New digital SiPMs from Philips: Applications and first tests

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www.Philips.com/DigitalPhotoncounting

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Oct4-5 2010, Kirchhof Institute for Physics, Heidelberg University, Detector Workshop of the Helmholtz Alliance "Physics at the Terascale"

Outline

- Photon detectors and requirements
- Our Projects
- new Philosophy from Philips , going Digital
- First Tests with real beam
- Outlook / our Plans

The Photon Detectors and requirements on them

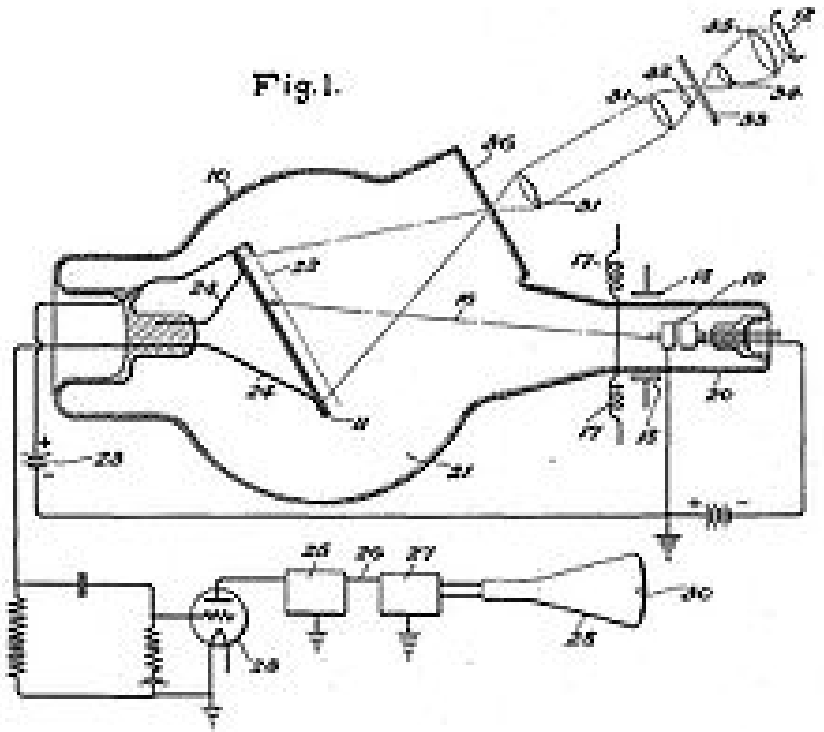
The „first“ requirement and „first” PMT
V.K. Zworykin, US Patent 2.021.907, 1935
„My invention relates to improvements in methods of and apparatus for producing images of objects or phenomena which are invisible to the human eye.“

Nov. 26, 1935. V. K. ZWORYKIN 2,021,907

METHOD OF AND APPARATUS FOR PRODUCING IMAGES OF OBJECTS

Filed Nov. 13, 1931

Fig. 1.



The Photon Detectors and requirements on them

Detect the Photons, Photon Counting....

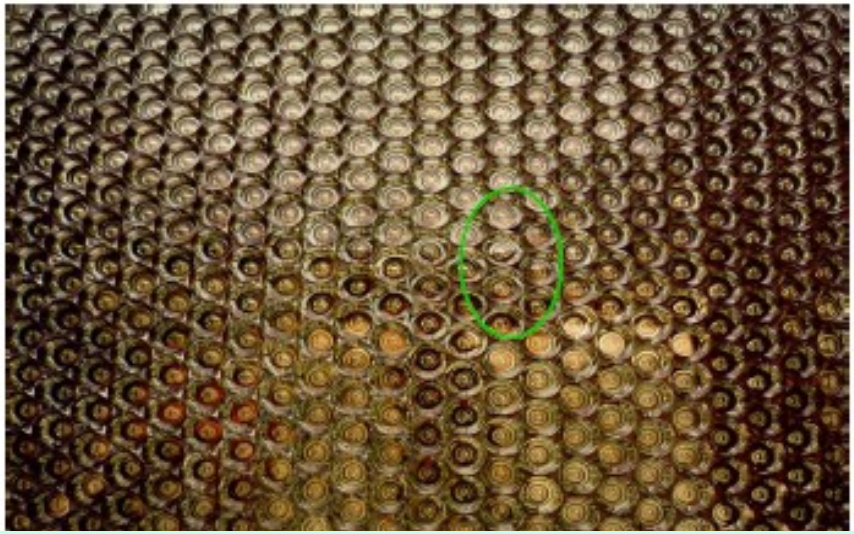
Detect the Photons and measure their position, Photon Imaging, RICH detectors

Detect the signal, measure their Positions and Time....3D TOP PID detector

The Photon Detectors and requirements

Detect the Photons, Photon Counting....

Detect the Photons and measure their position, Photon Imaging, RICH detectors.HERMES

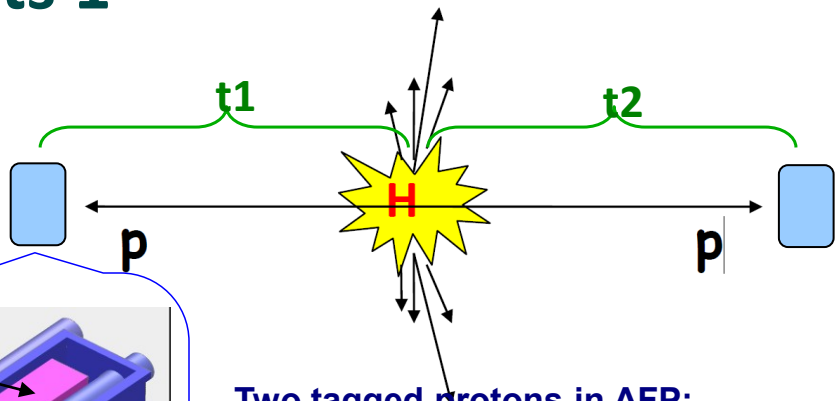


Photon detector

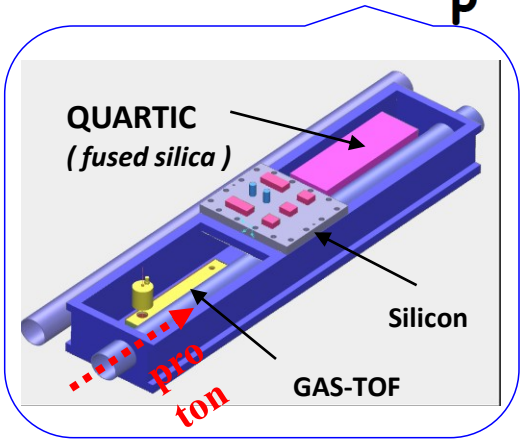
- **Hexagonal grid of 1934 PMTs per detector half**
- **PMT Type: Philips XP1911/UV**
- **¾ inch PMT diameter**
- **Active area increased to 91% by reflective funnel cones**

Our Projects 1

Use of fast Photon Detectors for ATLAS Forward Physics (AFP)



QUARTIC (fused silica) bars / fibers + GAS-TOF with MCP-PMT or APD



Two tagged protons in AFP:
study of Higgs, gγ and γγ with clean Central Mass and good mass resolution:

Central Mass: 50 GeV < M < 1 TeV ,
ΔM ≈ 3 – 5 GeV

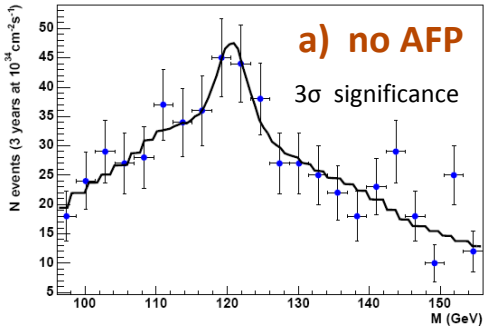
Scattered proton time resolution goals:

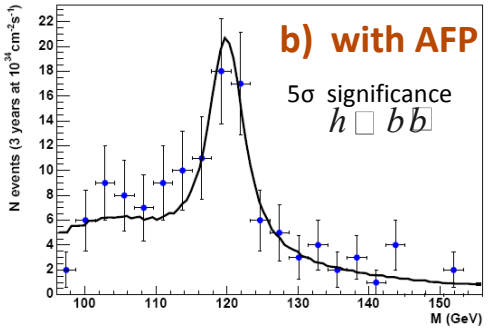
single bar δt ≈ 40-45 ps
GAS-TOF δt ≈ 30 ps

combinative → 10-20 ps

For more info about AFP see the talk of A. Astvatsatourov in this Workshop

MSSM Higgs (tan β = 40 , M_A = 120GeV): min 3 years nominal lumi



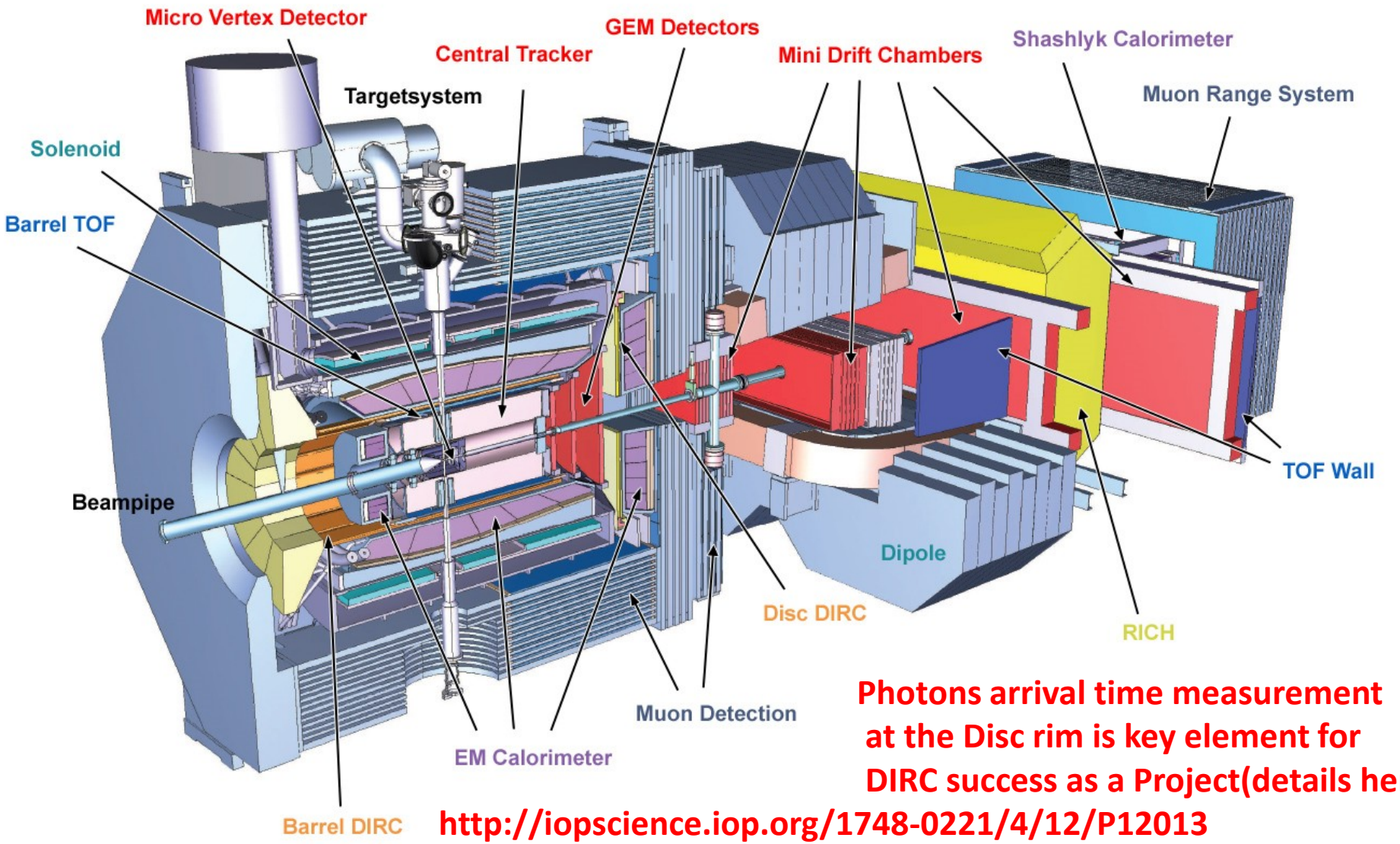


a) → b) : pile-up background rejection with ToF system

Our Projects 2

DIRC cherenkov of PANDA Experiment at FAIR

http://www-panda.gsi.de/



Photons arrival time measurement at the Disc rim is key element for DIRC success as a Project(details here)

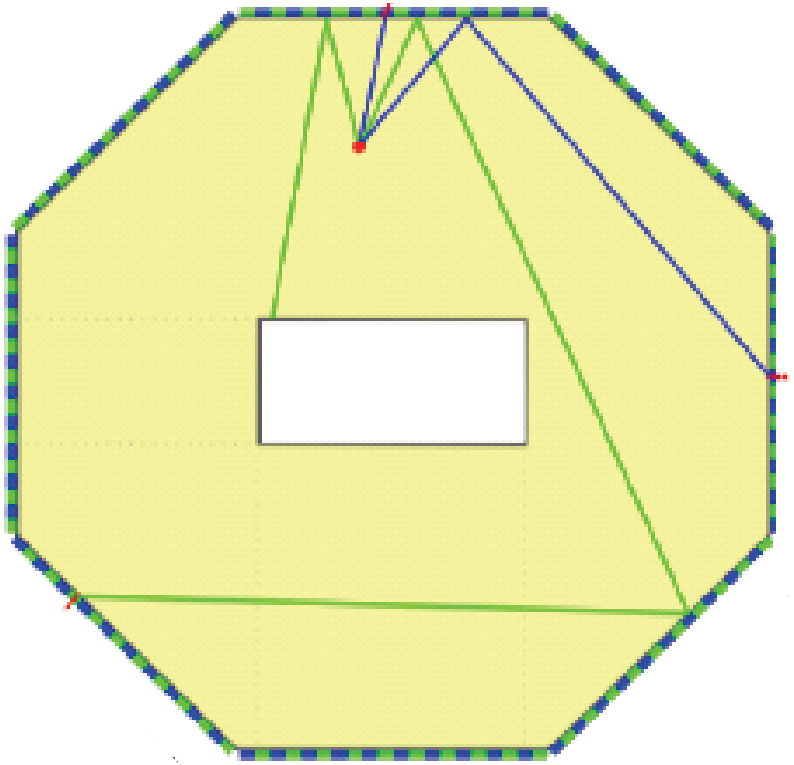
http://iopscience.iop.org/1748-0221/4/12/P12013

The Photon Detectors and requirements

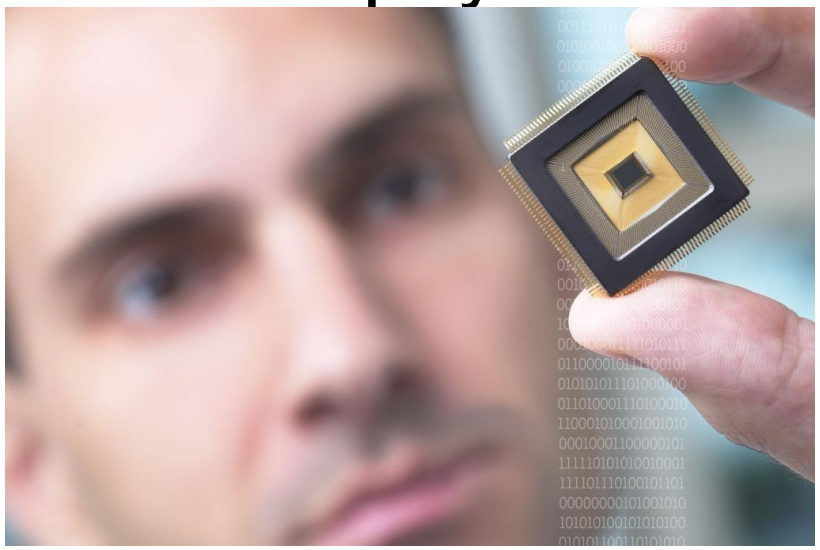
Detect the Photons, Photon Counting....

Detect the Photons and measure their position, Photon Imaging, RICH detectors

Detect the Photons, measure their Positions and Time and Color and ask Who is their Parents....ManyDimensional PID detector



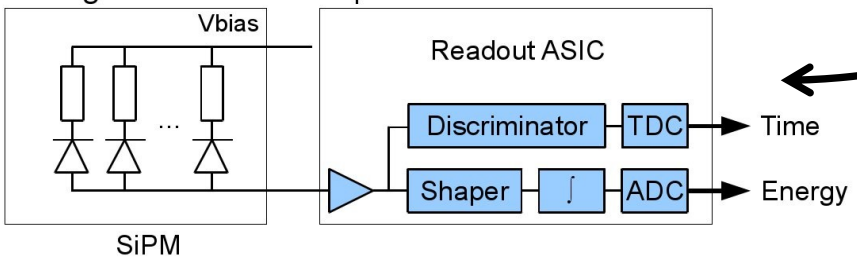
New Philosophy from Philips - going Digital



http://www.philips.com/digitalphotoncounting

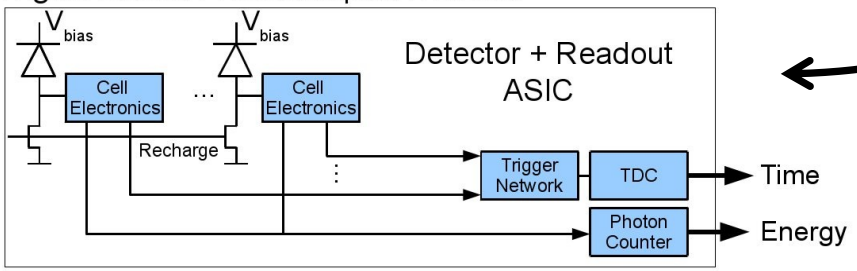
Digital SiPM – The Concept

Analog Silicon Photomultiplier Detector



Old way to get Photon information from SiPMs

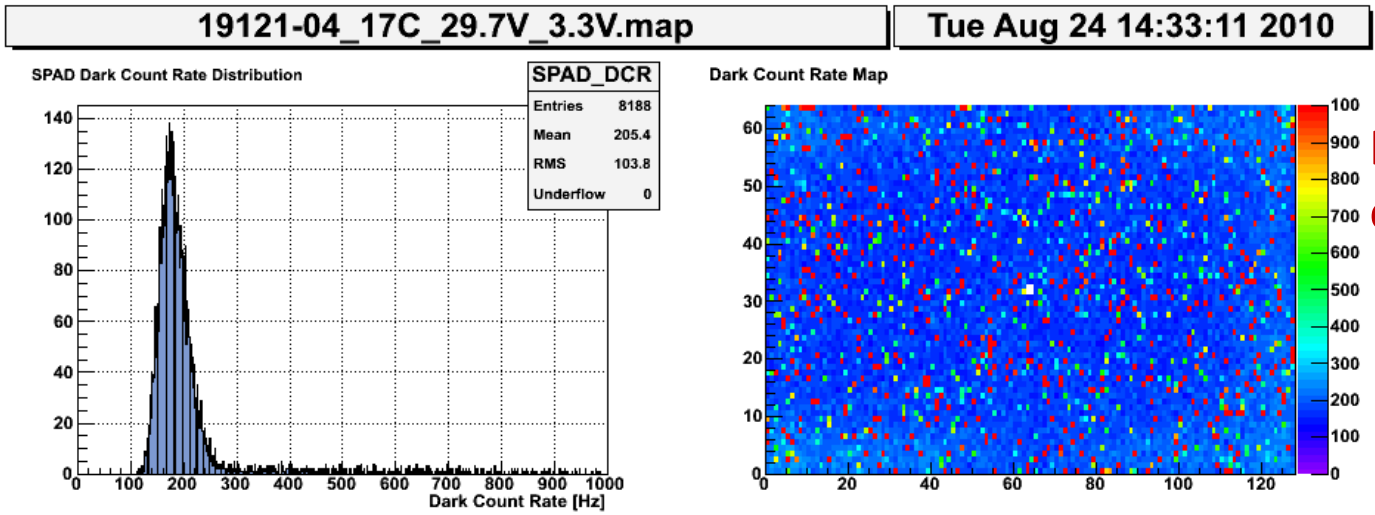
Digital Silicon Photomultiplier Detector



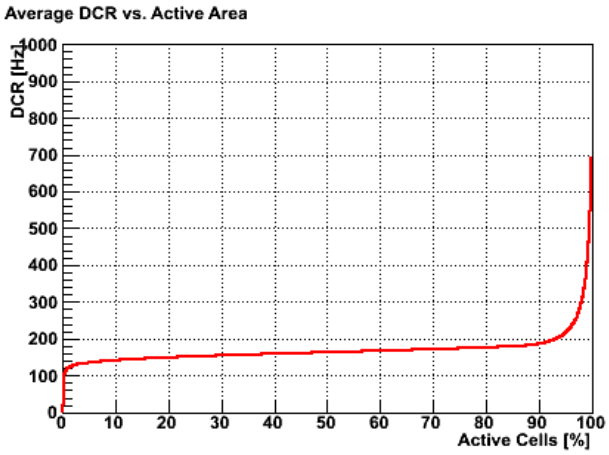
New way to get Photon information from SiPMs

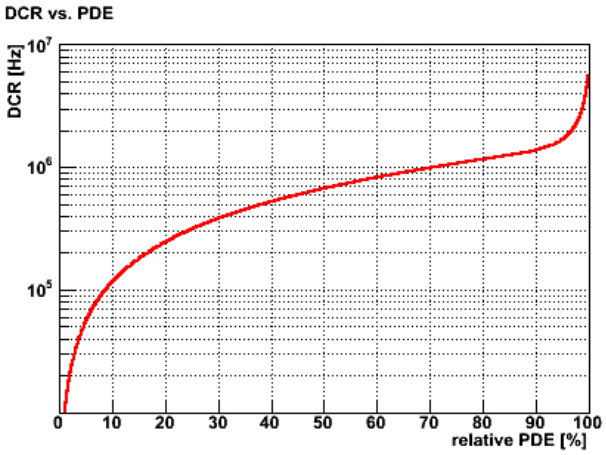
T.Frach, G. Prescher and C. Degenhardt
Optoelectronic Innovation 2010

dSiPM and its features



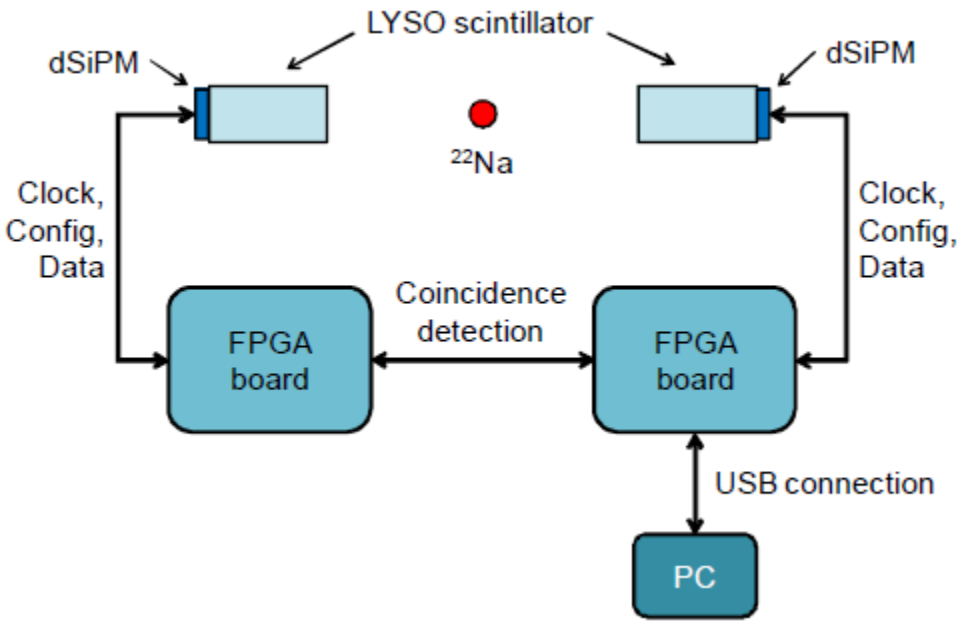
Individual microcells can be deactivated

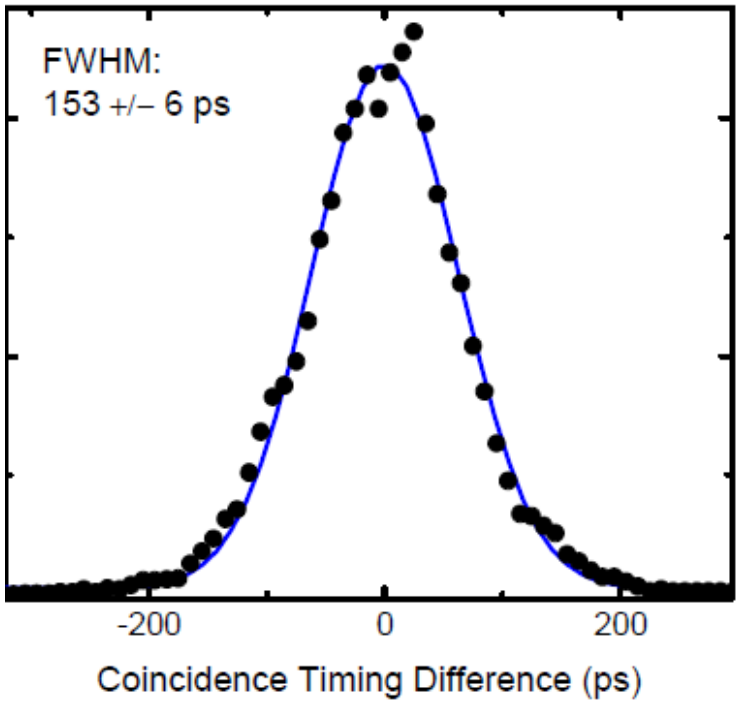




Digital output for e.g. only >=2,3,4 photons to suppress dark rate

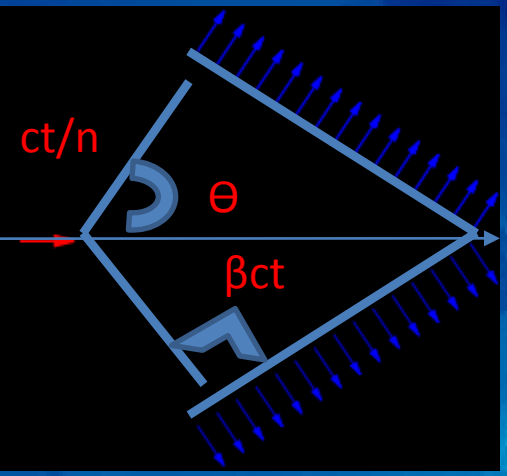
The Time Resolution with Scintillation





C. Degenhardt et. Al. 2009 IEEE Nuclear Science Symposium

Our suggestion was to test it with Cherenkov Photons



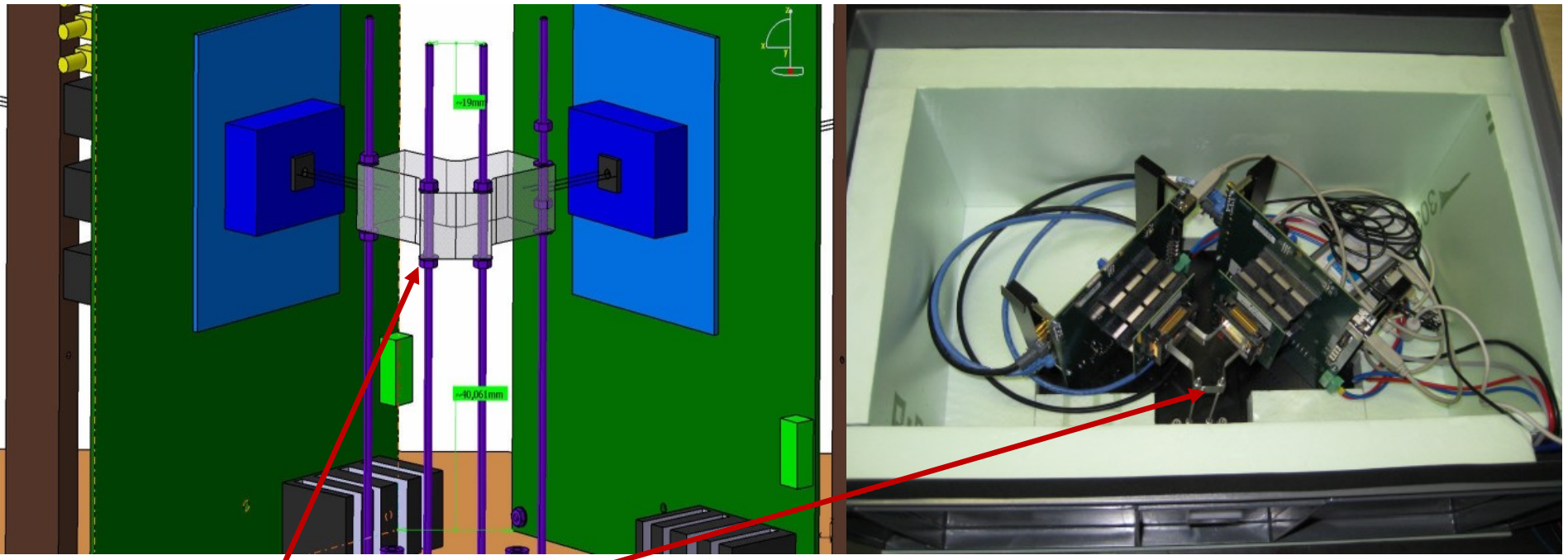
Advantages

-it is much faster than Scintillation

-it has well defined angular distribution defined by medium and particle type

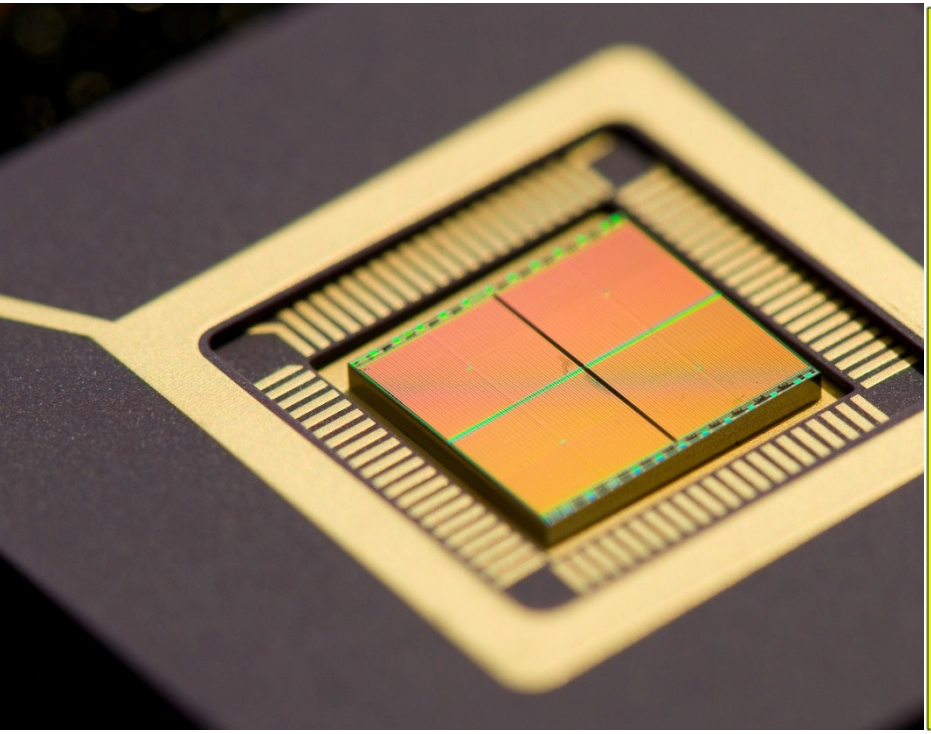
-it has continuous spectra from UV to IR well covering QE region of SiPMs

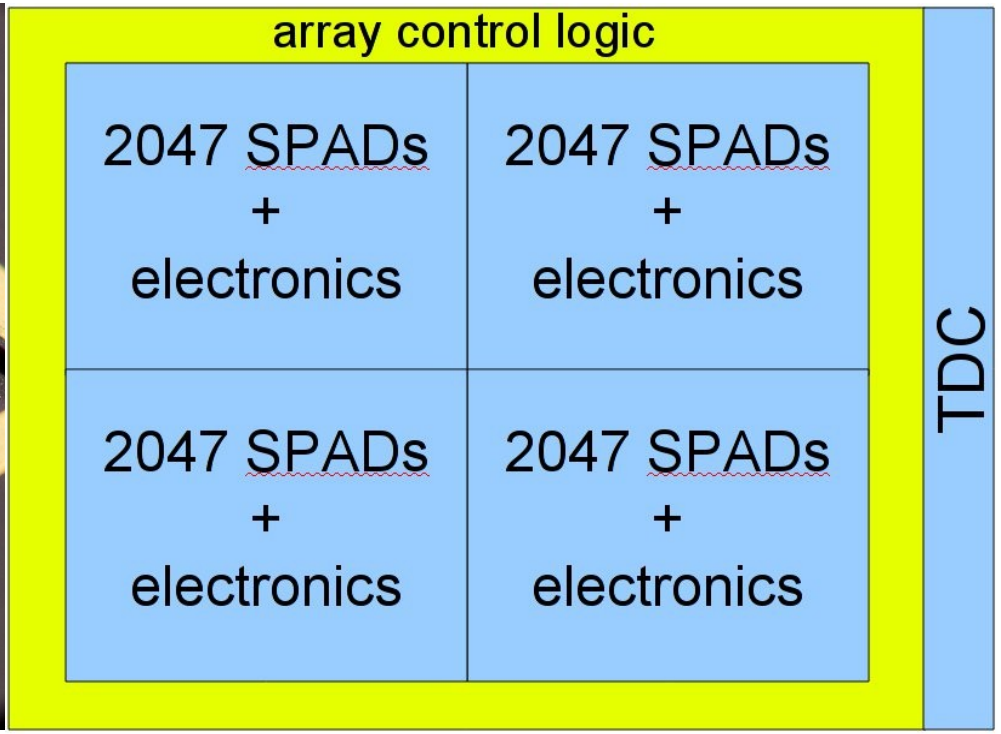
The new Prototype



The radiator is made from Plexiglas with 1.5 refraction index,
Making Cherenkov light at 48.2 degree, this defines the geometry
With good cooperation between Philips and JLU Giessen it was possible to build it and test first with pulsed laser

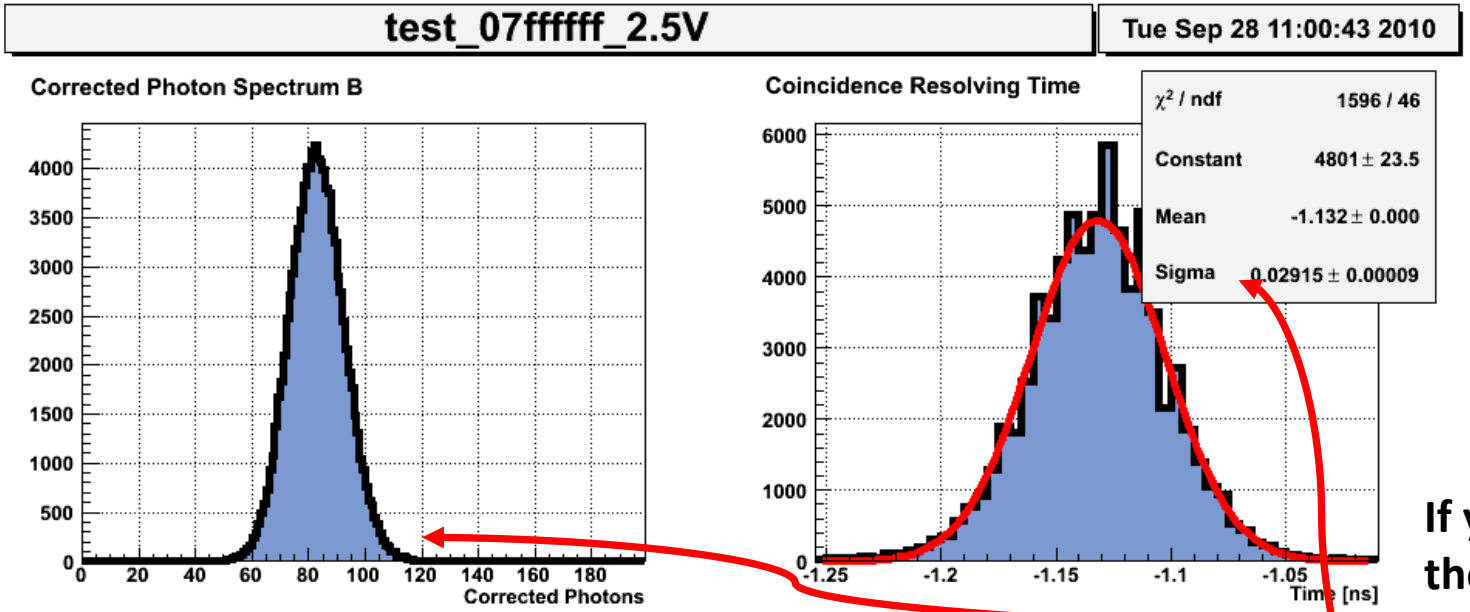
Philips sensor build in

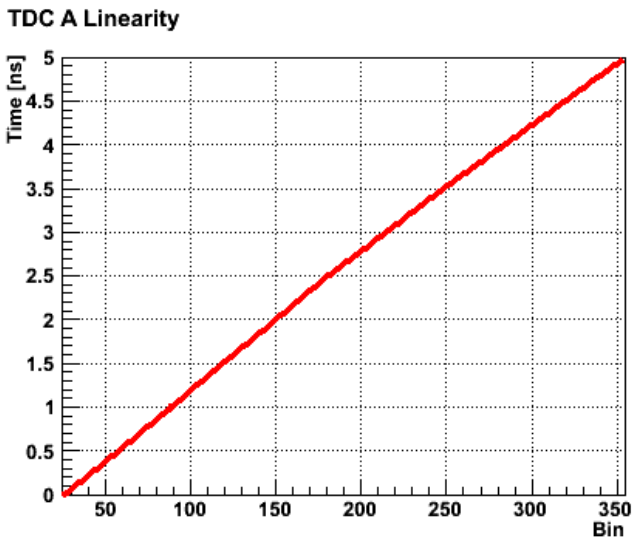


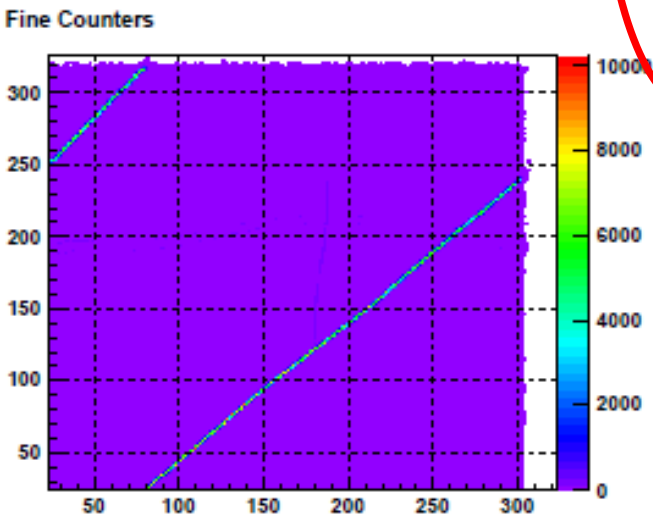


One arm of the detector composed from 4 arrays each of them with 2047 SiPM
1 SiPMT has a size 30X52um and array had ~54% fill factor
It includes possibiliy to inhibit single SiPM
Integrated TDC with 8ps sigma Resolution
Possibility to have variable trigger(1-4 photons) and energy thresholds(1-64)
DAQ controller is in FPGA allowing whole flexibility of Tests

One of the Results from Laser tests more relevant to AFP(many photons)

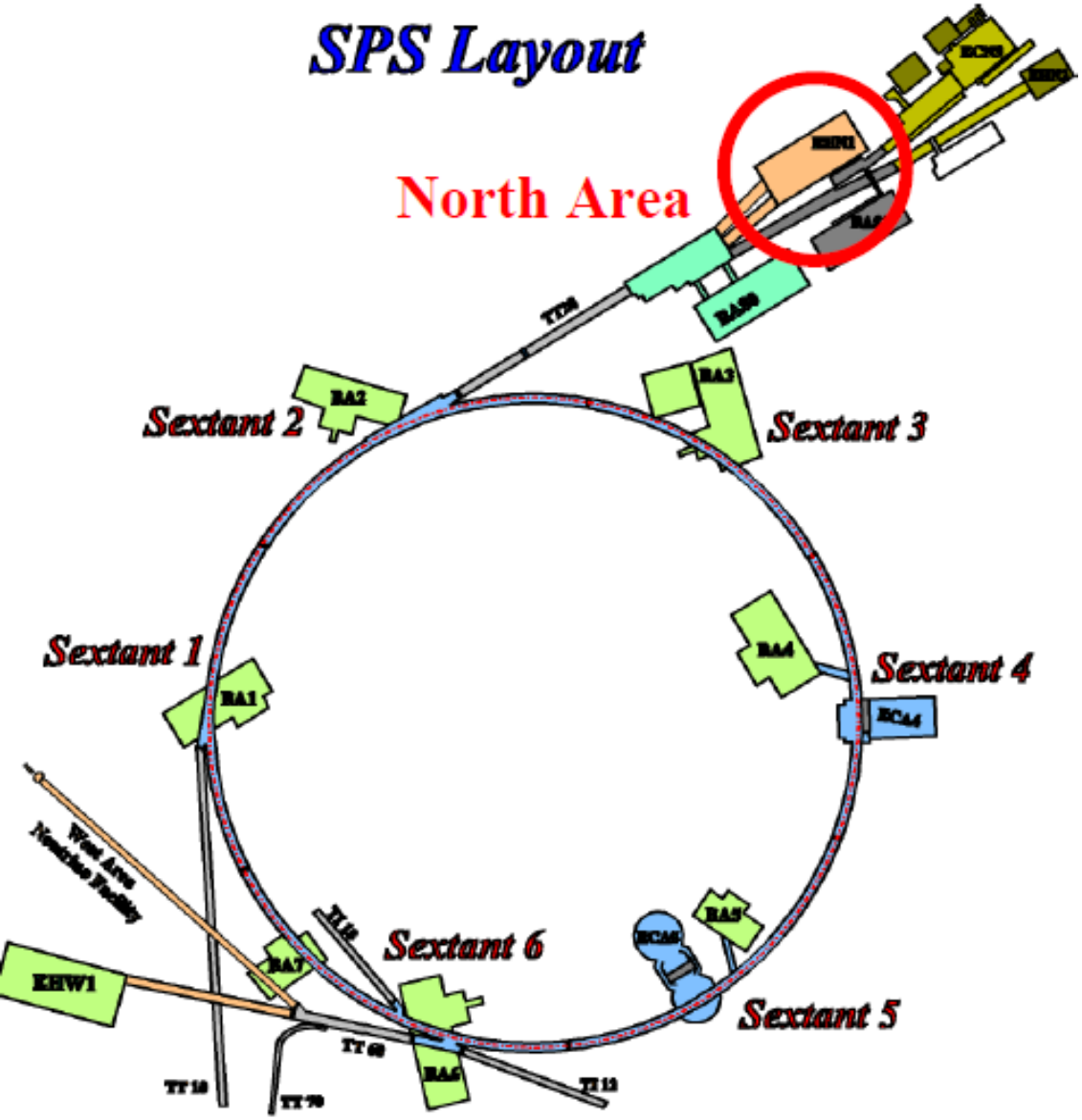






If you provide to the surface of dSiPM Enough Photons Then the anticipating resolution is close what requirements is

CERN Testbeam



*Protons of 120 GeV
Focused on radiator with
small angular divergence

*Special Thanks goes to AFP
People (Hasko Stenzel)
making beam
time available in short notice

*Beam diameter ~6mm RMS

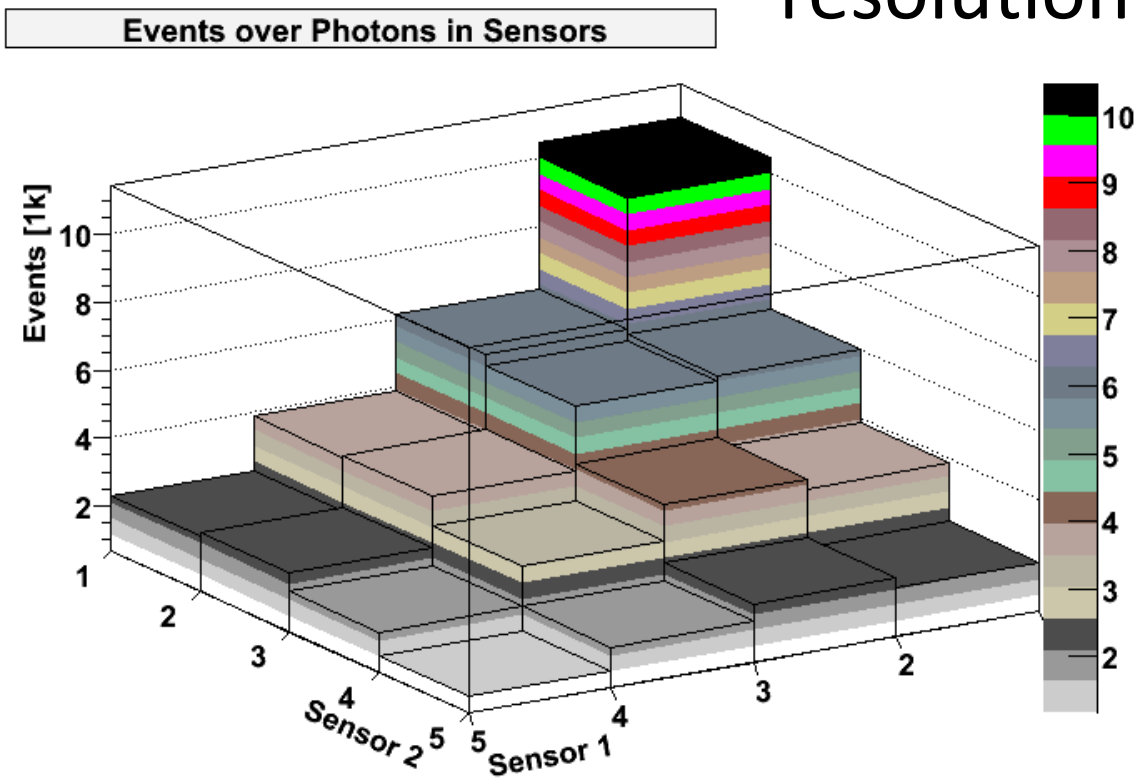
*Duty cicle was only ~17% ,
allowing influence of the
Background

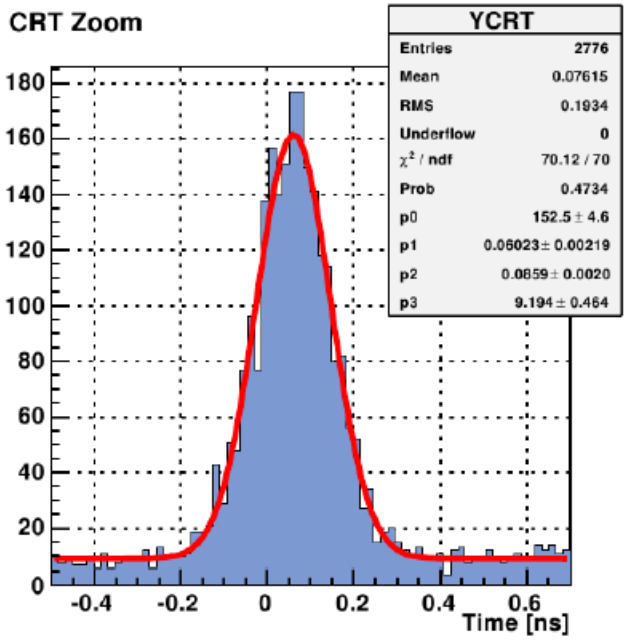
*Possibility of external trigger

*Measurement credits goes to
Thomas Frach and Cristoph Rembser
doing ALL measurements

Results of CERN Test

Number of detected Photons and single photon resolution

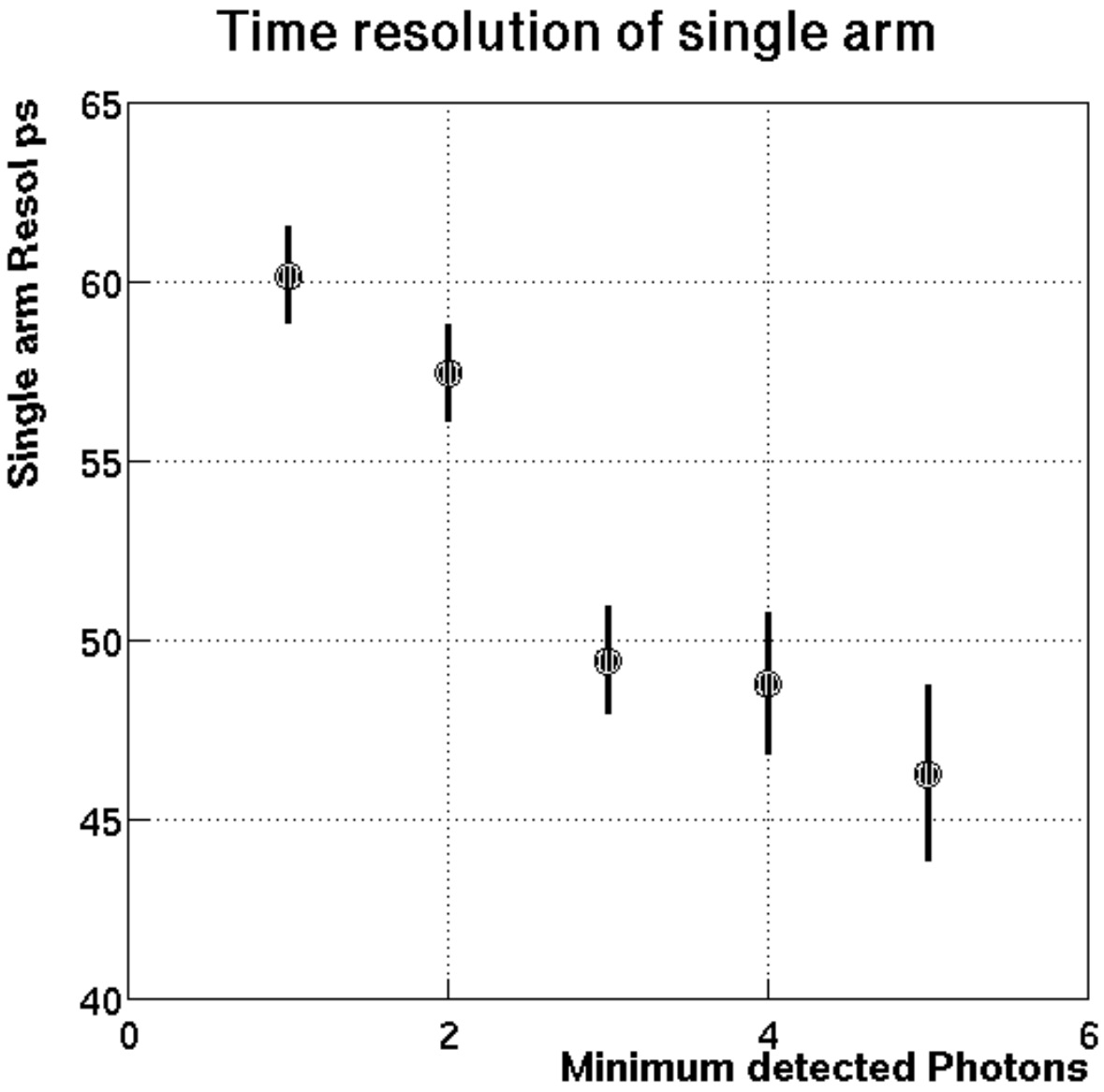




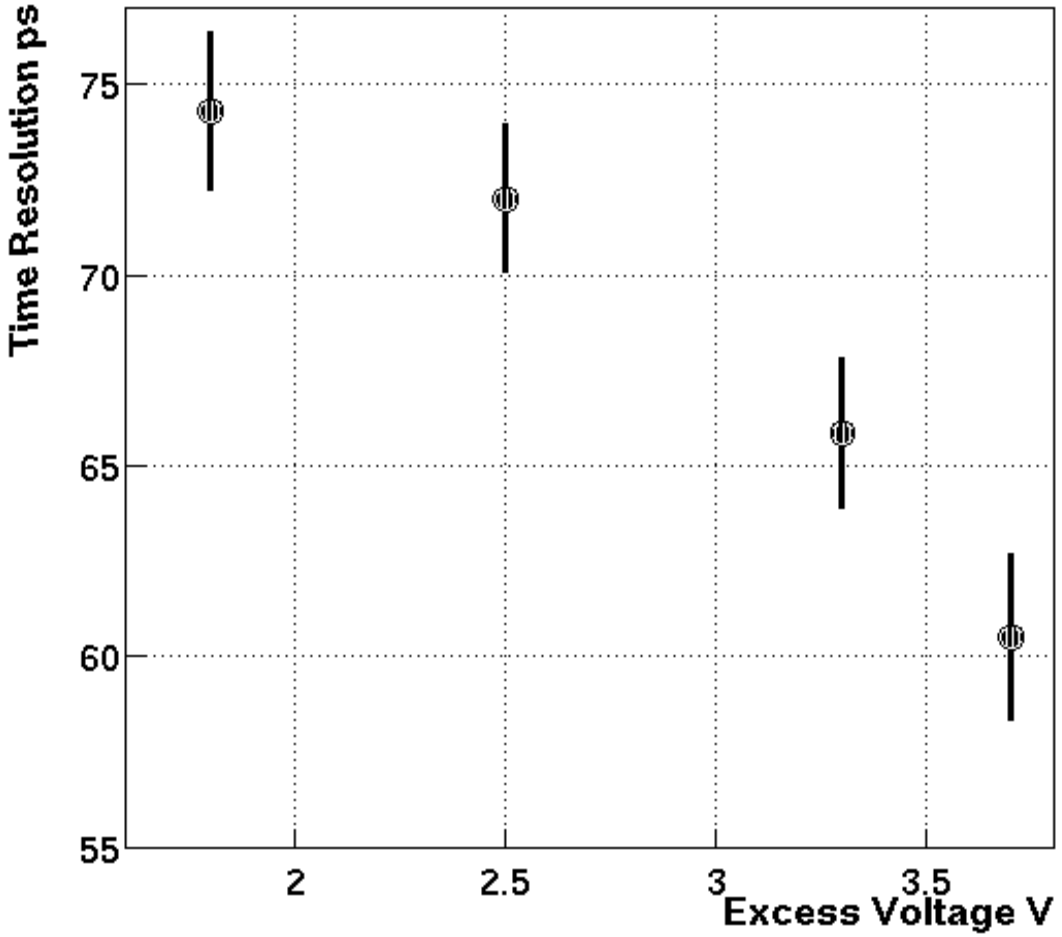
- *98% diodes active*
- *3.7V excess voltage*
- *T=2°C, DCR = 477/553kHz*
- *First photon trigger*
- *No energy threshold*

- *CRT σ = 85.9ps*
- *Sensor resolution = 60.7ps*

Resolution against number of detected photons



Results of CERN Test
Time Resolution against excess voltage



The „Game“ of Optimization Should be played to find out optimal working conditions

Excess voltage

Temperature

N of disabled channels

Conclusions/Outlook

> Philips dSiPM was tested to detect Cherenkov Photons first time

> Promising results in terms of time resolution

> Cooling is a MUST for detecting single photons

>new version will improve the fill factor and trigger network

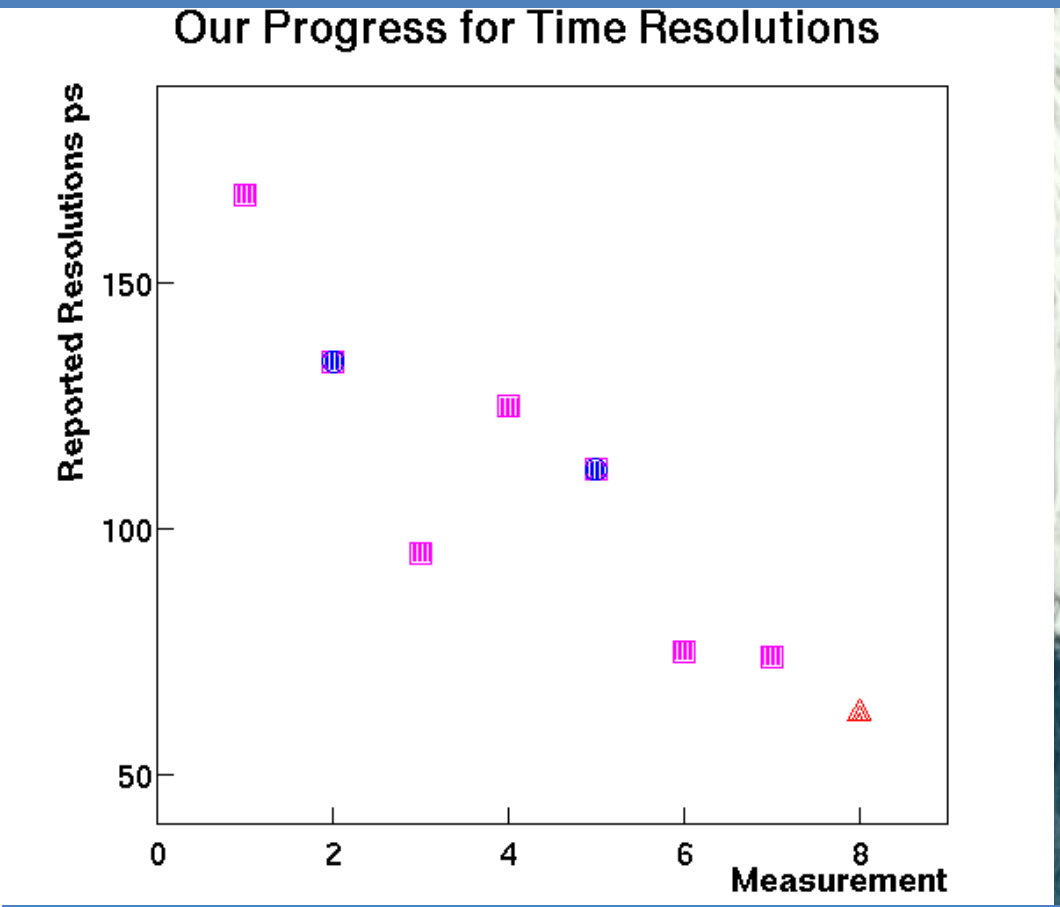
> Next test beam (DESY December 2010) with more time for systematic studies

Backup goes here


On our way to ManyD TOP

redo left graph with new measurement

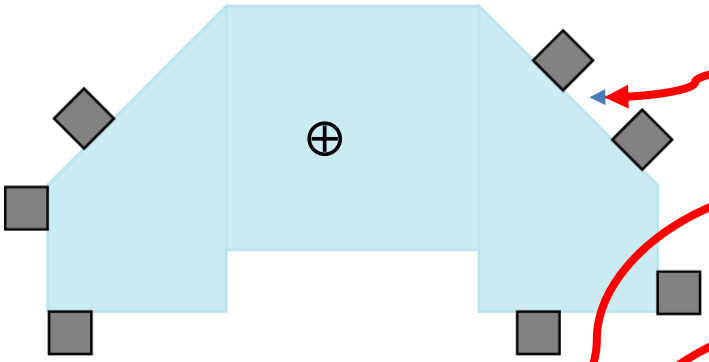
Our Reported Time Resolutions in ps from Prototypes



Measurement
1)DESY Test 2008
2)GSI Sep 2009
3)Benno in Labor Cosmics
4)Jülich Feb 2010
5)GSI 2009(Offline)
6)Jülich April 2010
7)DESY June 2010
8)CERN Aug 2010

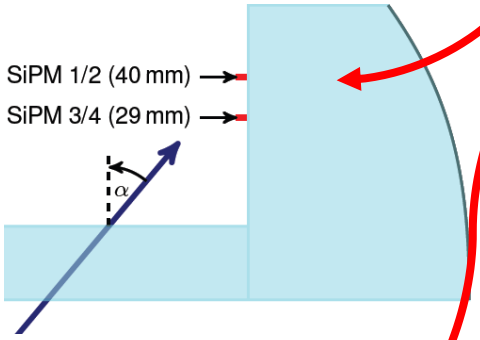
Measurement(blue APDs, magenta MCPs, red dSiPM from Philips)

Prototypes we built so far



780mmX390mm Glas coupled with BINP MCPs

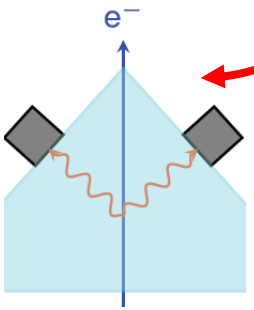
Small Plexiglas radiator with FLG coupled with SiPMs

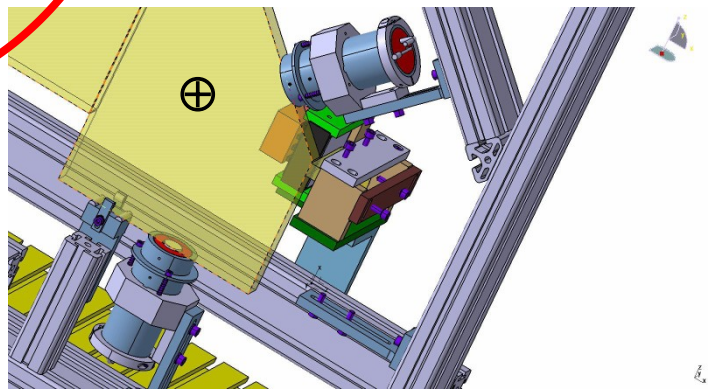


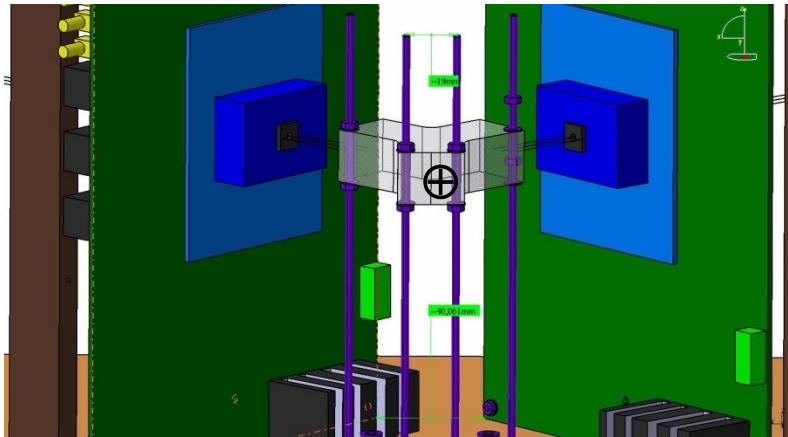
Small Plexiglas radiator coupled with SiPMs looking under Cherenkov angle for Coincidence

780mmX390mm Glas coupled with BINP MCPs and with FLG coupled with Photonis MCP too

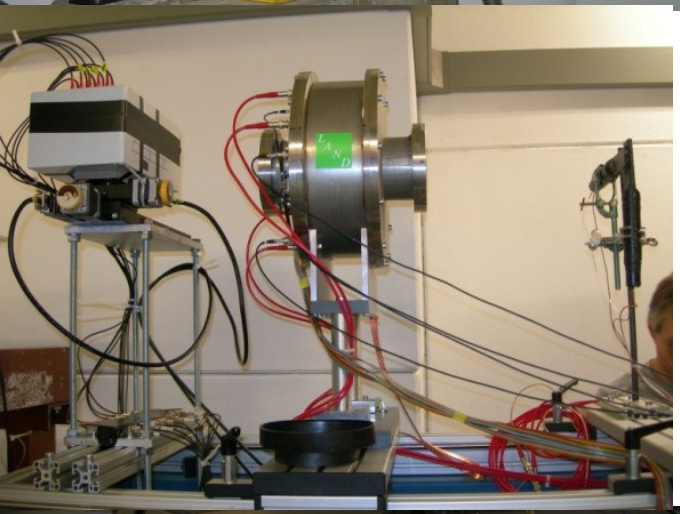
Current one, small Plexiglas radiator coupled with dSiPM and PCB board from Philips

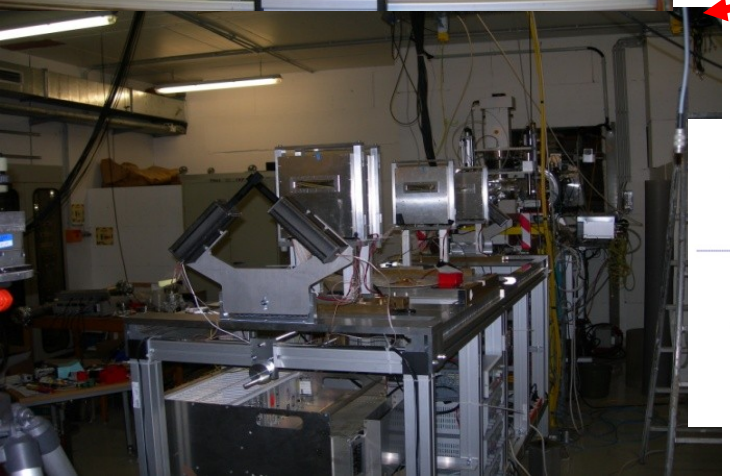






Our TestBeams



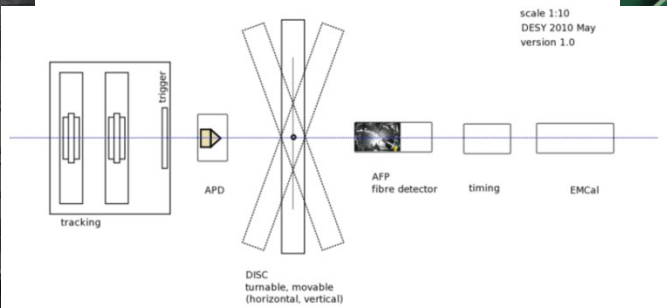


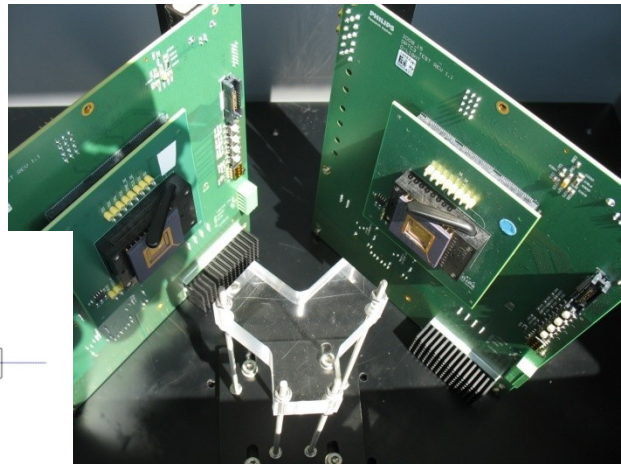
DESY(2008,2010,2010) e +- E=1-6 GeV

GSI (2009) Protons P=2.95 GeV/c

Jülich (2010,2010) Protons T=2.9 GeV

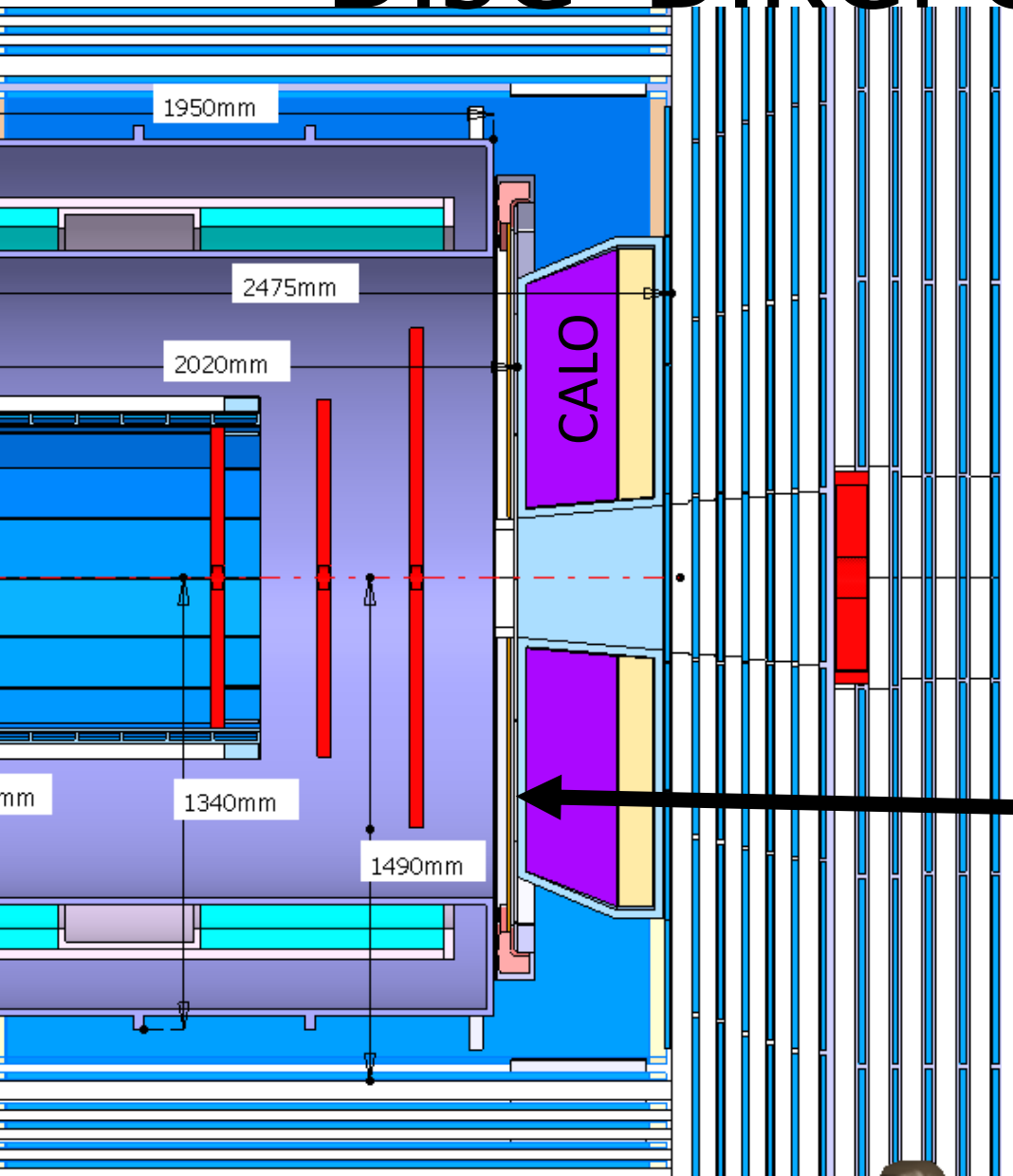
CERN(2010) Protons120 GeV

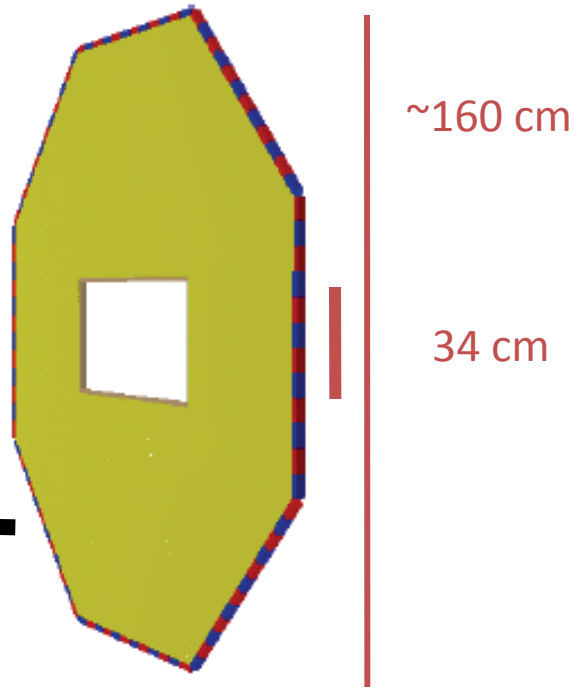




DISC-DIRC: Geometry

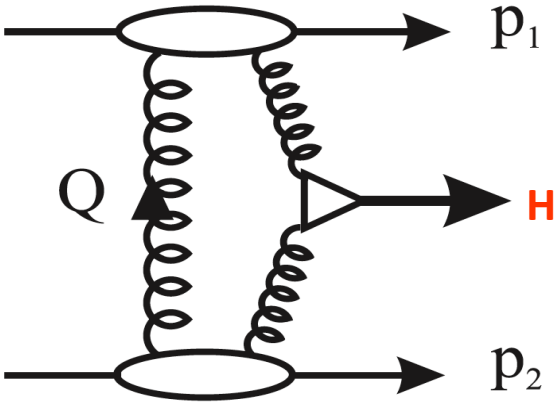
- Acceptance: 5° -22°
- Hole for forward spectrometer
- Few cm thickness (2 cm plate)

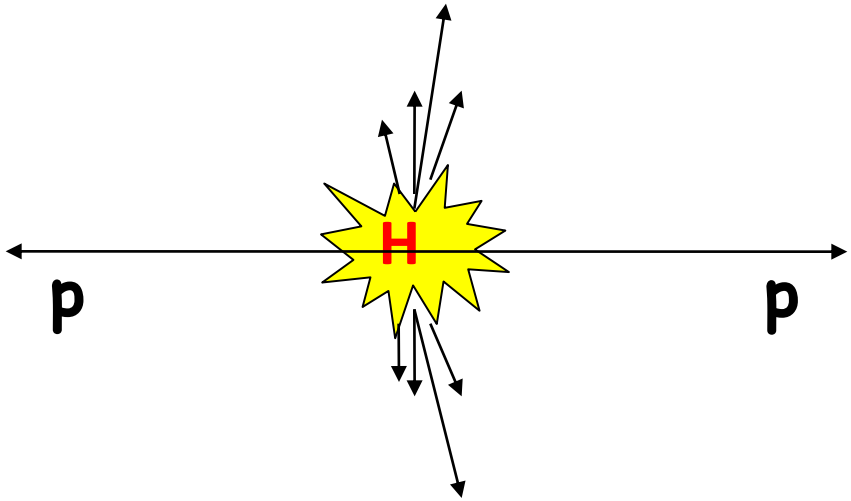




Project , Atlas Forward Physics

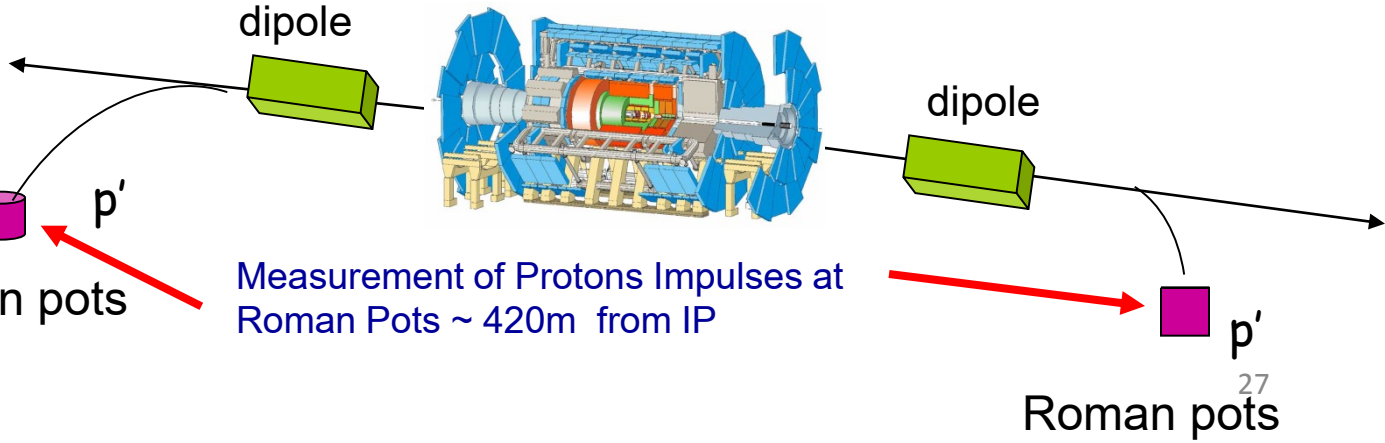
Exclusive diffractive Higgs production pp→ p H p :





$$N_H^2 \propto \mathcal{L}(p\bar{p} \to p\bar{p}X)$$

Scattered Protons Time measurement with 10ps is crucial element, for this search



See A. Astvatcaturov Talk in this Workshop for more