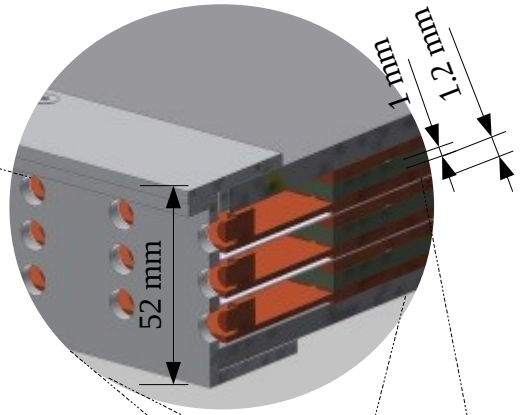
1. Close acceptance holes
2. Loosen coincidence requirements
   - ➔ Improve efficiency at same HV
   - ➔ Reduce HV of legacy RPCs
   - ➔ Extend system longevity

SYSTEM EFFICIENCY @ VARIOUS COINCIDENCE REQUIREMENTS



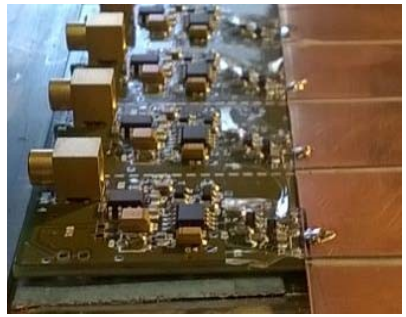
New sMDT-RPC chambers

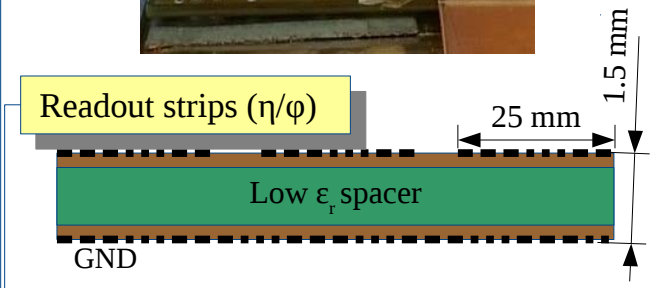
Gas inlet		
Ionizing gas	95%	TFE
Quencher gas	4.5%	i-C4H10
Electronegative gas	0.3%	SF6



FE electronics

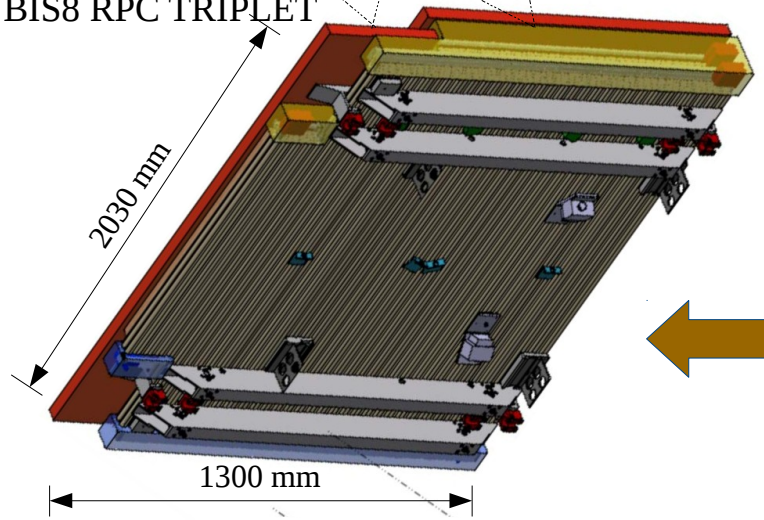
New fast, sensitive amplifier
100ps resolution
Fast serial output





BIS7 RPC TRIPLET

BIS8 RPC TRIPLET



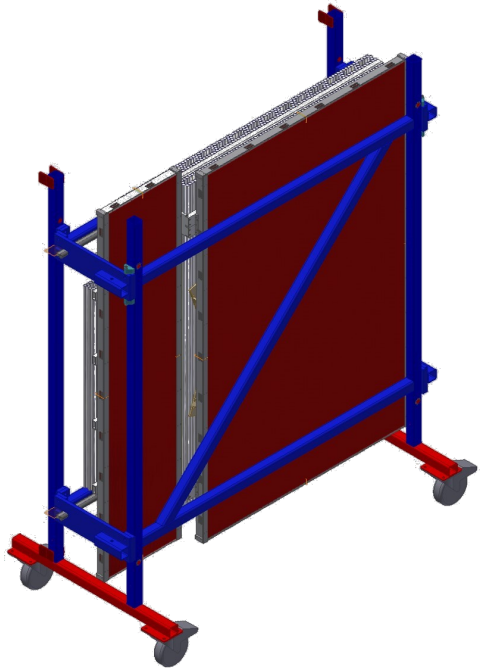
Thin RPC triplets

1 mm gas gaps

1.2 mm electrodes

5800 V

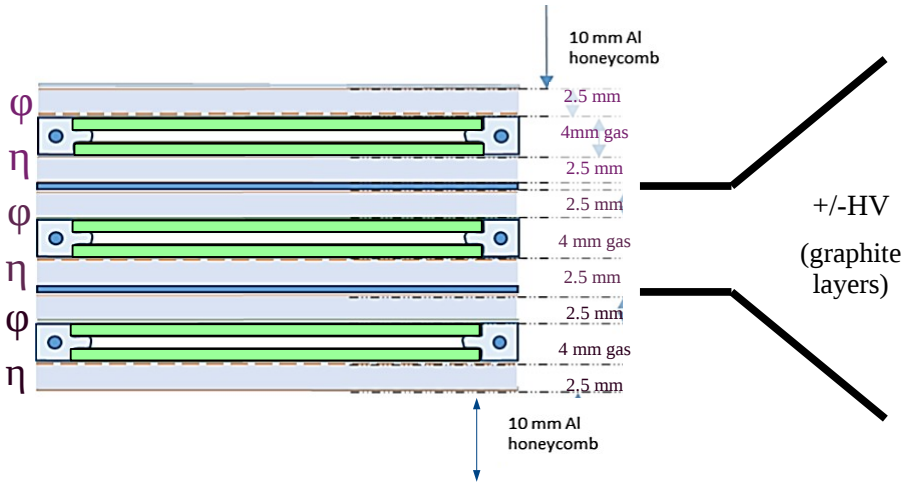
15x less avalanche charge

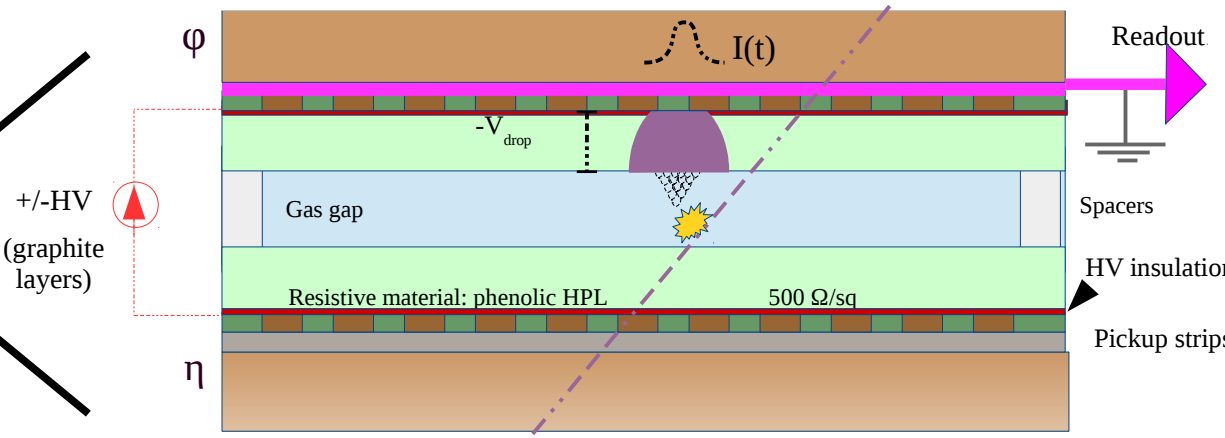


BIS78 sMDT

Covered in other talks

BIS78 RPC triplets

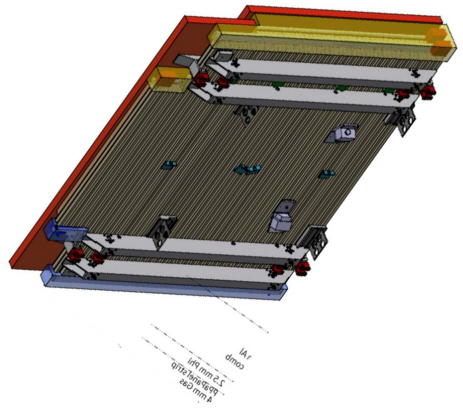




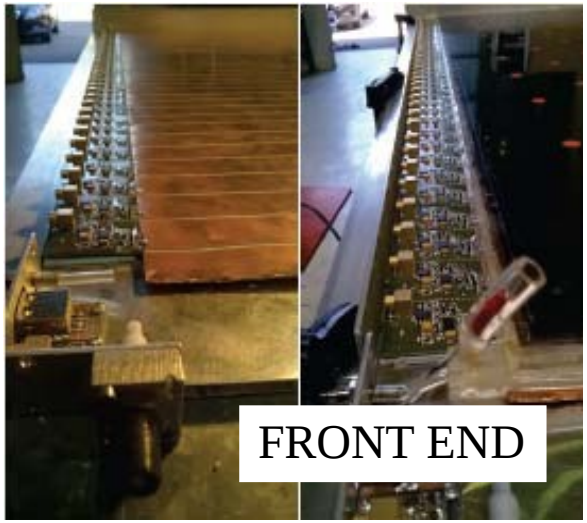
RPC principle: the resistive plate

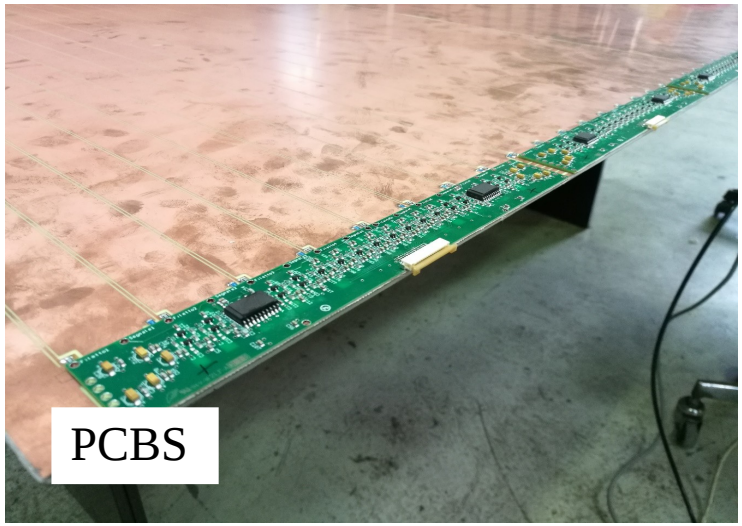
Stops avalanche development but is transparent to fast signal

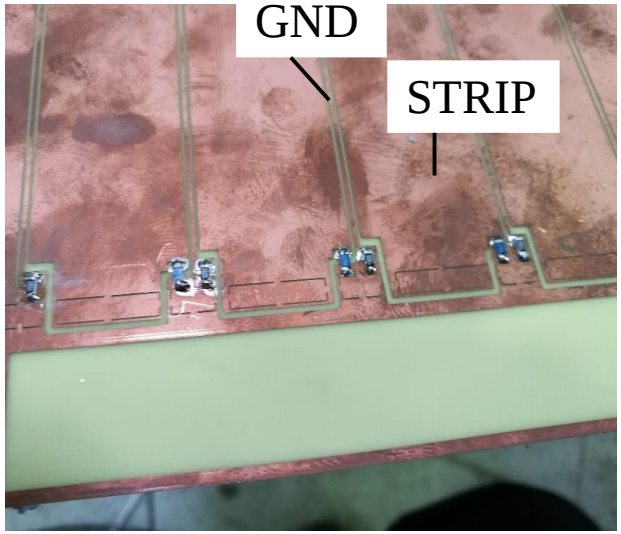
	Standard RPC	BIS78 RPC
Gaps per chamber	2	3
Power consumption	30 mW	6 mW
Technology	GaAs	BJT Si + SiGe
Gap width	2 mm	1 mm
Operating voltage	9600 V	5800 V
Charge x hit	30 pC	7 down to 3pC
Electrode thickness	1.8 mm	1.2 mm
Time resolution	1 ns	0.4 ns

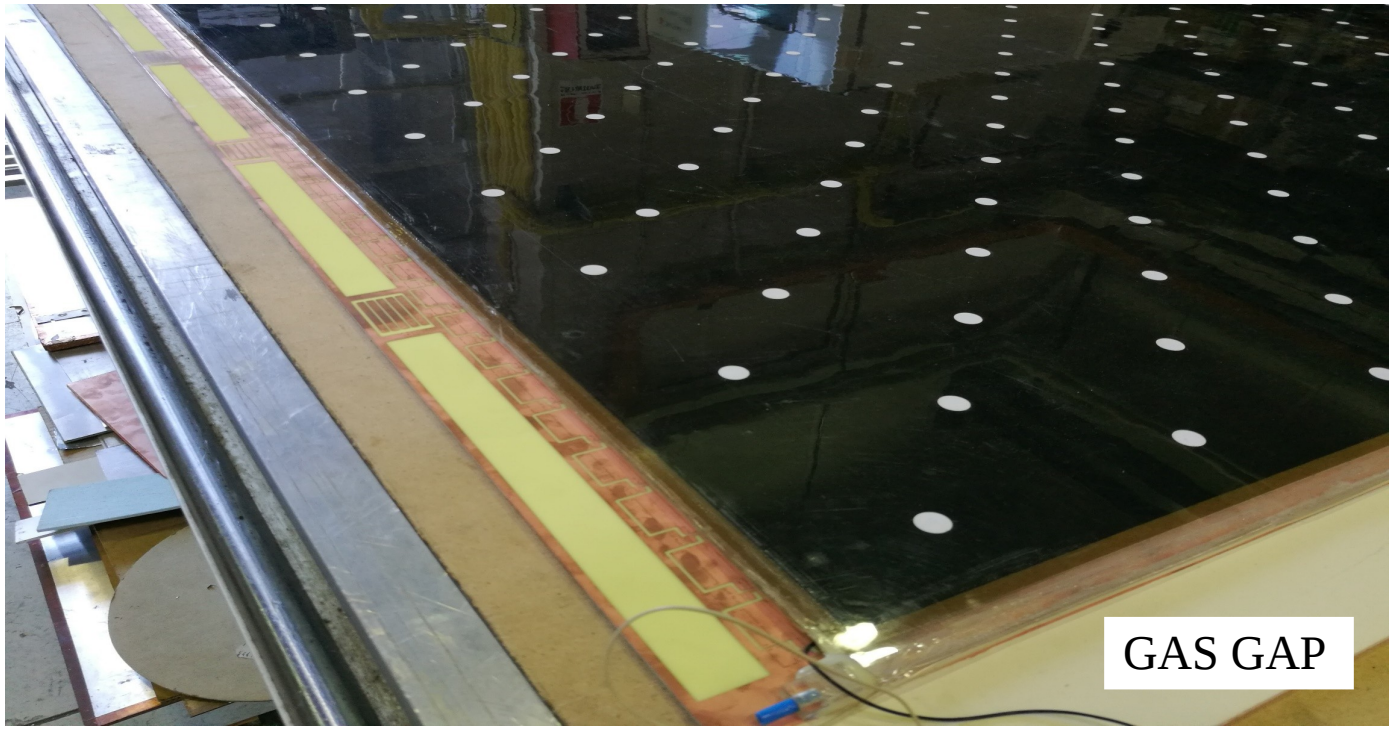


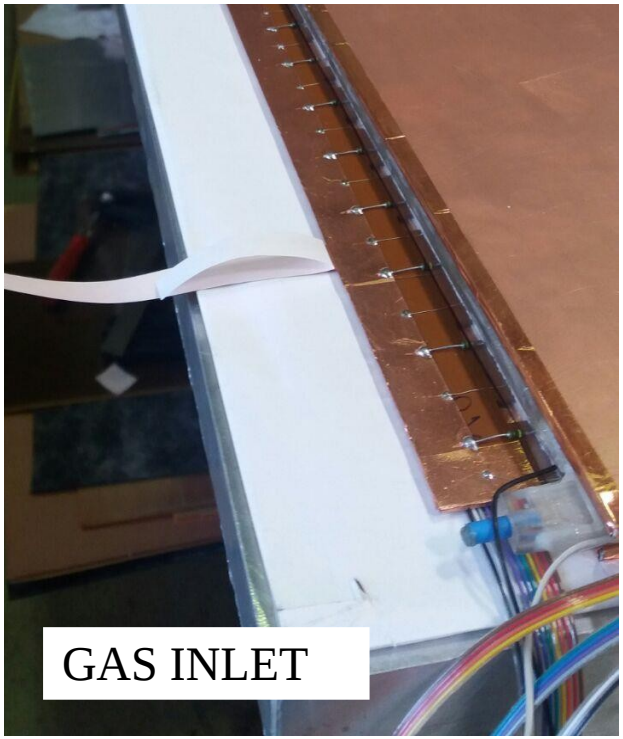
BIS78 RPC triplets





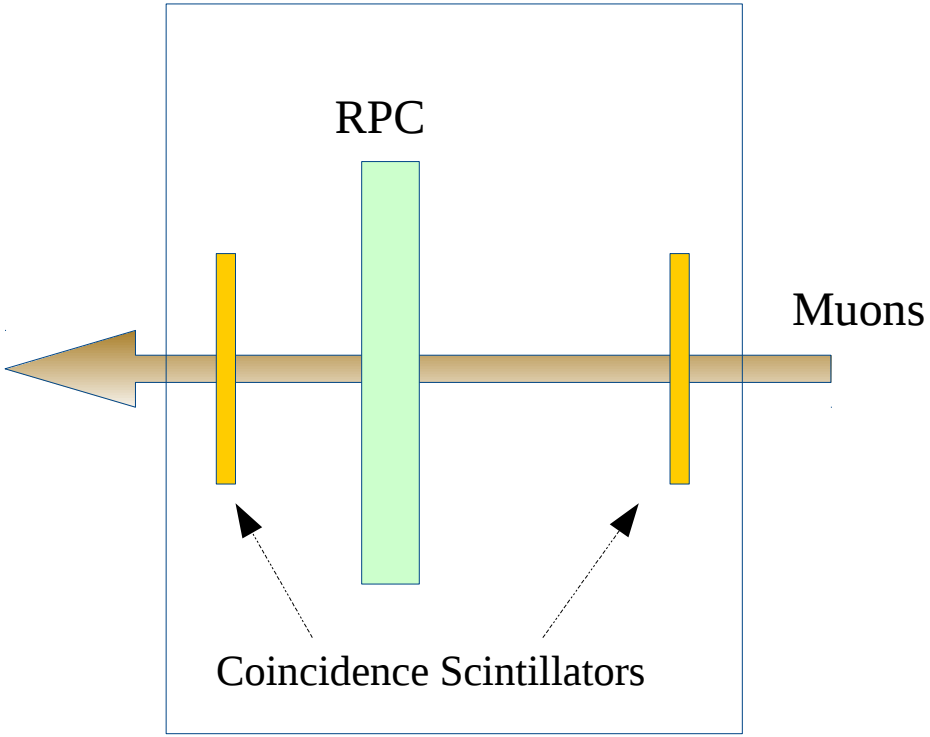






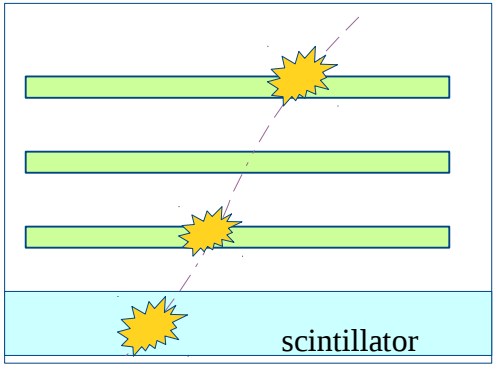
Test setup at H8

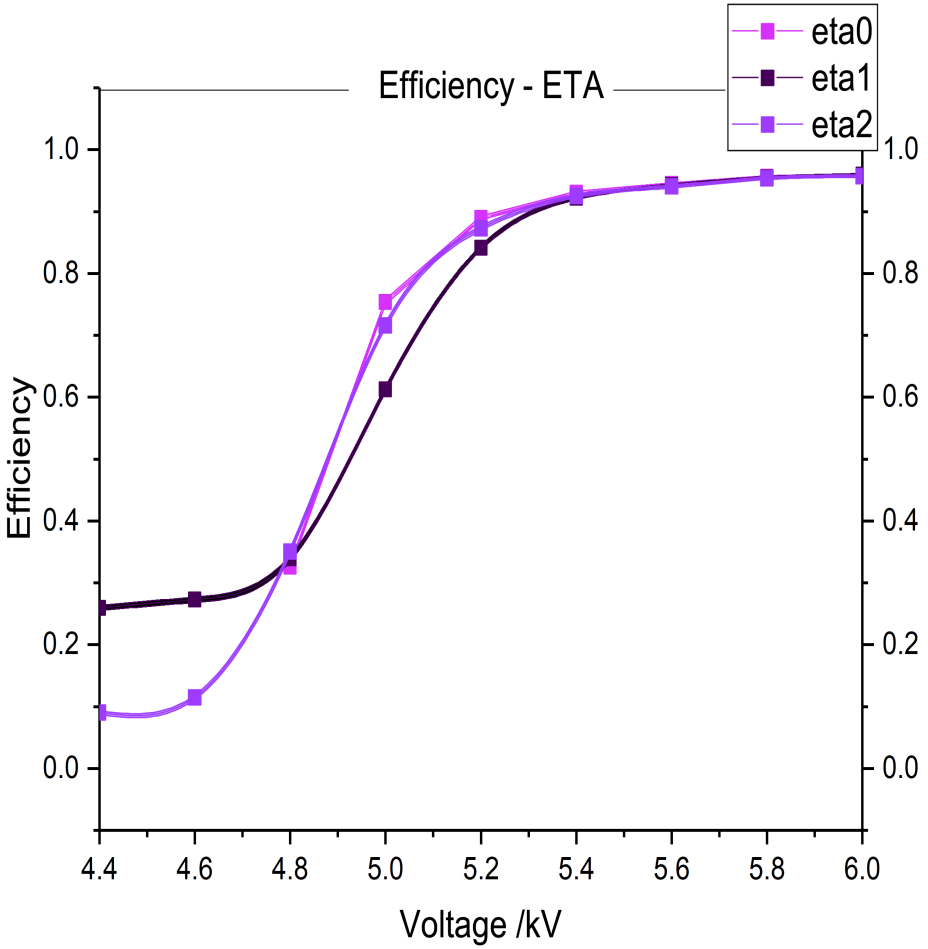
- Test beam: Muons and energetic pions (no background)
- Scintillator-triggered TDC data
- Time recorded to nearest nanosecond (close to intrinsic RPC resolution)
  - With several layers collecting data we will achieve subnanosecond resolution

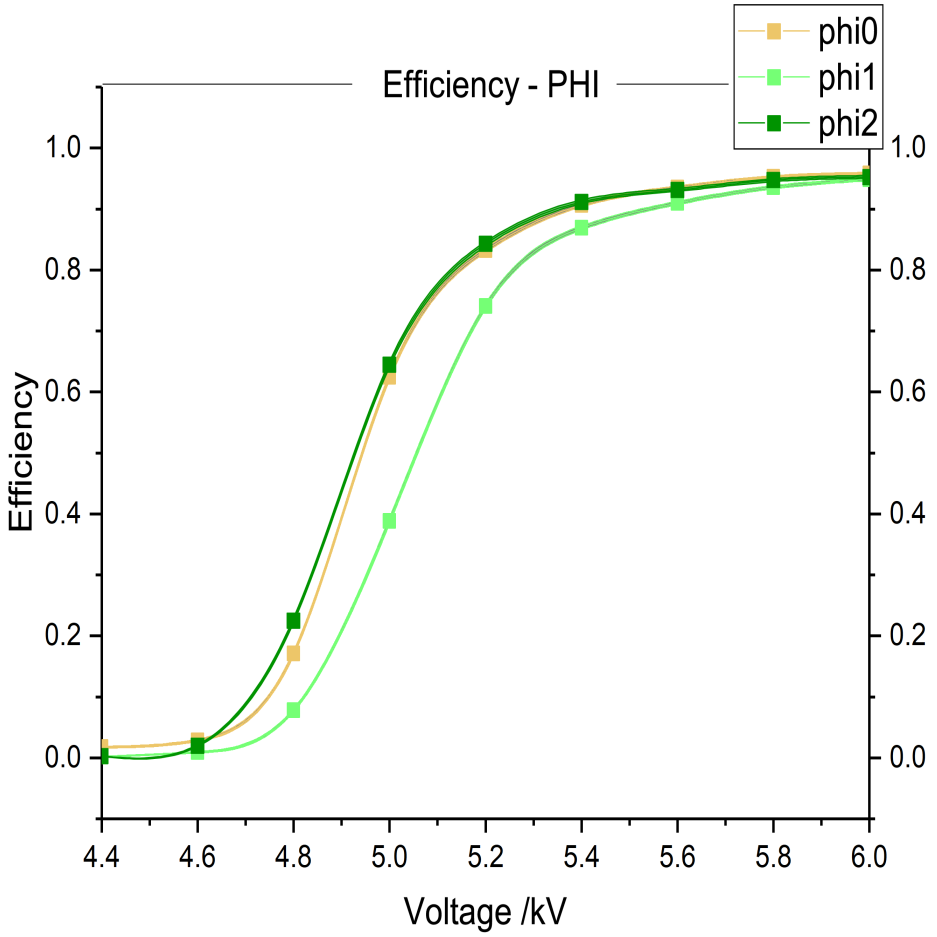


Efficiency

- Nominal voltage 5.6kV
- Efficiency plateau begins 5.4kV
- Resolution gains to be had by operating a little higher...

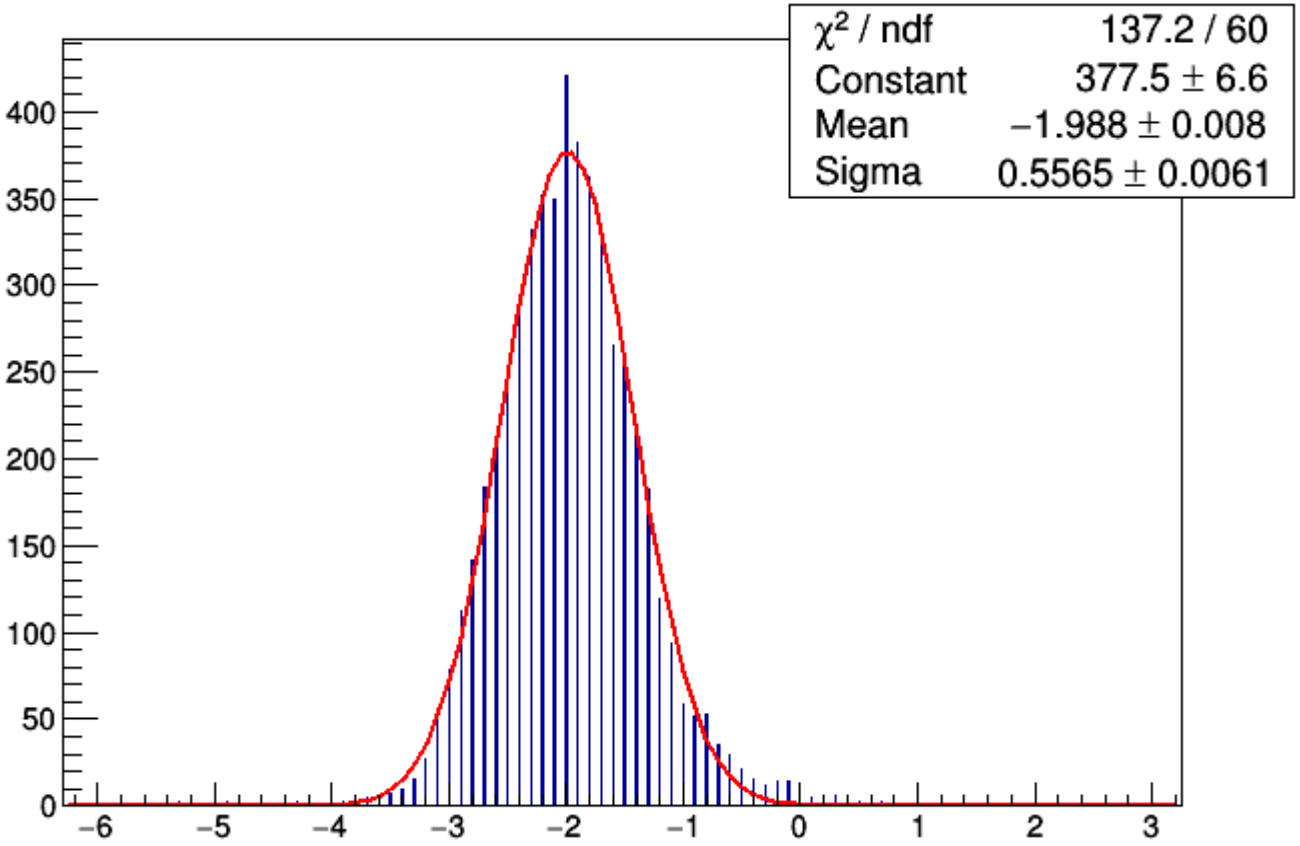






Time resolution

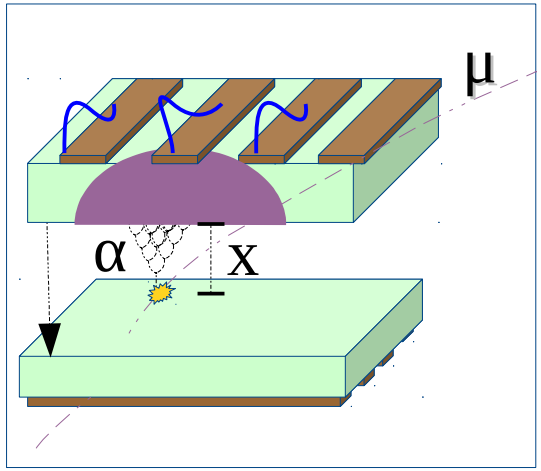
- 0.557/√2 = 0.394 ns down from 1.1 ns
- Principally thanks to thinner gap, thinner electrodes
- No walk correction, temperature/humidity correction applied

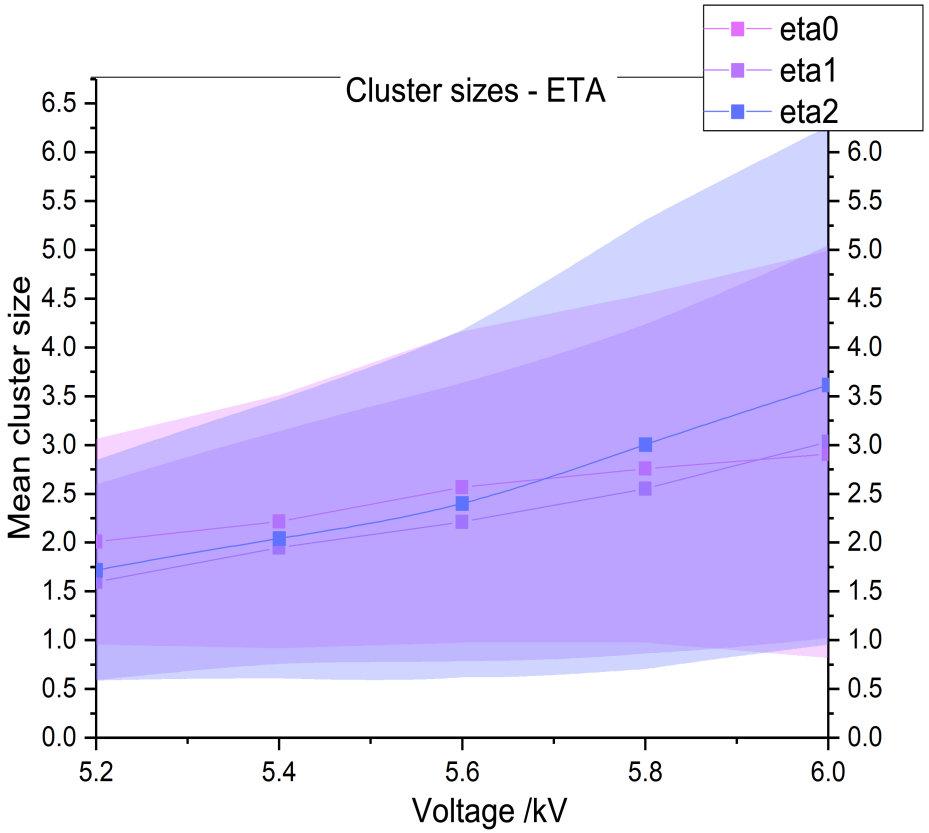


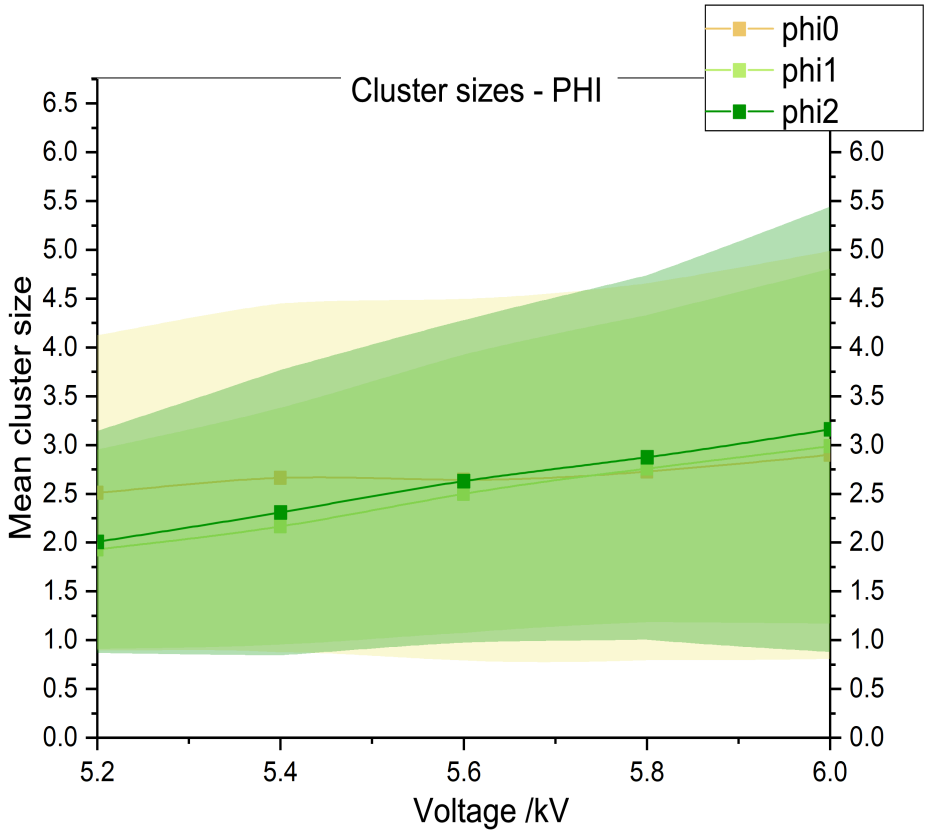
(Voltage sweep data to come...)

Cluster size

- Optimal cluster size ~2
- Steady growth as gas gain increases
- Spatial resolution at 5.6kV:
  - 13.5 mm unweighted, 11.3 mm weighted

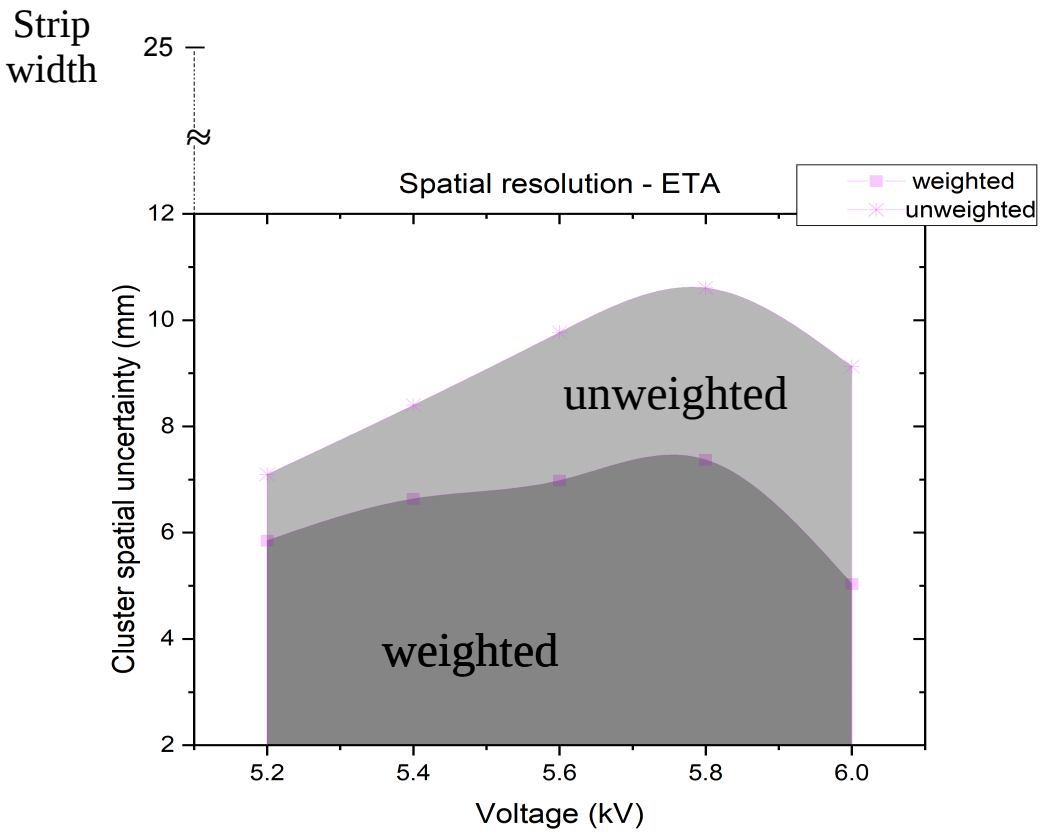


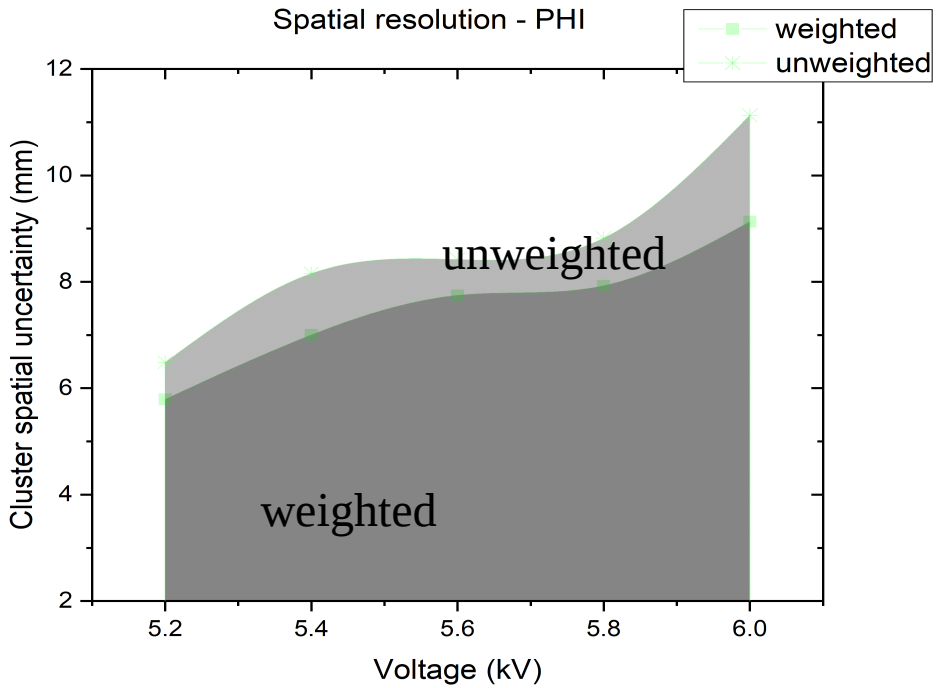




Spatial resolution

- Weighting cluster position by time over threshold (dark gray)
- Resolution of less than half a strip width



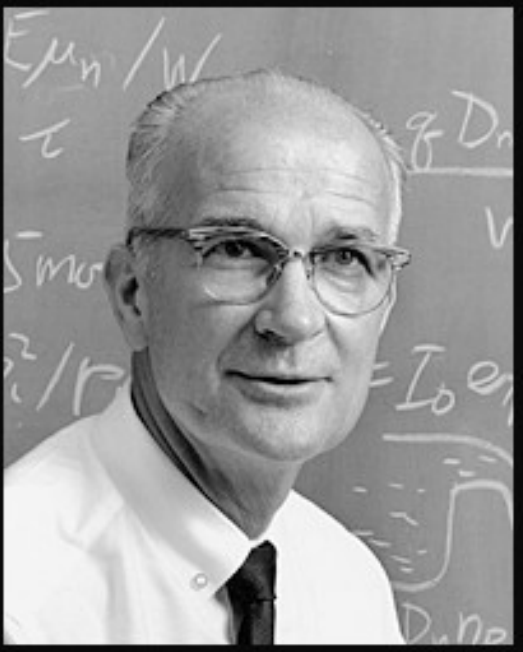


Summary: Results of voltage sweep

- **Singlet efficiency** above 95% at nominal voltage
  - Plateau begins as low as 5400V
- **Mulitilayer coincidence** around 80% of the time
- **Cluster size** just big enough for strip redundancy
- **Time resolution** improved by a factor of 3
- **Spatial resolution** half a strip width

catriona@mpp.mpg.de

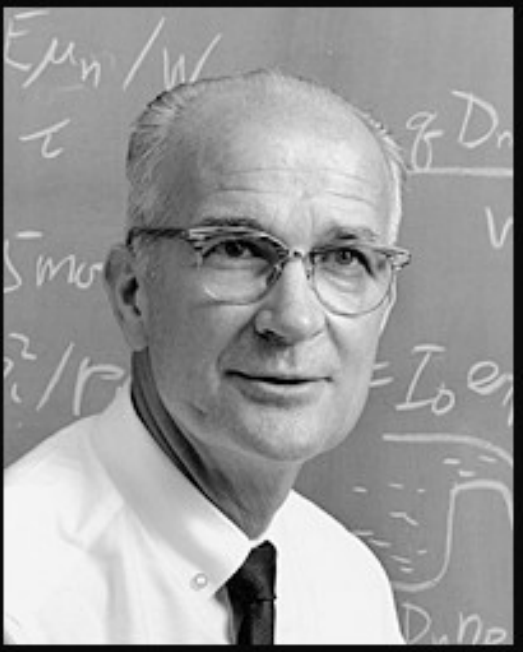
End



If you take a bale of hay and tie it to the tail of a mule and then strike a match and set the bale of hay on fire, and if you then compare the energy expended shortly thereafter by the mule with the energy expended by yourself in the striking of the match, you will understand the concept of amplification.

(William Shockley)

End



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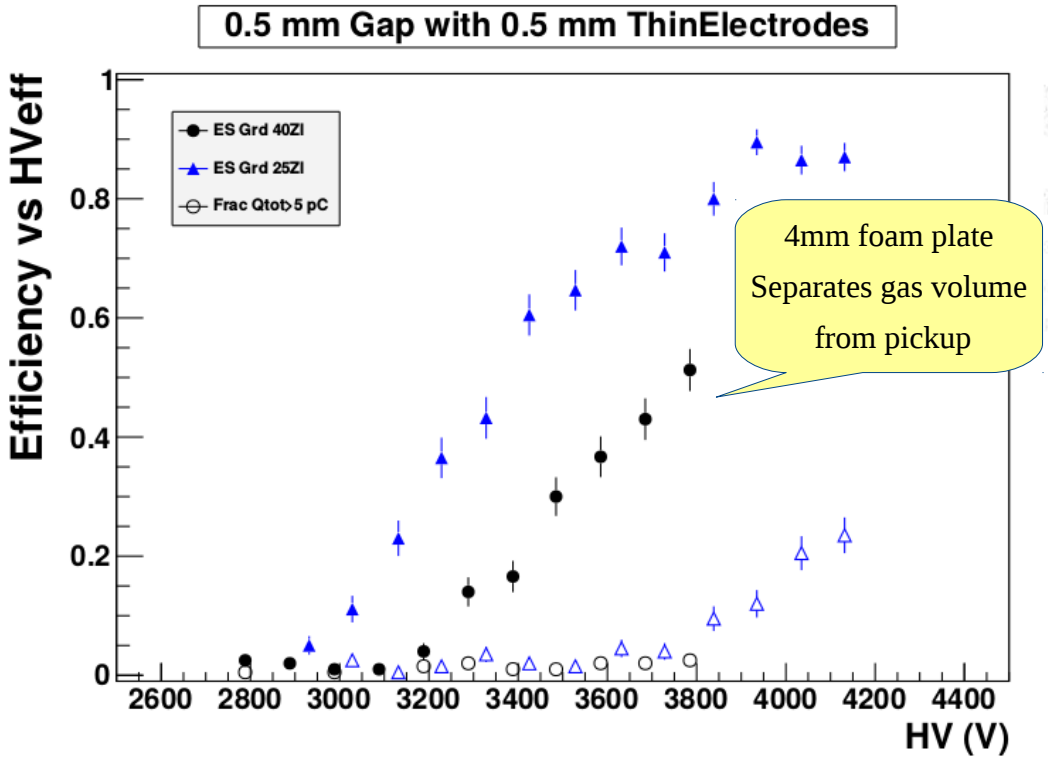
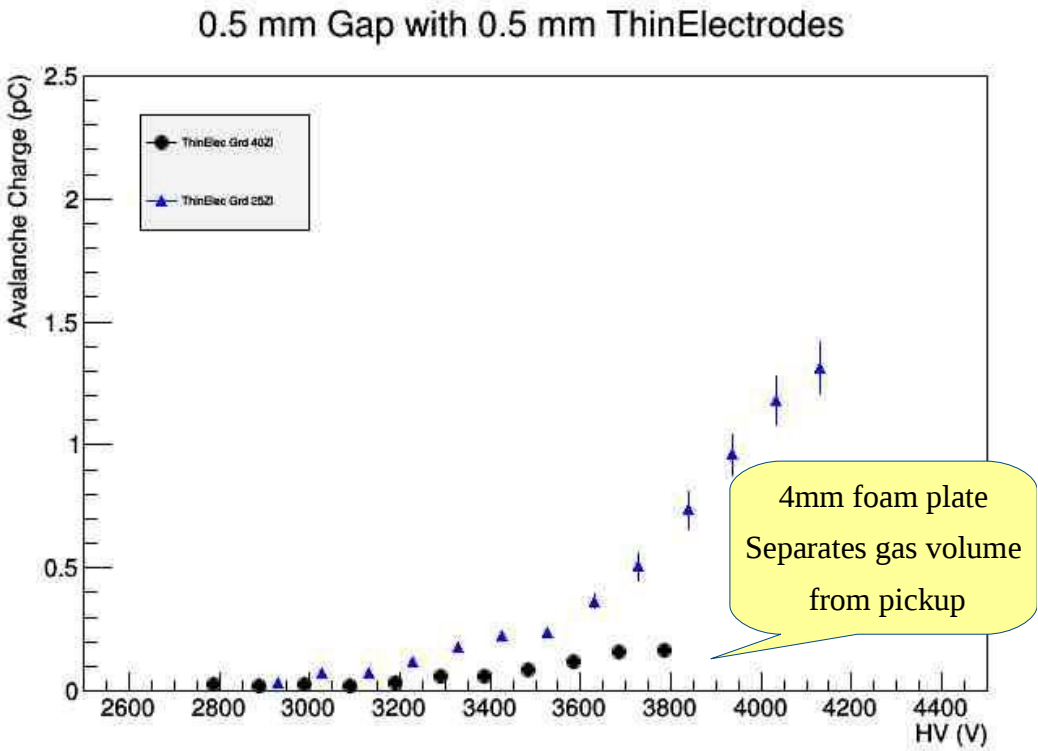
(William Shockley)

RPC development

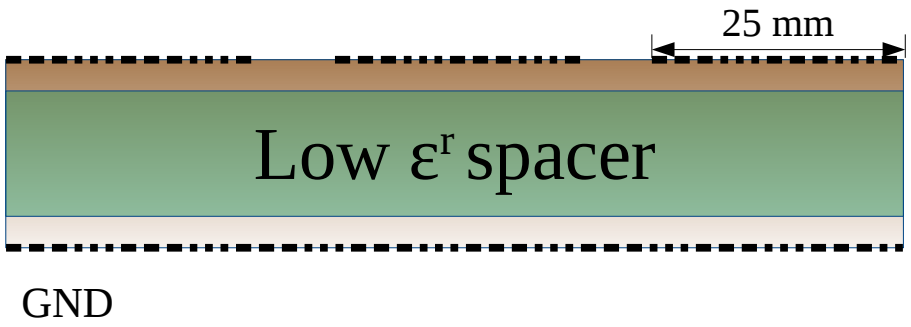
Pure phenolic glass



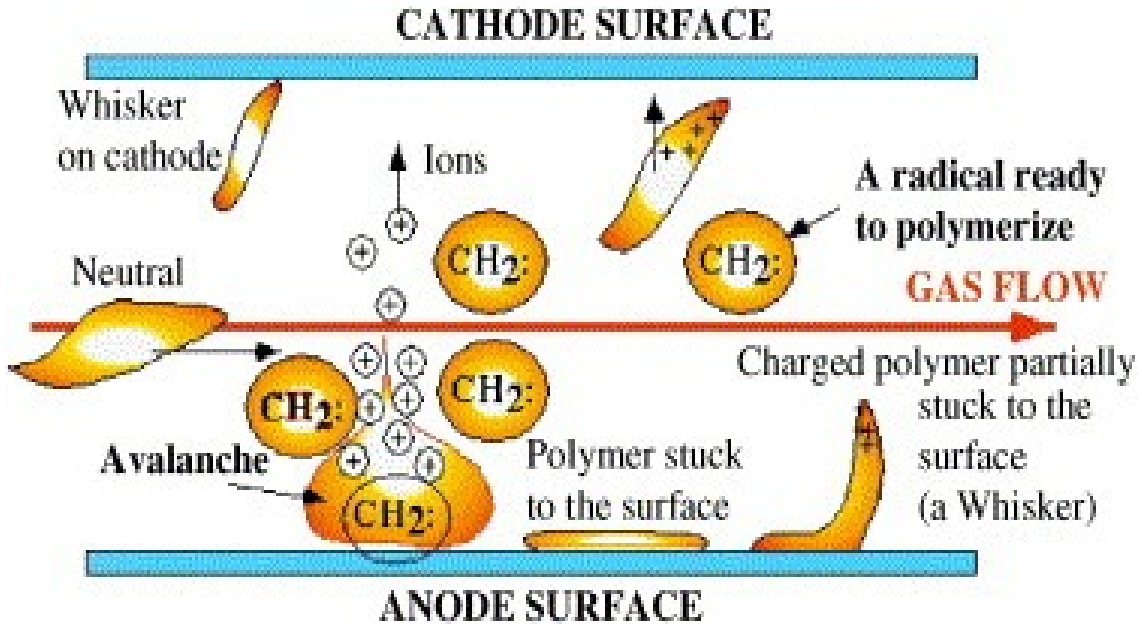


Effect of thin electrodes

- $q_{ind}/Q = 1/(1+2t/\varepsilon_r\, g)$ relates charge induced on an electrode q_{ind} to its thickness t
- (Q is the total charge in the gas, g is the gas gap)
- Signal attenuation proportional to t



The aging process

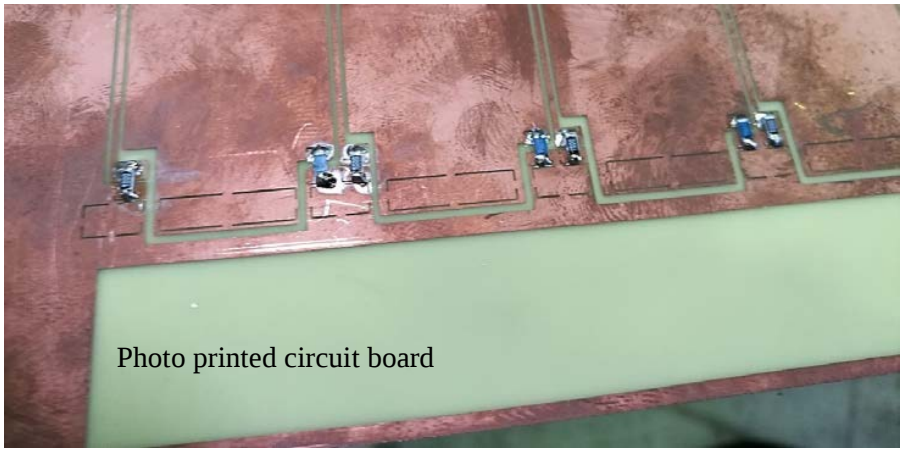


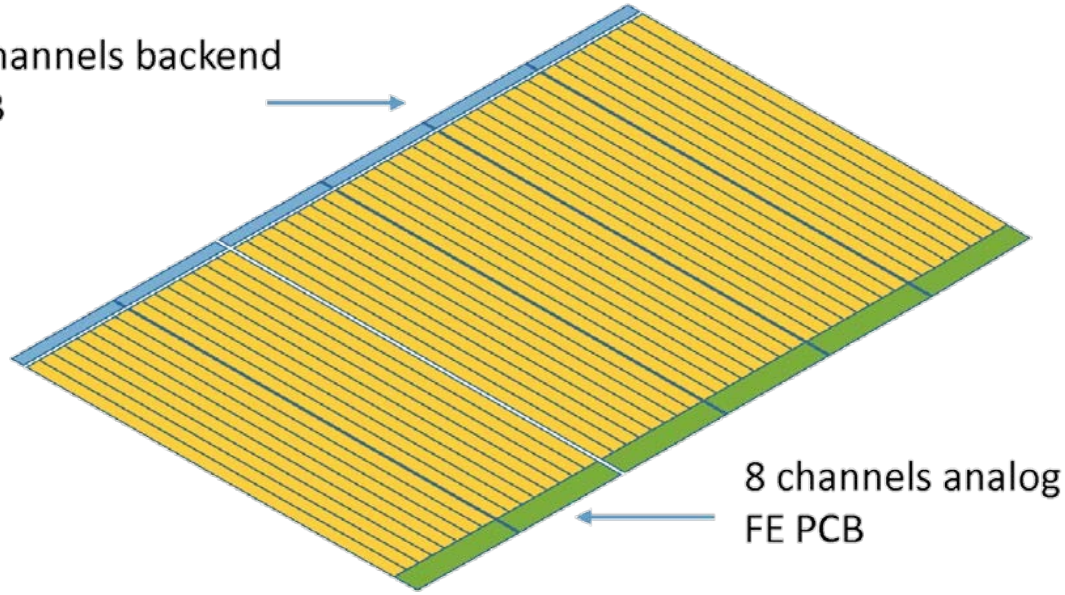
https://doi.org/10.1016/j.nima.2006.05.130

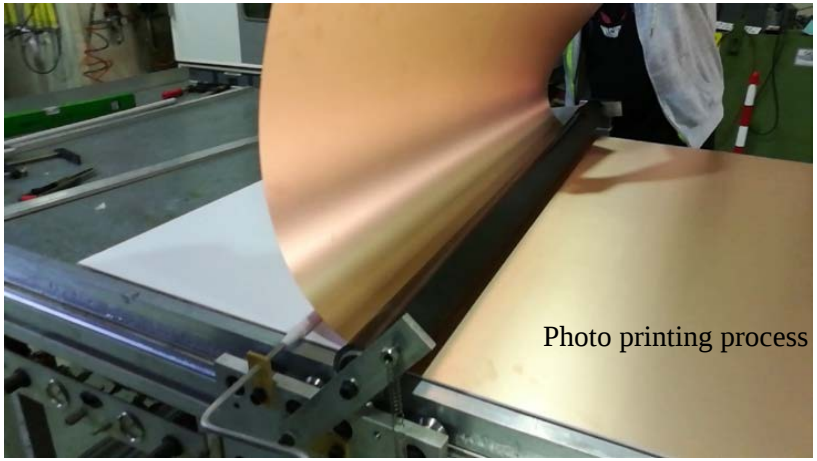
Gas inlet		
Ionizing gas	95%	TFE
Quencher gas	4.5%	i-C4H10
Electronegative gas	0.3%	SF6

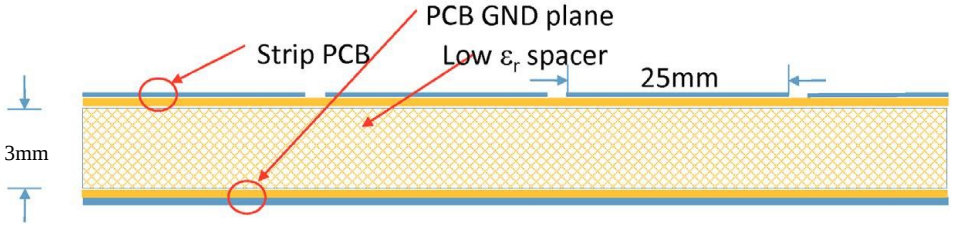
New strip panel layout

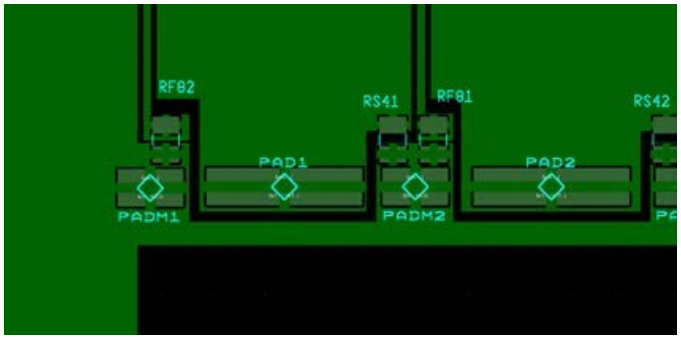
- Replacing the milled PET film by Fiberglass photo printed skins + Forex strip panel



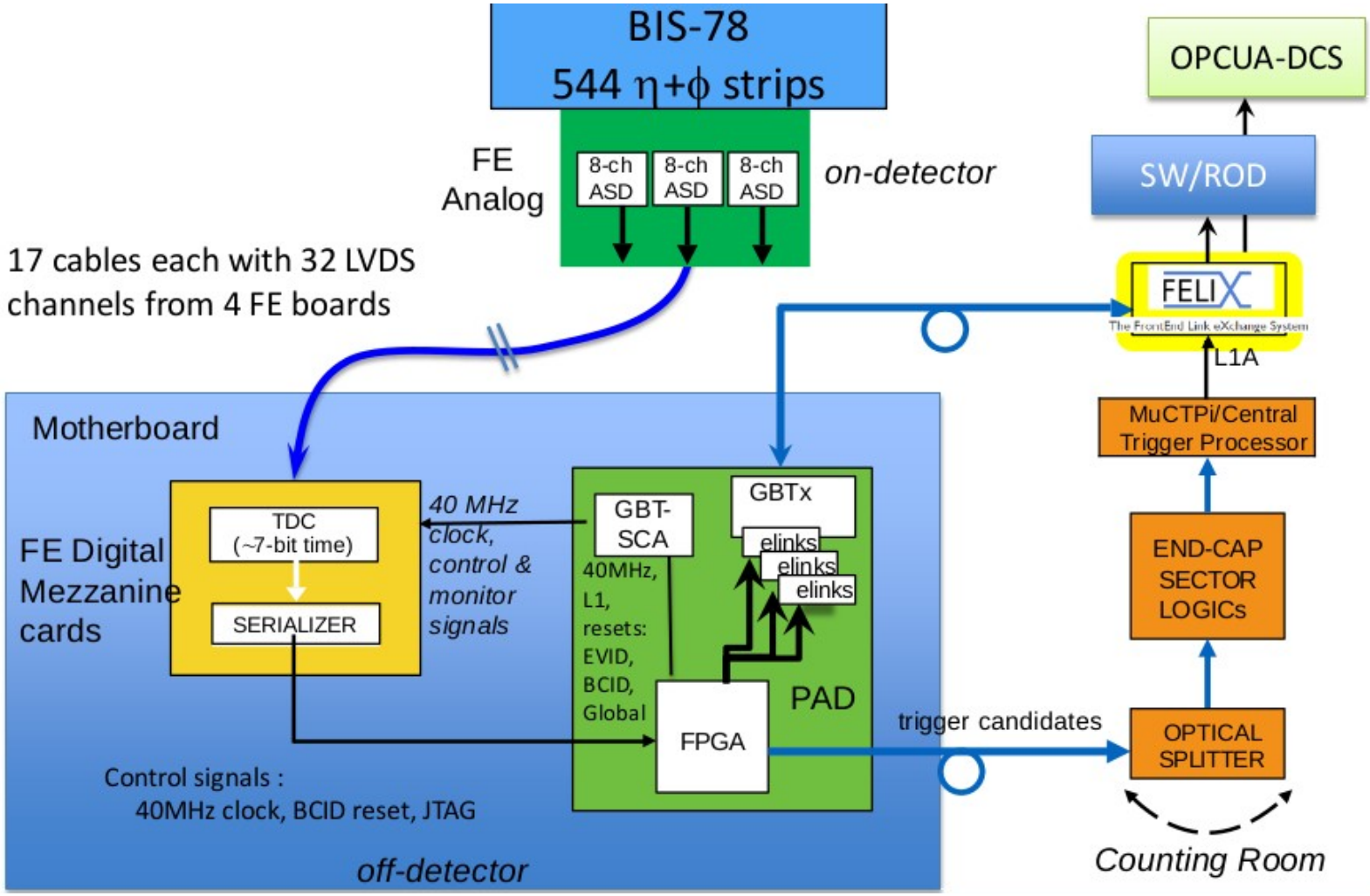






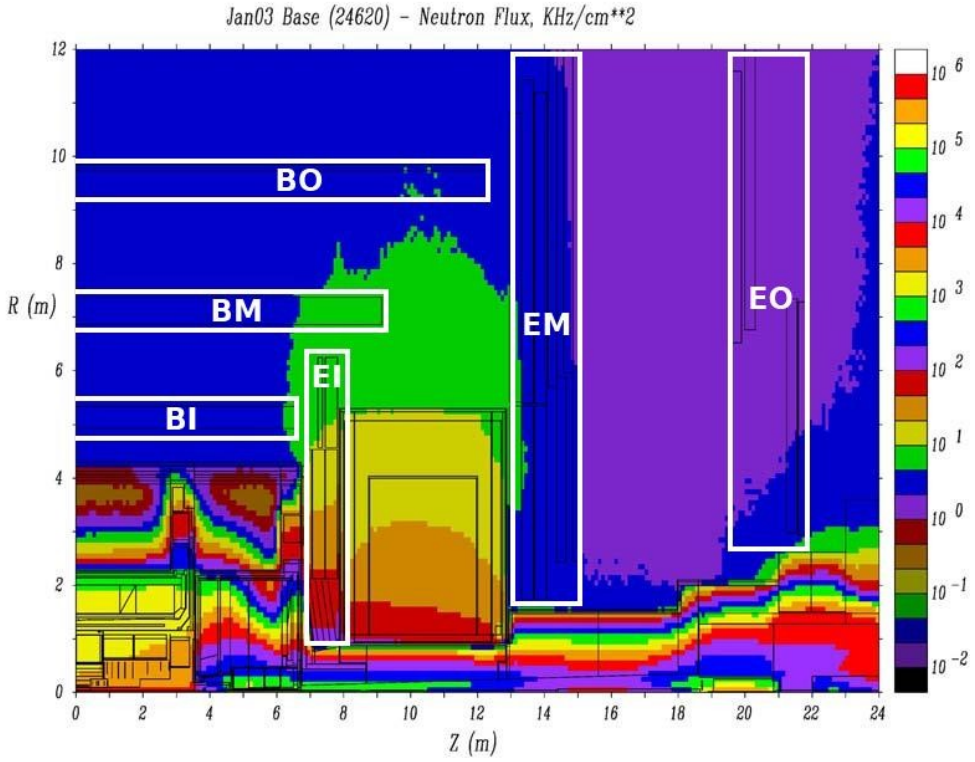


Data flow

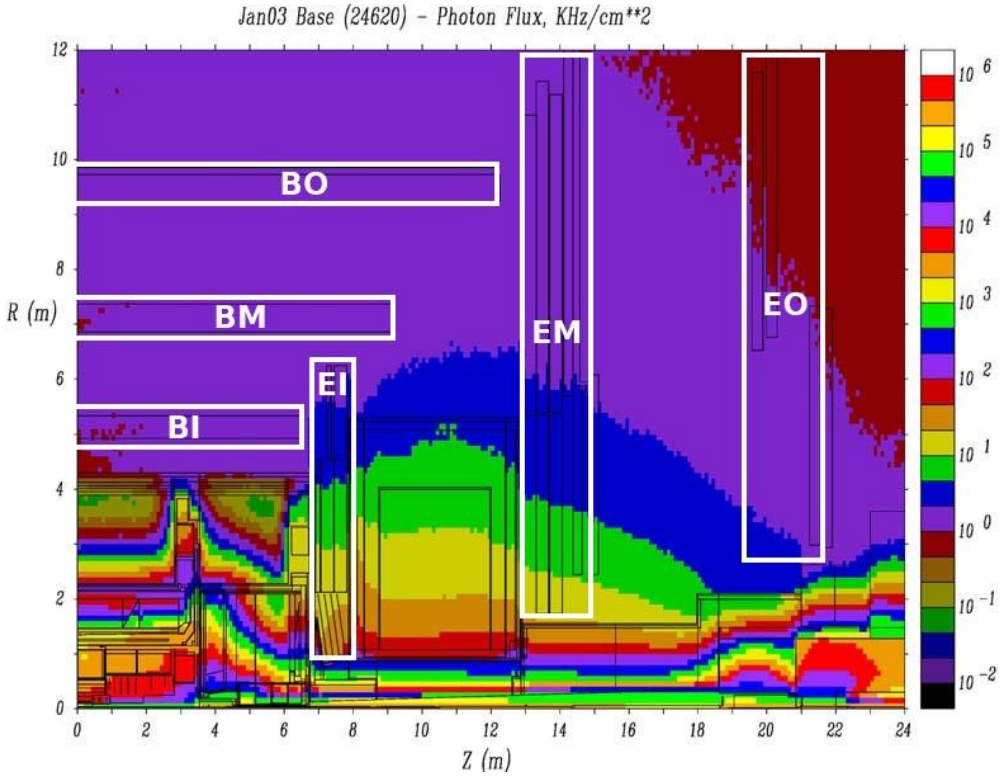

BIS-78
544 η+ϕ strips
FE
Analog
8-ch ASD
8-ch ASD
8-ch ASD
on-detector
17 cables each with 32 LVDS channels from 4 FE boards
OPCUA-DCS
SW/ROD
FELIX
The FrontEnd Link eXchange System
L1A
MuCTPi/Central Trigger Processor
END-CAP SECTOR LOGICs
OPTICAL SPLITTER
Counting Room
trigger candidates
Motherboard
FE Digital Mezzanine cards
TDC (~7-bit time)
SERIALIZER
40 MHz clock, control & monitor signals
GBT-SCA
40MHz, L1, resets: EVID, BCID, Global
GBTx
elinks
elinks
elinks
PAD
FPGA
Control signals :
40MHz clock, BCID reset, JTAG
off-detector

Radiation background

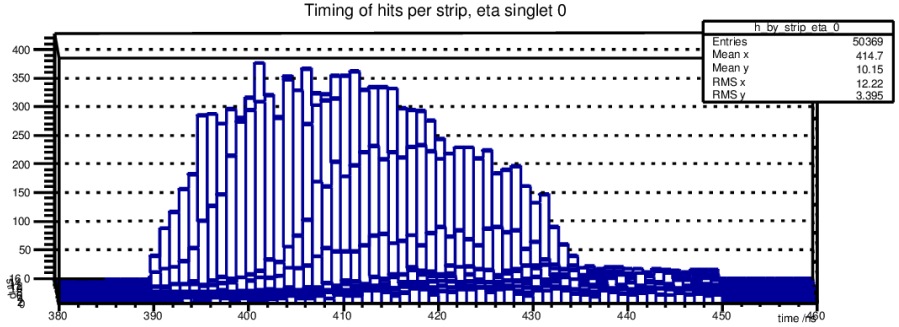
Neutron flux [kHz/cmq]



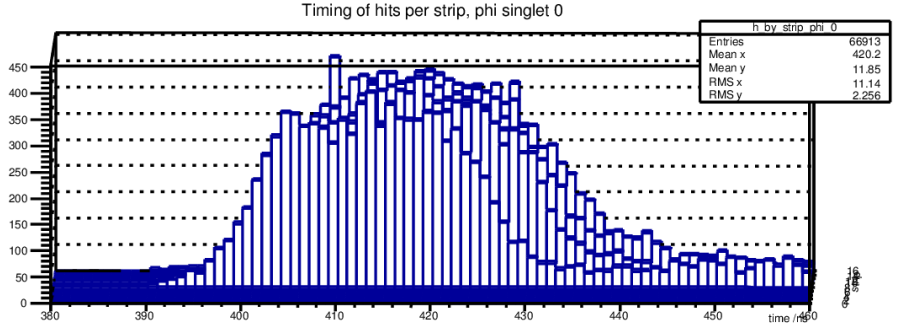
Photon flux [kHz/cmq]



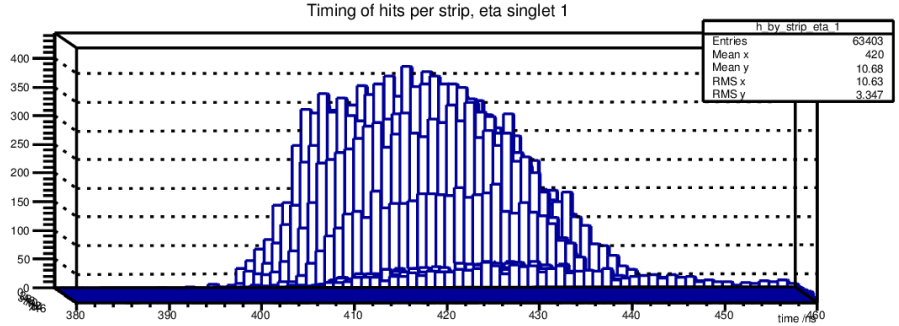
Timing of hits per strip, eta singlet 0



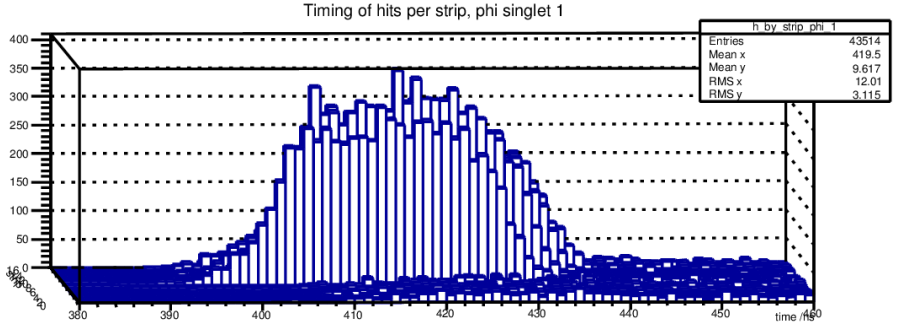
Timing of hits per strip, phi singlet 0



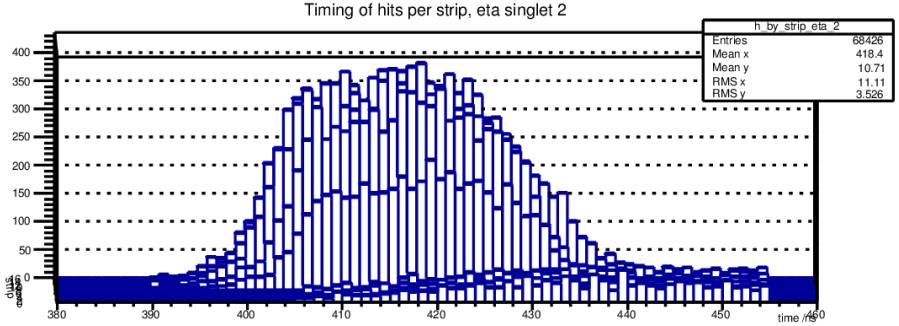
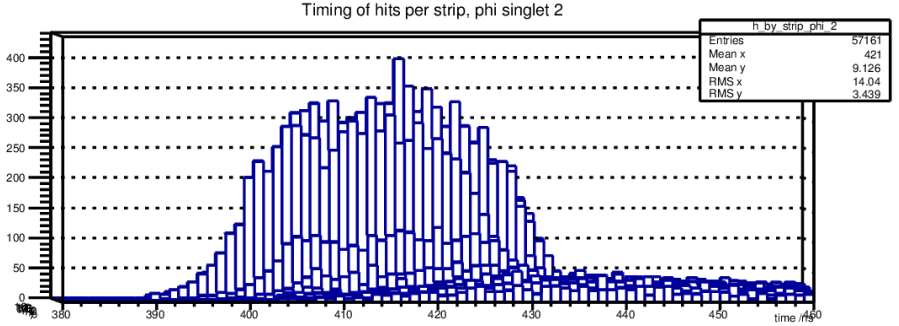
Timing of hits per strip, eta singlet 1



Timing of hits per strip, phi singlet 1



Timing of hits per strip, eta singlet 2



Timing of hits per strip, phi singlet 2