IDEA: The vertical slice Test Beam

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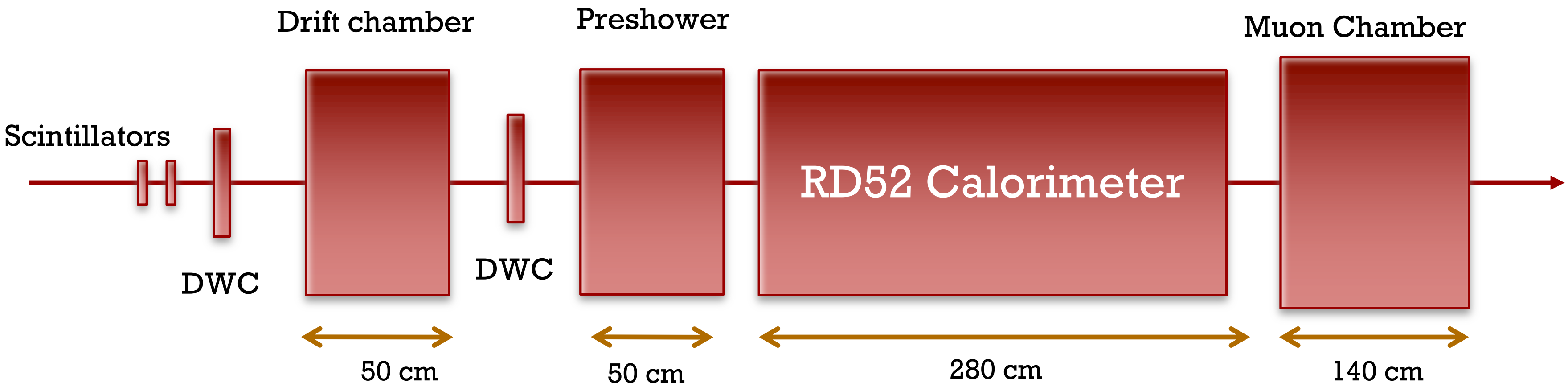
On behalf of the test beam team

IDEA Test Beam

- Measurements:
  - Particle Identification with:
    - Drift Chamber Prototype (p, π, k) using dE/dx VS cluster counting
    - Preshower + Dual Readout Calorimeters (e, π, μ)
    - μRWell (e, μ)
  - Preshower optimization studies
  - Tracking qualification
  - Qualification of a RD52 calorimeter with staggered fibers
  - Qualification of a small calorimeter module readout with SiPM

Setup schema



- Trigger with 2 scintillators in coincidence + 1 veto (if needed)
- 2 DWC (Delayed Wire Chamber)
- CEDAR (Differential Cherenkov detector)
- Drift Chamber Prototype
- Preshower with GEM: 2 layers GEM + absorber (0 – 2 X_0)
- Different Dual Readout prototypes
  - RD52 calorimeter with PMT readout
  - RD52 calorimeter with staggered fibers
  - Small calorimeter module with SiPM readout

- Muon chamber: 1 layer GEM + 2 layers μRWell
  - The large scintillator usually used in the RD52 test beam will be also readout

EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

Control room: HNA – 468 (0887-1- Q70)

Gas delivery

Space for the muon chamber

RD52 calorimeter (already installed in the area)

Some space for the preshower

Space for the drift chamber

Trigger + Delay Wire Chamber (DWC) already installed

EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

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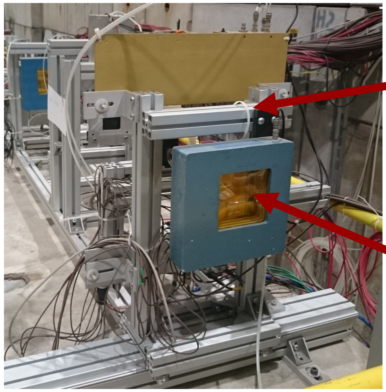
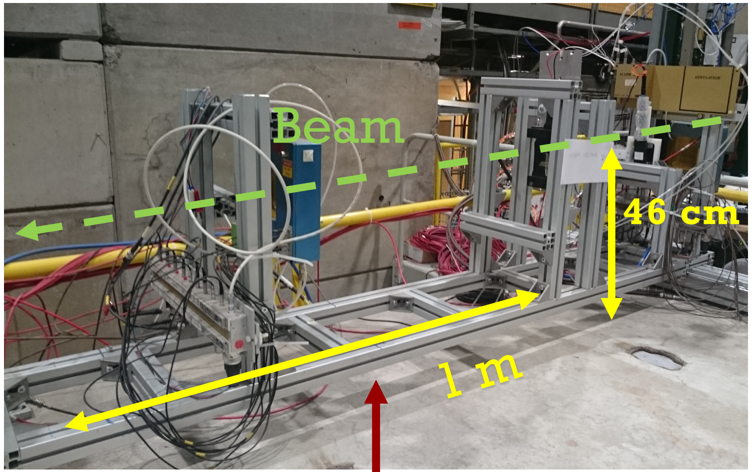


Trigger

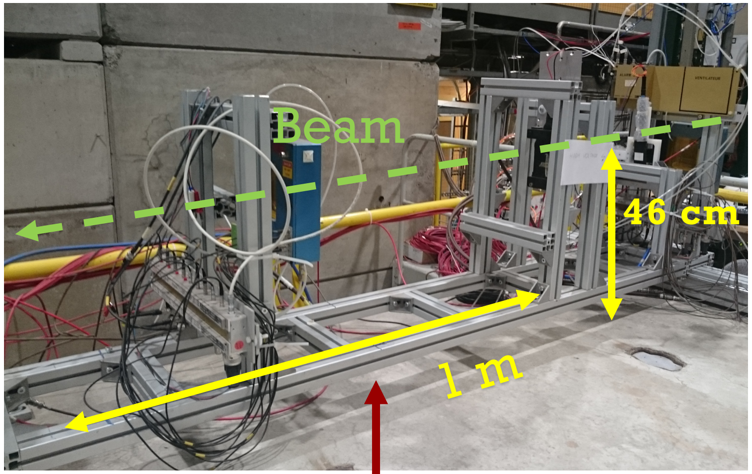
DWC



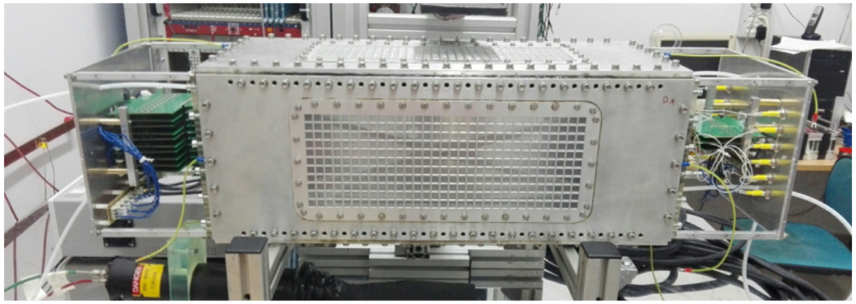
The space for the drift chamber

EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

Control room: HNA – 468 (0887-1- Q70)



Drift chamber prototype

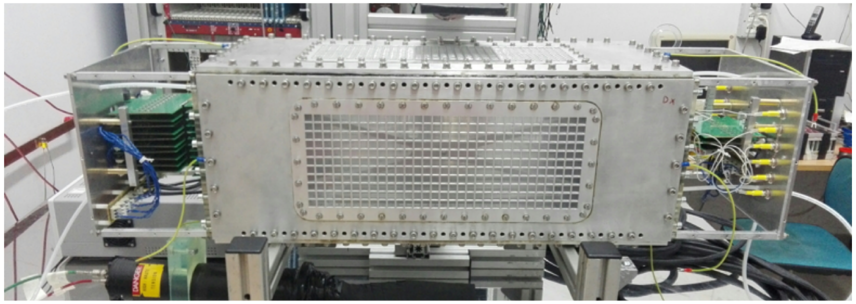


EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

Control room: HNA – 468 (0887-1- Q70)

- 1 RAC for the Drift chamber. Space available close to the detector is 50cm. It should be enough
  - 1 Crate Camac
  - 1 Crate VME
- The HV module will be installed in the RAC used by the preshower + muon chamber

Drift chamber prototype



EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

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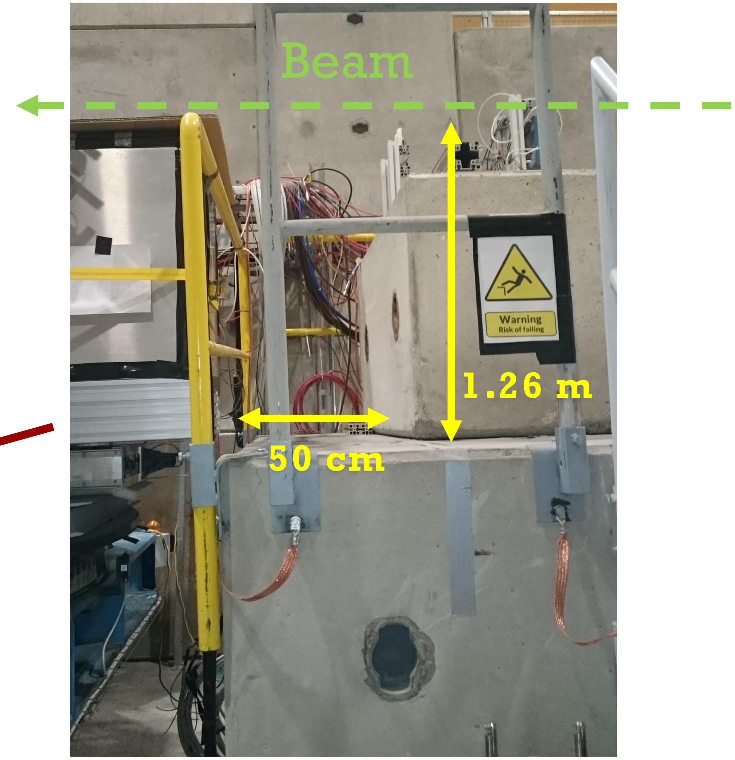
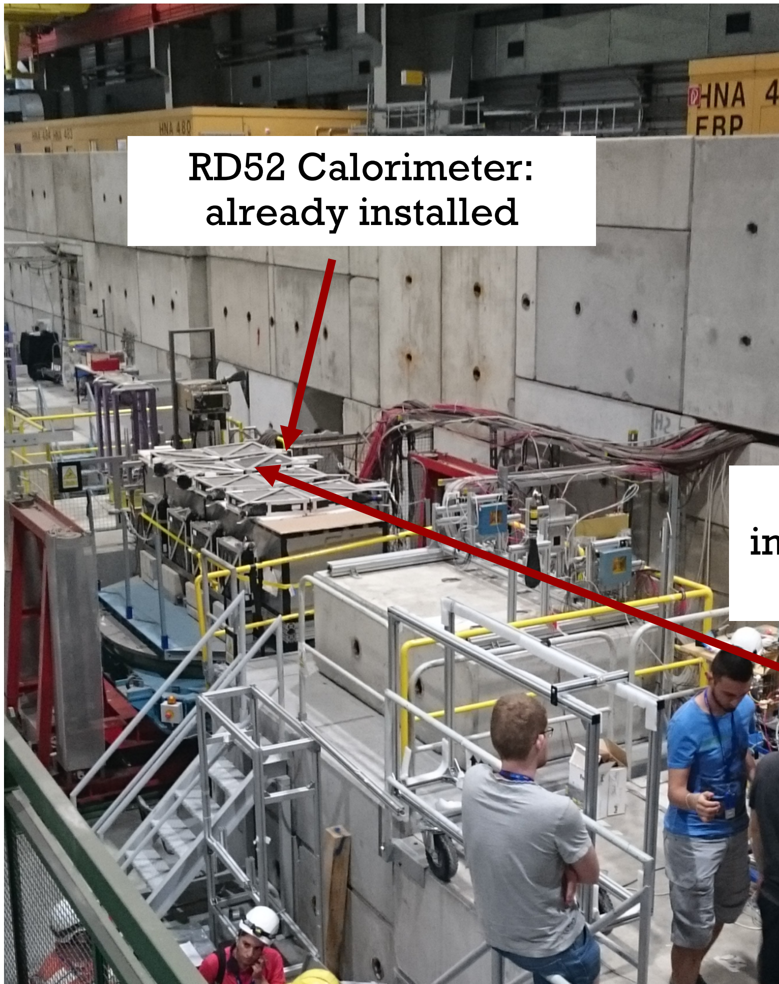


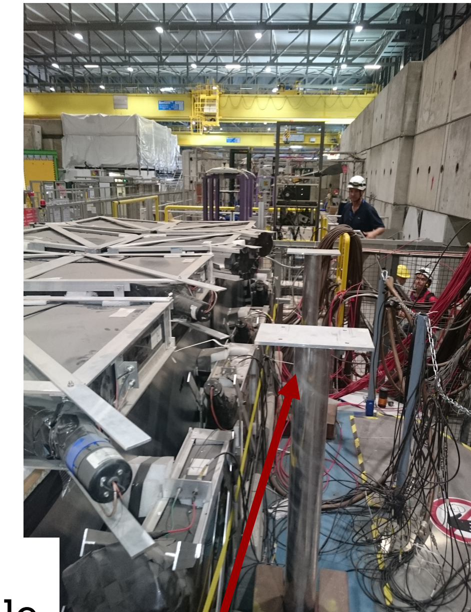
Preshower:
downstream the Drift chamber
and just in front to the calorimeter

EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

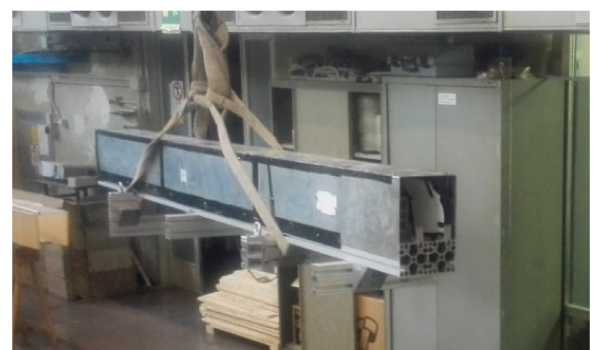
Control room: HNA – 468 (0887-1- Q70)



RD52 Calorimeter: already installed



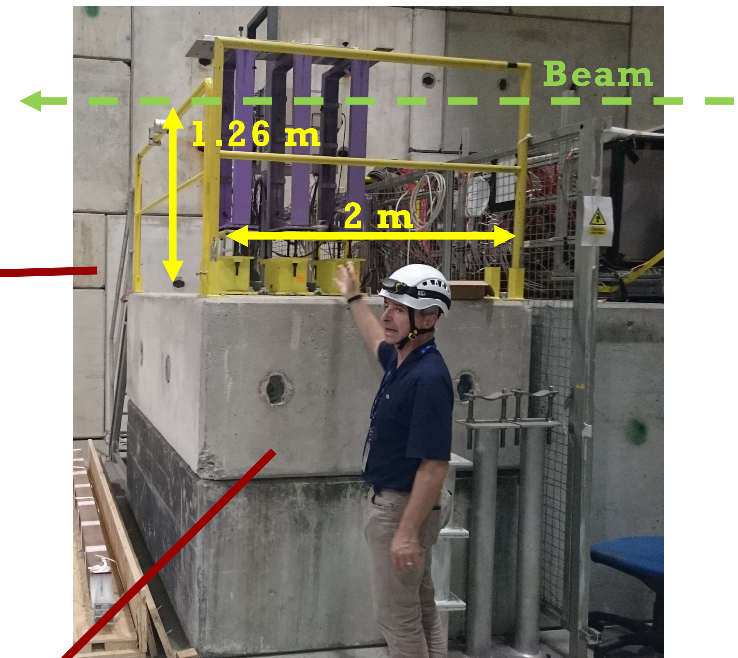
Possible places where to install the calorimetric module with staggered fibres



EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

Control room: HNA – 468 (0887-1- Q70)

Space for the muon chamber downstream the calorimeter



1 RAC to install the electronics for the preshower and mu-chamber + HV power supply

EHN1 – H8 – C (door 168, between ATLAS tile and Totem)

Control room: HNA – 468 (0887-1- Q70)

Place where to install the gas bottles (?? m from the detector)

$ArCO_2CF_4$: requested by preshower and muon chamber

He/Isobutene (90/10): requested by drift chamber

Trigger and DaQ

- Trigger based on scintillators in coincidence. It will be prepared in counting room and it will be delivered to all subsystems (expected delay 200 ns)
- All subsystems are able to sustain 1kHz trigger rate with the exception of the drift chamber (≈ ??)
  - Under investigation the possibility to record the number of the accepted trigger in the data header
- 3 different DaQ systems and Qas running in parallel
  - Central (trigger, calorimeters, CEDAR and ancillaries detectors used the measure the energy leakage in the RD52 calorimeter)
  - Preshower and muon chamber
  - Drift chamber
- 1 Quasi on-line system (see talk from Tom Coates)
  - Gets the data from each subsystem and displays the summary plots when the run is closed
  - The data merging will be also tried during the test beam period
- Test beam simulation (see talk from Lorenzo Pezzotti)

Some general information

- Access to the Area since August the 29th
  - Free access with beam dumped upstream (beam dump before PPE168)
- Safety inspection: September the 5th at 12:00
- Alignment service: September the 5th at 14:00
- Beam on: September the 5th at 18:00
- Beam stop: September the 12th at 8:00
- No machine development between us and the next users

A preliminary plan (I)

- Detector installation and qualification (from Aug - 29th to Sept. – 2nd)
- System integration (from Sept – 3rd to Sept – 5th)
- Beam on (Sept - 5th)
- Calibration (1.5 days):
  - Dual readout calorimeter calibration (60 GeV electrons)
    - All modules without the ≈ 1 X_0 of preshower absorber
    - Few modules when the preshower absorber is in front the calorimeter
  - Drift Chamber HV scan at fixed energy (beam? Energy?)
- Measurements with all systems (2.5 days)
  - Scan in energy
  - Preshower impact to the calorimeter energy resolution
  - PID
  - Test with multi-particle environment (target): under discussion

A preliminary plan (II)

- Tests with new calorimeters (2 days)
  - Module with staggered fibres
    - Calibration strategy
    - Test with electrons and pions
  - Module with SiPM
    - Ph-e / Gev measurement
    - Cross-talk measurement

Costs

- Missioni: Old
  - Drift Chamber: 2 persone x 10 giorni
  - Calorimetro: 5 persone x 10 giorni
  - µRWell: 3 persone x 10 giorni
  - Modulo con fibre disallineate: 2 keuro (costi trasprto)
  - Smantellamento area RD52: circa 3 keuro

- Missioni: New
  - Drift Chamber: 2 persone x 15 giorni
  - Calorimetro: 5 persone x 15 giorni
  - µRWell: 5 persone x 10 giorni
  - Modulo con fibre disallineate: 2 keuro (costi trasprto)
  - Smantellamento area RD52: circa 3 keuro

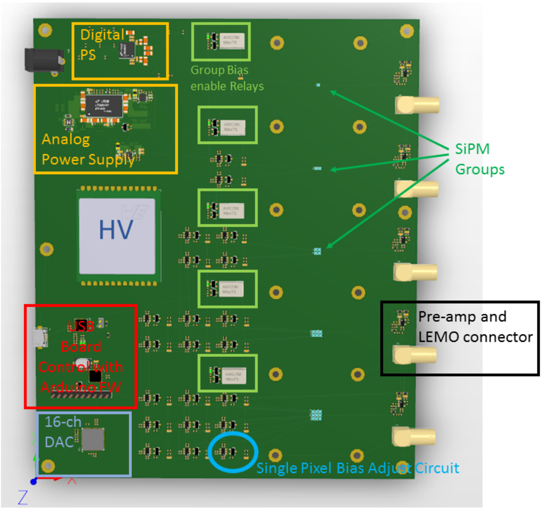
Summary

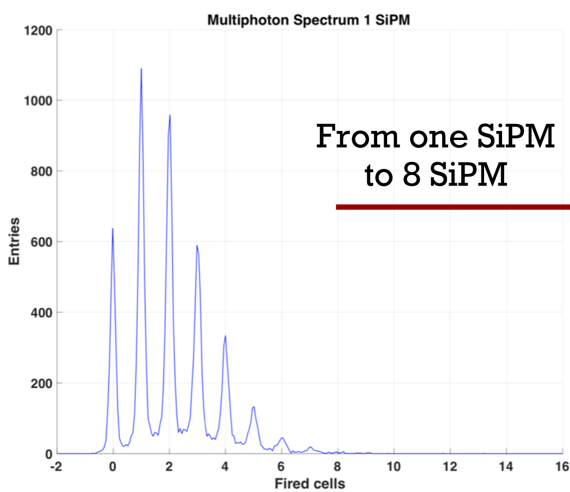
- The space available is good enough to install all subsystems
- Each subsystem will come at CERN with his own support structure and it will be placed onto the platform / concrete block
- The installation will start 1 week in advance (i.e. 29-Aug) and there will be the possibility to test the system integration.
- Quasi on-line and simulation is progressing. I'm always more convinced that they will be crucial for a successful test beam
- There are still details in the hardware (readout / gas) to be finalized but I'm optimistic
- The next test beam meetings will be mainly focused to finalize the measurement plan
  - Input from subsystem experts is crucial
  - Whoever is interested in contributing to the test beam has to follow the meeting especially who is interested in the data analysis

Back up Slides

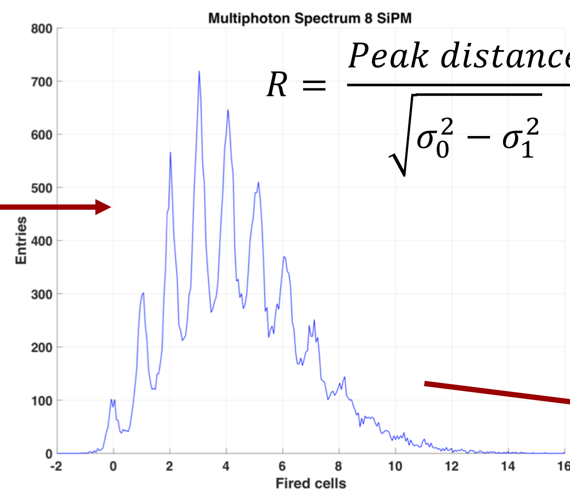
Signal Grouping

- This board allows to investigate the SiPM performances when the signals are grouped analogically (from 1 to 9 SiPMs)
- Each SiPM is individually biased
- Same FEE used in the test beam

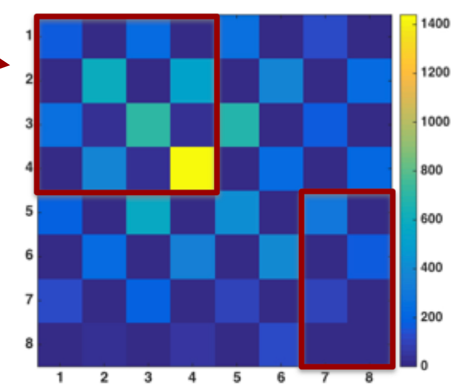




From one SiPM to 8 SiPM



$$R = \frac{Peak\ distance}{\sqrt{\sigma_0^2 - \sigma_1^2}}$$



	1 SiPM	4 SiPM	8 SiPM
R = resolving power (ph-e)	24.5	16.6	10.0
Space granularity (mm^2)	≈4.5	≈18	≈36

SiPM dynamic range

A strong push for larger number of cells is not an easy game.

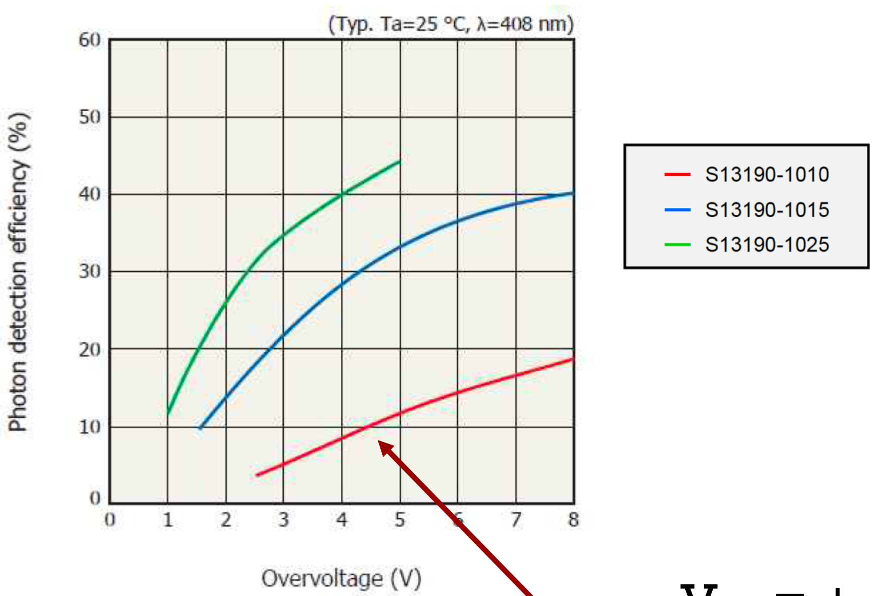
This approach, in a first approximation, would show:

- Reduced fill factor (lower PDE)
- Higher spurious effect (higher Dark counts)
- Lower capacitance ≈ lower gain and reduced possibility to see the multi-photon spectrum

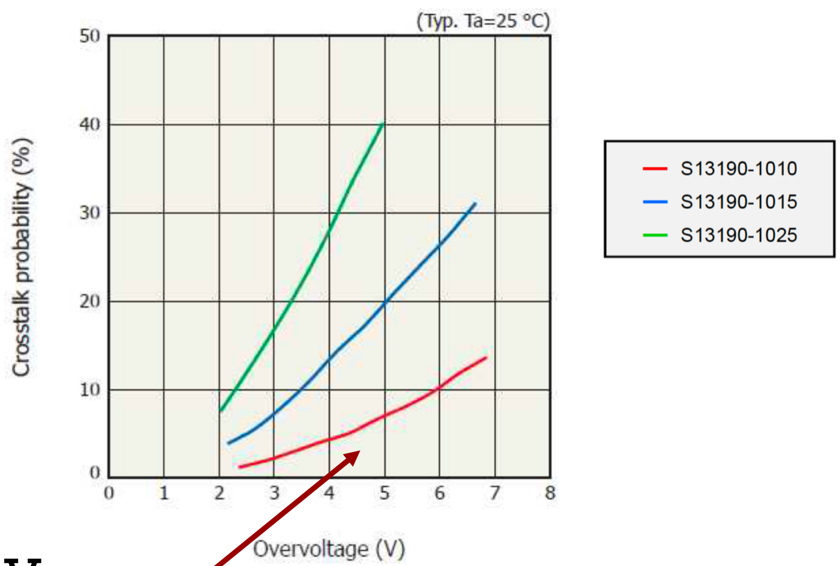
Nevertheless the companies are working hard in this direction ...

SiPM dynamic range

- Hamamatsu has the S13190-1010
  - 10 x 10 μm^2, ≈ 10^4 cells, PDE 10%, Typical DCR = 100 kcp, Xtalk 5%, Expected Gain ad Vop = $1.3*10^5$



■ Crosstalkprobabilityvs. overvoltage



V_{op} = + 4.5V over breakdown

SiPM dynamic range

- FBK has Ultra High Density (UHD) SiPM: sensor with 5 μm pitch and $4.6 * 10^4$ cells (IEEE-explore, 24, No. 2, 2018)

Special care has to be used to reduce border region effects at the edge of the high-field region modifying the doping profile (NGR)

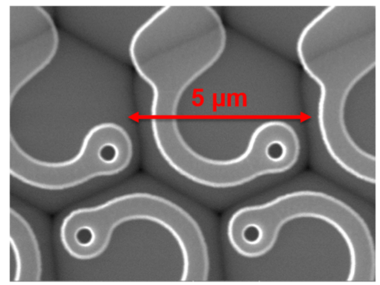


Fig. 4. SEM image of UHD SiPM, with 5 μm cell pitch. The honeycomb configuration of the cells and the top polysilicon resistor are visible.

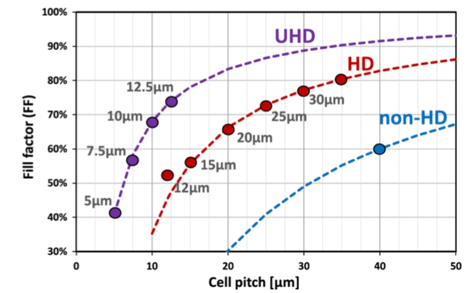
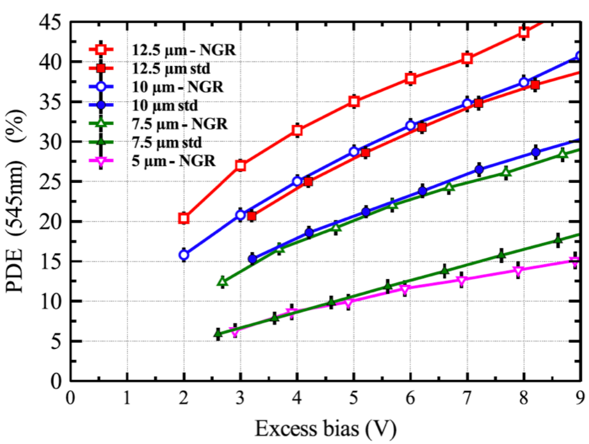
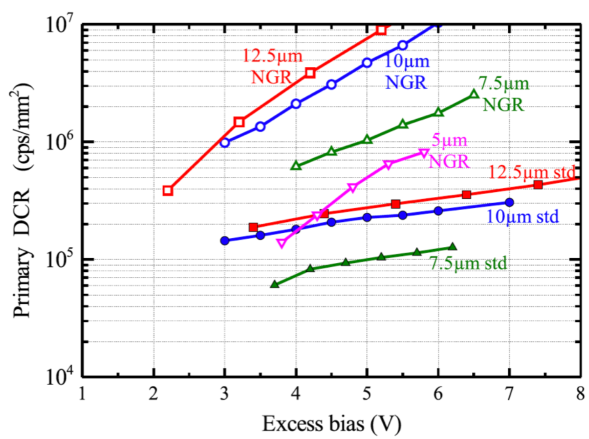
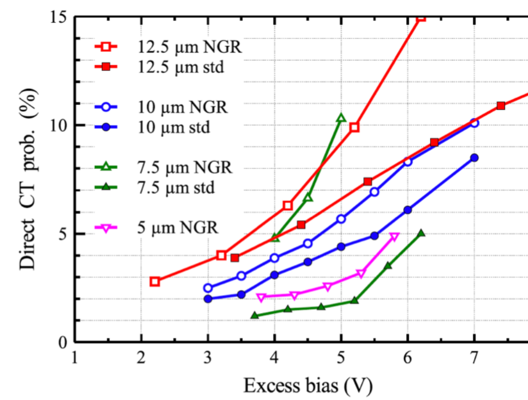


Fig. 5. Nominal fill factor comparison between different FBK SiPM technologies: non-HD, high-density, and ultra-high-density. Thanks to the technology improvements, the fill-factor is generally high, despite the smaller cell pitch. Dots represent the produced and tested variants.



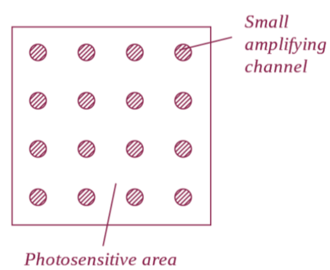




SiPM dynamic range

- A new design where the cells are integrated into a continuous photosensitive area (DEPHAN Solid-State Photomultipliers - SSPM). This concept has been recently proposed by S.V. Bogdanova et al.

Schematic DEPHAN image, top view



https://dephandetectors.com

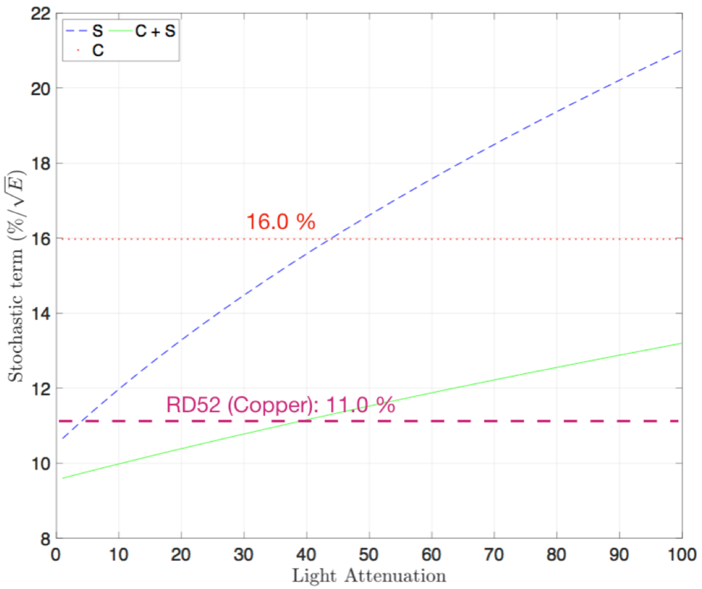
Pilot prototypes of the solid-state photomultipliers DEPHAN with 1×1 mm^2 surface area have amplification channels (cells) density 4.4×10^4 mm^{-2} with light-sensitive area (fill-factor) ***0.83.***

It was compared to the DEPHAN detector, an experimental SSPM of a new type, in which the amplifying channels (cells) are integrated into a continuous photosensitive area. Due to the new design, it became possible to increase its dynamic range by several times (cell density 4.5·10^4 per mm^2), significantly improving the other key characteristics: fill factor > 80%, ***PDE***$_0$~25%, and crosstalk probability < 2%.

(https://doi. /10.1117/12.2290956)

Is the dynamic range not enough?

The stochastic term contribution to the EM resolution considering the latest test beam results



Too much light can always be filtered!

- The error from sampling fluctuations for both S and C channels is: $\varepsilon_{Sampling} \sim 10.5\%$
- The relative error of the number of fired cells/GeV is: $\varepsilon_{N_{FC/GeV}} = \frac{1}{\sqrt{N_{FC/GeV}}}$
- The combined error for each channel is: $\varepsilon_{Combined} = \sqrt{\varepsilon^2_{Sampling} + \varepsilon^2_{N_{FC/GeV}}}$
- The stochastic term in the EM resolution is: $\varepsilon_{C+S} = \frac{\sqrt{\varepsilon^2_{Combined}(S) + \varepsilon^2_{Combined}(C)}}{2}$