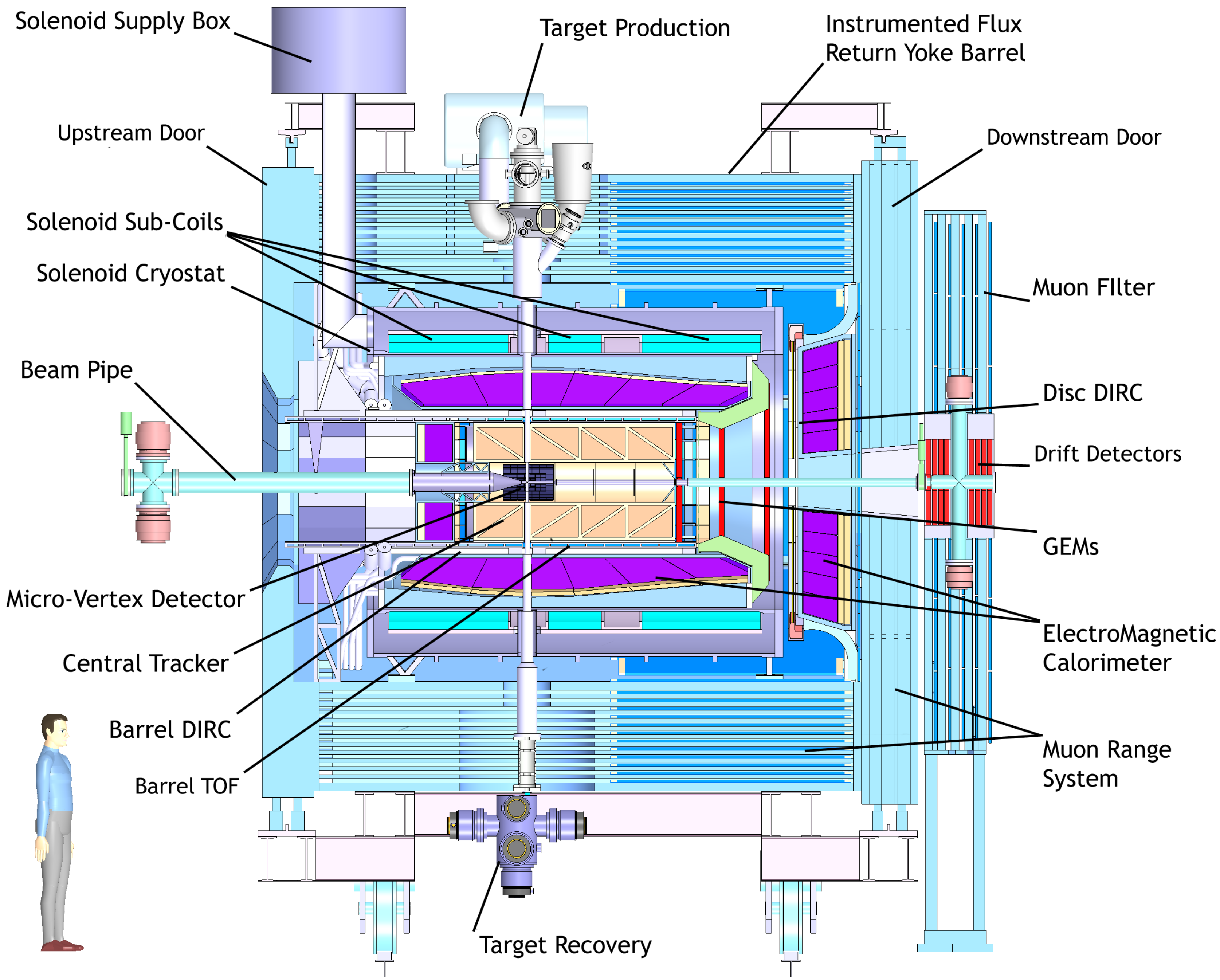
SciTil/BarrelTOF Status Overview

Ken Suzuki, Stefan-Meyer-Institut, ÖAW
03.12.2015 PANDA LV. Collaboration Meeting, Vienna

Barrel-TOF Detector in TS a.k.a. SciTil



MVD<STT<DIRC<SciTil<EMC

Conceptual design, Proposal

Proposal for a Scintillator Tile Hodoscope for $\overline{\mathrm{P}}$ANDA

Version 1.1

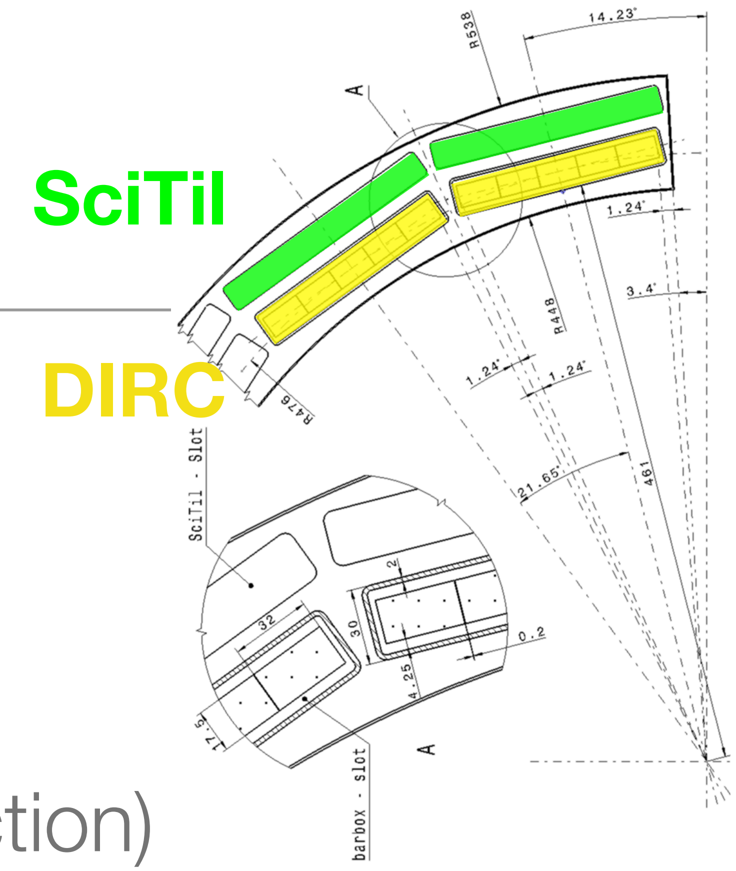
K. Goetzen, H. Orth, G. Schepers, L. Schmitt, C. Schwarz, A. Wilms

Abstract

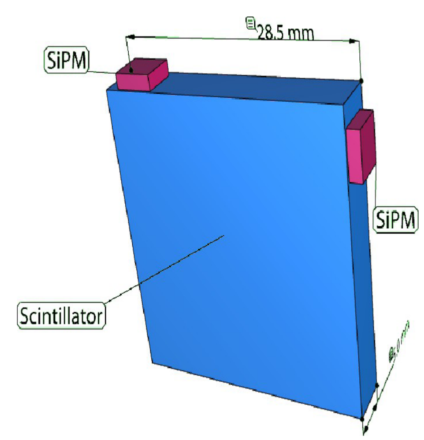
In this document a new detector in place of the barrel time-of-flight detector is proposed. This detector is based on small scintillator tiles read out by silicon photomultipliers. The motivation in terms of physics and technical benefits are summarized. Details of the detector layout are given.

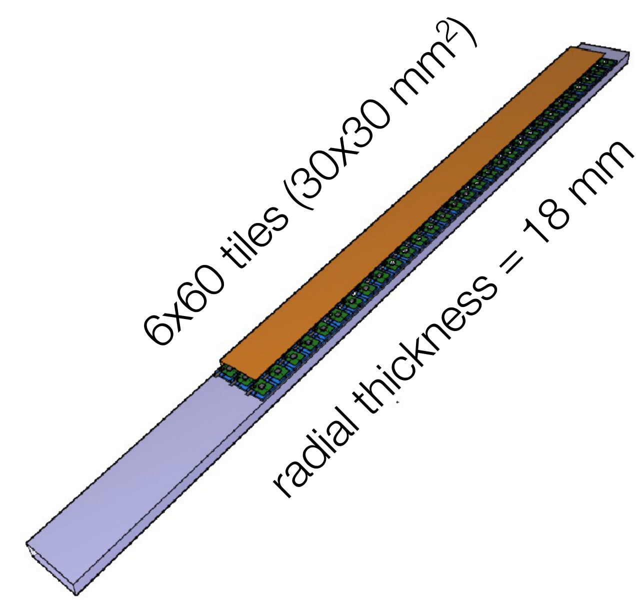
K. Goetzen et al., Proposal for a scintillator barrel hodoscope for $\bar{\mathrm{P}}$ANDA

SciTil Boundary Conditions



- Timing counter (σ_t<100ps) hodoscope
- Mechanics shared with DIRC
  - To fit to the limited space (<2 cm in radial direction)
- Scintillator + SiPM
  - Simple and robust
  - Fast readout





- Online tracking, t0, EMC Preshower detection, Relative TOF, PID, ..

SciTil Group

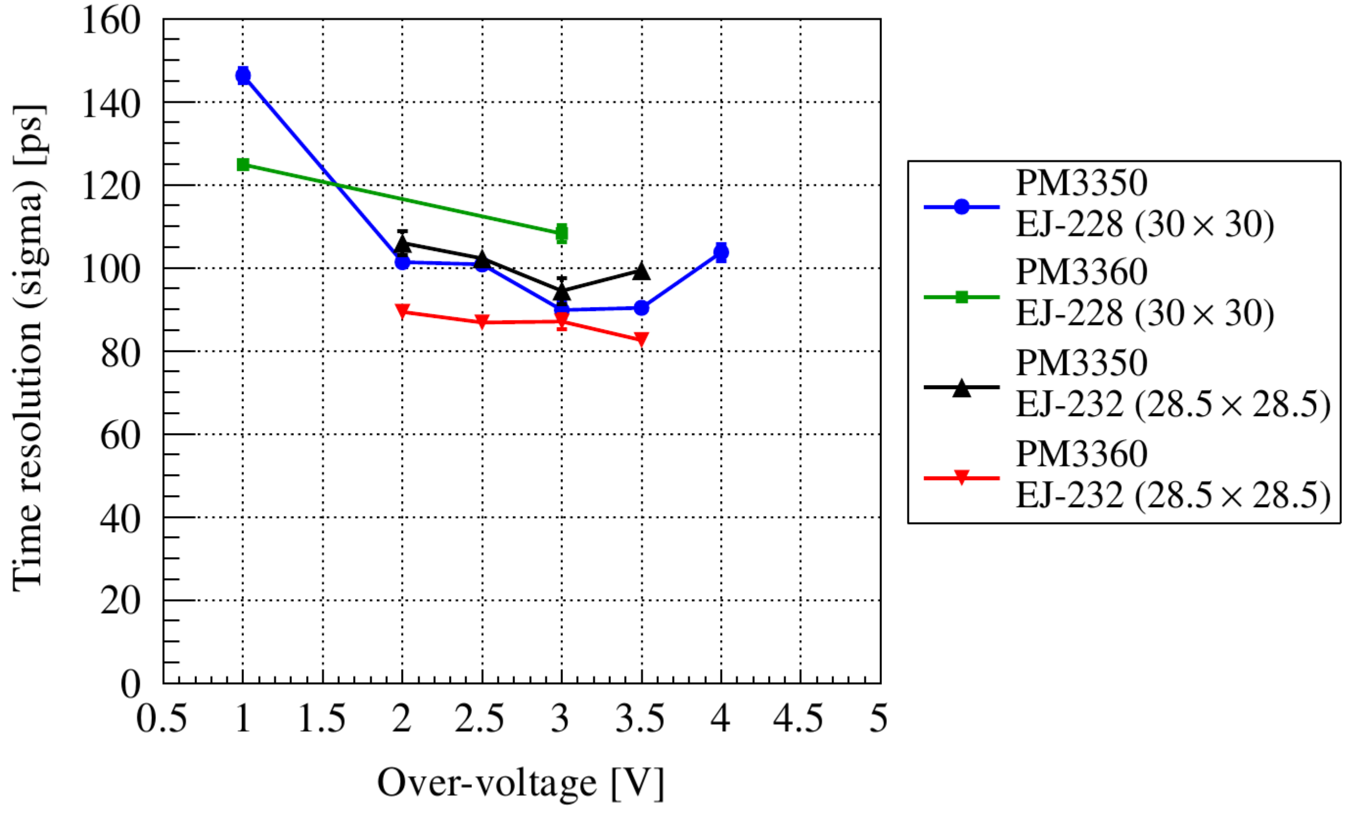
- Erlangen
- GSI
- Mainz
- Stefan-Meyer-Institut, Vienna
- India (Gauhati-U. Assam, Visva Bharati-U. Bolpur, BARC Mumbai)

Status

Milestone
desired time resolution reached

Parameters to optimise Optical Coupling / Photosensor / Operation conditions / Position of the sensor / Number of sensors / Scintillator material / Geometry / Wrapping / Waveform analysis

Ketek time resolution



Time resolution dependent on SiPM type, scintillator and over-voltage.
Time resolution of about 85 ps reached with PM3360TS!

Further optimisation of Single-Tile Performance

- You may say, it is well below or marginally below the goal?
  - real $\bar{\mathrm{P}}$ANDA environment and high rate?
  - quality variation of sensor and assembly?
  - ageing, radiation?
- high spec. hardly an overkill
- Two key ideas
  - SciRod (Erlangen, Cracow, MEG2@PSI)
  - SiPM serial connection

SciRod (Erlangen)

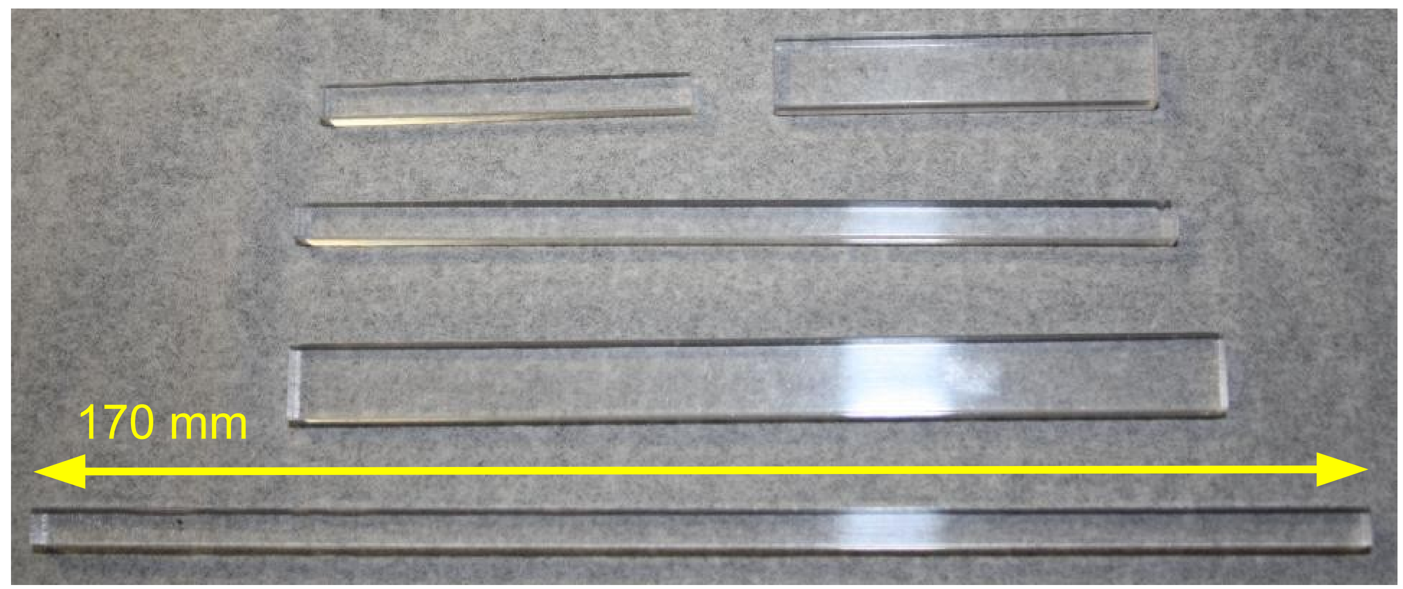
more lightguide-like tile geometry

Scintillator Samples

BC408 (τ = 2.1 ns)

- 5 x 5 x 170 mm^3
- 5 x 5 x 120 mm^3
- 5 x 5 x 50 mm^3
- 5 x 10 x 120 mm^3
- 5 x 10 x 50 mm^3

- 5 x 30 x 30 mm^3



BC420 (τ = 1.5 ns)

- 5 x 5 x 120 mm^3
- 5 x 5 x 50 mm^3
- 5 x 5 x 30 mm^3
- 5 x 10 x 120 mm^3
- 5 x 10 x 50 mm^3
- 5 x 10 x 30 mm^3

SciRod (Erlangen) cont'd

More Time Resolutions (1)

Scintillator 5 x 5 x 120 mm^3

Scintillator	MPPC	left		center		right
		σ_t	σ_t	σ_t	σ_t	σ_t
BC408	S10362-100P	88		94		101
	S10362-100P(x10)	71		77		74
	S12572-050P	72		77		74
BC420	S12572-015P	60		108		63
	S12572-050P	50	79	74	57	52

Scintillator 5 x 10 x 120 mm^3

Scintillator	MPPC	left		center		right
		σ_t	σ_t	σ_t	σ_t	σ_t
BC408	S10362-100P	88	116	132	98	93
BC420	S10362-100P	75		121		82

BC420 scintillator provides better results than BC408

SciRod (Erlangen) cont'd

More Time Resolutions (2)

Scintillator 5 x 5 x 50 mm^3

Scintillator	MPPC	left		center		right
		σ_t	σ_t	σ_t	σ_t	σ_t
BC408	S10362-100P	68		103		74
	S12572-050P	74		67		68
BC420	S12572-050P	78		64		51

Scintillator 5 x 10 x 50 mm^3

Scintillator	MPPC	left		center		right
		σ_t	σ_t	σ_t	σ_t	σ_t
BC408	S10362-100P	113		123		92

Scintillator 5 x 5 x 170 mm^3

Scintillator	MPPC	left		center		right
		σ_t	σ_t	σ_t	σ_t	σ_t
BC408	S10362-100P	88	85	129	85	99

Longer and wider rods tend to give worse time resolution

SciRod Summary

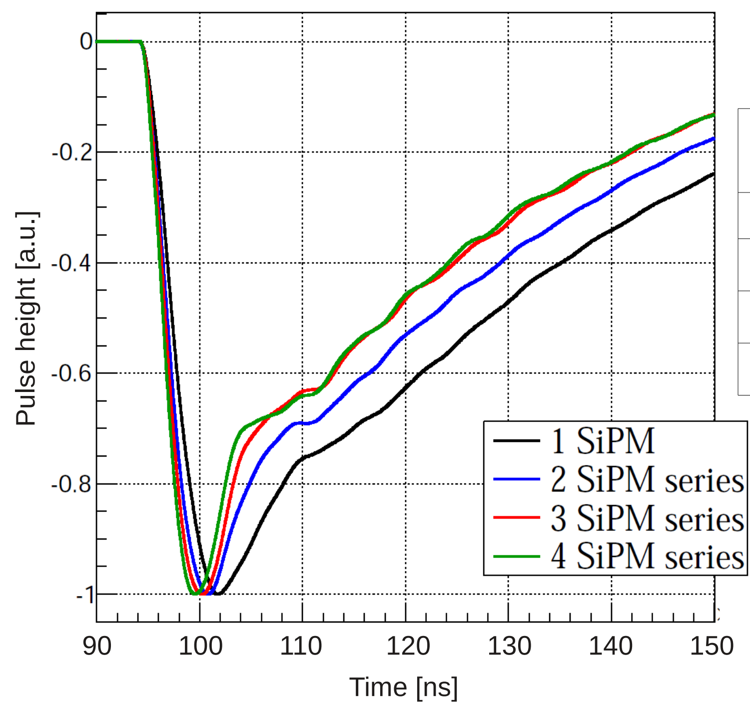
- Various geometry tested. Convincingly better.
- Gives better results primarily due to better light collection.
- Time resolution 50-100 ps.
- shorter, narrower geometry preferred.
- position resolution along rod. 13mm, actually better.

Serial connection of SiPM

Relatively new technique to increase effectively the sensitive area of SiPM (typically $3x3mm^2$)

Laser test

Picosecond laser (30 ps width) on Ketek PM3350 (1 – 4 in series) amplified with Photonique preamp. Plot shows an average of 1000 recorded waveforms.



	Rise time [ns] (10% – 90%)	Width [ns] @ 50% level
1 SiPM	4.6	30.6
2 SiPM series	3.875	25.375
3 SiPM series	3.375	21.875
4 SiPM series	3.125	21.85

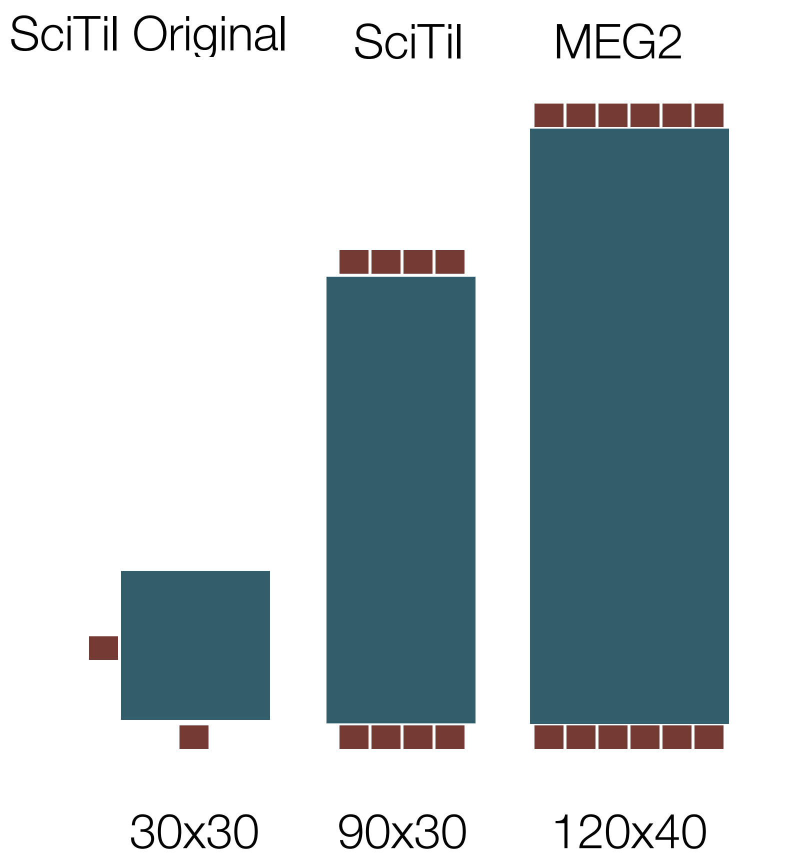
~ 32% faster signal rise time
~ 30% smaller signal width

L. Gruber PANDA TOF meeting - 01.12.2015 7

more sensors, less capacity

with a side effect of making the signal response faster

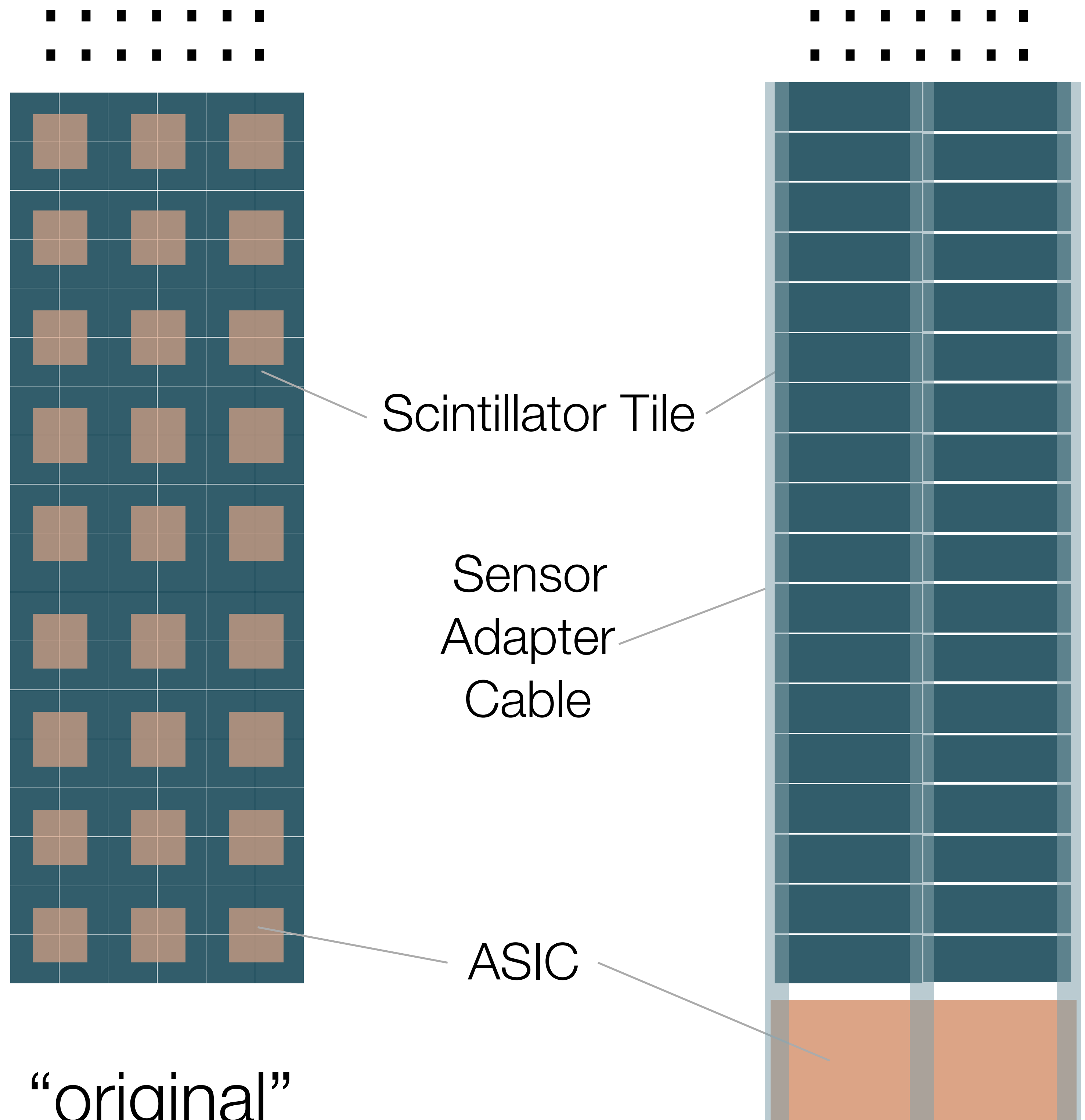
Configuration



σ~85ps

σ~60ps

very first result
σ<75ps

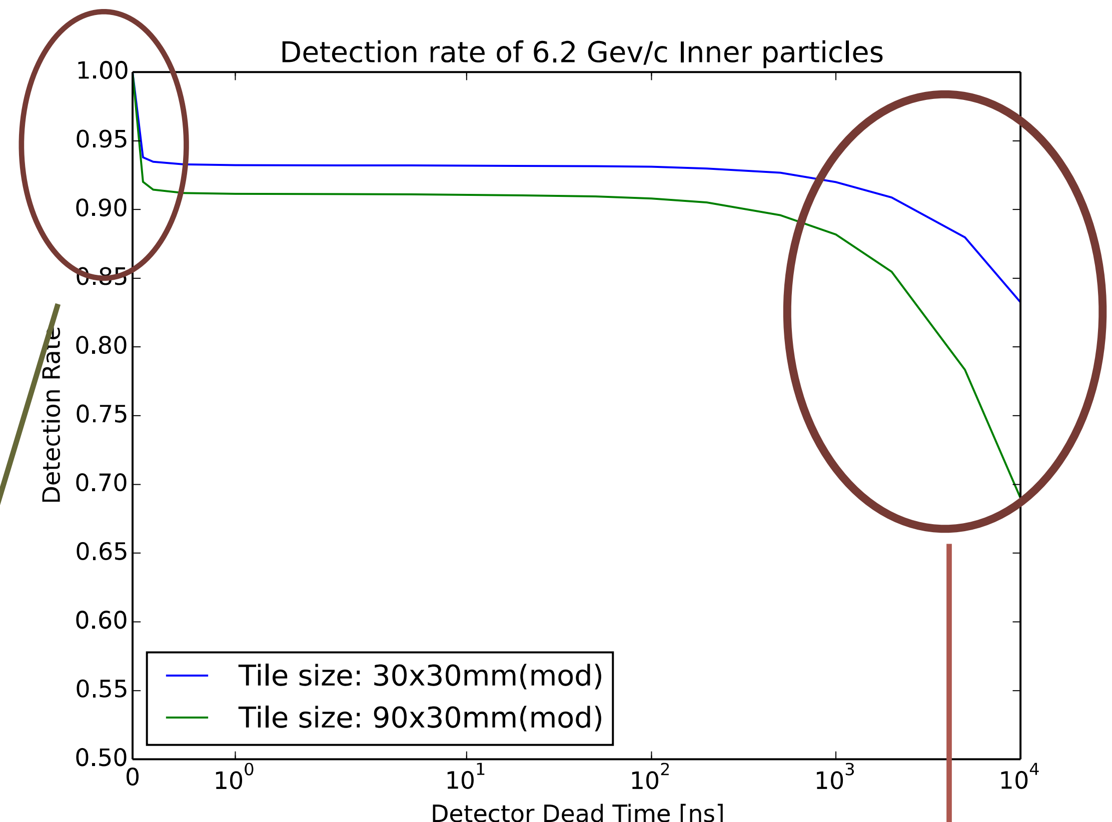


“original”

- Pros
    - less number of readout channel (1/3)
    - (much) better time resolution (~60 ps, instead of 100 ps), less position dependent
    - simpler construction
    - less material
    - better position resolution from “Left–Right” (σ~10mm)
- Cons
    - slight increase of the number of sensors (4/3)
    - higher pile up probability

Efficiency for different tile sizes Preliminary

- Simulation parameters
  - DPM generator
  - $N_{avg} = 20$ MHz
  - Modified Fairroot
- Perfect geometrical fill factor assumed



pile up due to secondaries e.g. $\gamma \rightarrow e^+e^-$ in DIRC

1 μs

pile up from different collisions

Handling of secondaries in simulation still to be checked

Status/Software

ÖAW AUSTRIAN ACADEMY OF SCIENCES

SMI – STEFAN MEYER INSTITUTE

Sept. 2015 → **Former Status**

<u>SciTil in Pandaroot:</u>

- updated to current project status
- Time based simulation ready to use

<u>Outlook:</u>

- Using the framework to investigate
  - Event mixing
  - Detection efficiency
  - . . .

WWW:OEAW.AC.AT/SMI

Panda Collaboration Meeting,
Dominik Steinschaden, Wien, 1.12.2015

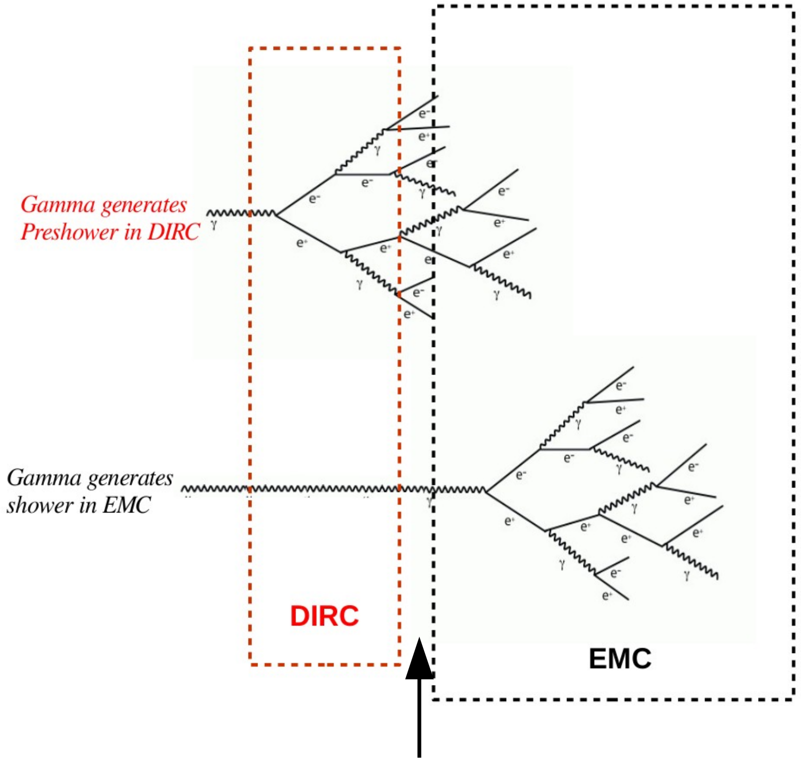
2/13

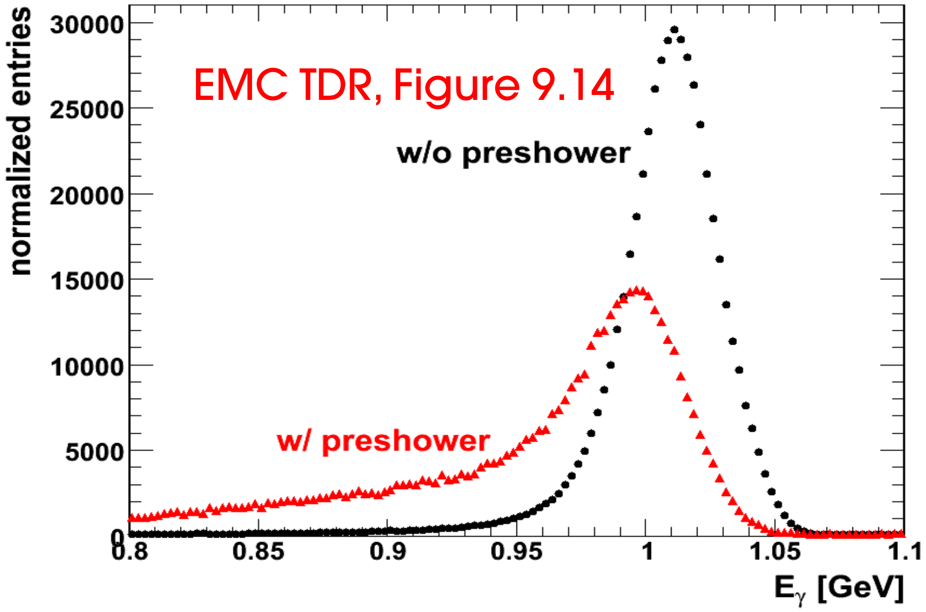
SciTil Software improving quickly. Make more use of SciTil!
Software contact person, Dominik Steinschaden (Vienna).

Use case

- EMC preshower detection/correction
- Relative TOF
- Online tracking (t0, pattern recognition,)
- Physics simulations

Preshower in DIRC



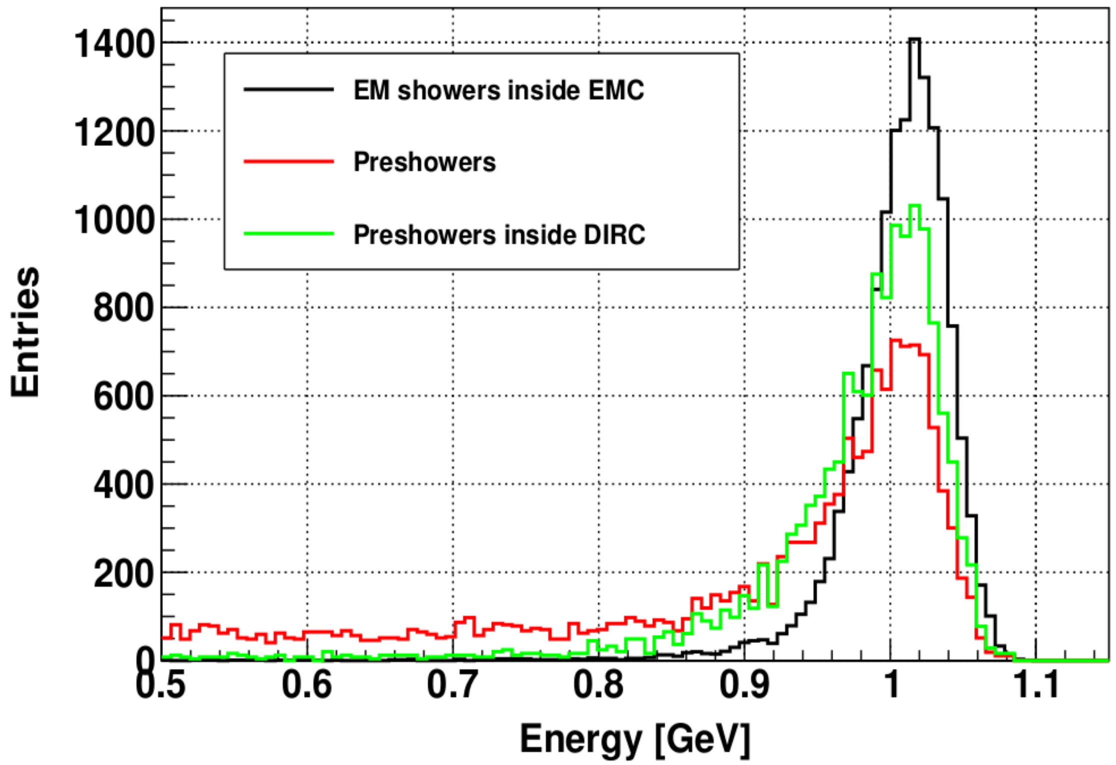


DIRC preshowers lead to a degradation of the energy resolution.

- In Panda, we have a SciTil in between DIRC and EMC, which has low material budget, insensitive to gamma, but has a high efficiency to charged particles. In a study for BaBar experiment, it was shown that, by detecting preshower by DIRC itself, 50% of the converted gamma can be recovered. But in our case, separate detector would discover conversion with full efficiency and enhance the energy resolution.

Updated simulation result using the PANDARoot

normalised by the area

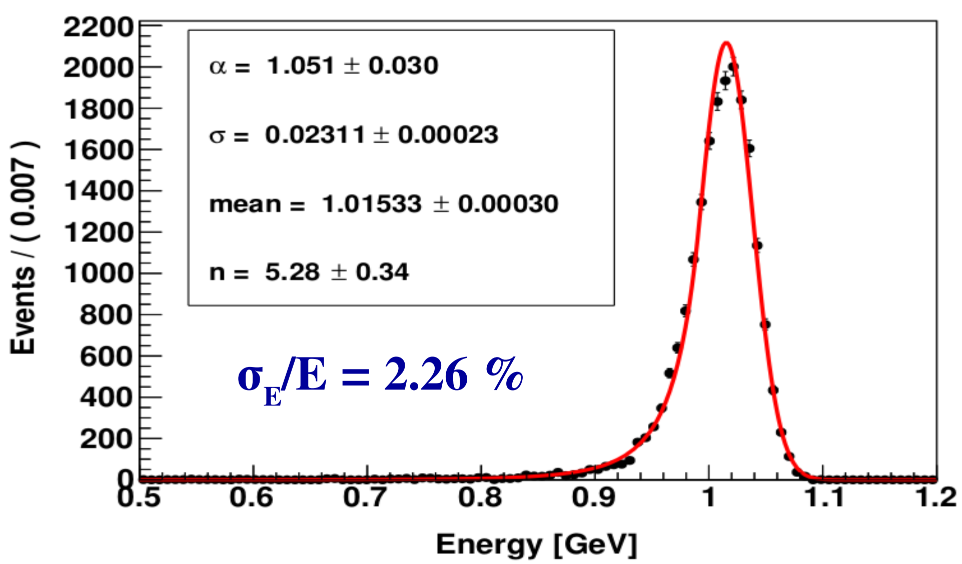


- In our study, it is observed that the energy spectrum of non preshower events is more or less of the Gaussian type. The Preshower events contributes a low end tail part to the distribution. But the effect of the preshower is not as prominent as found in the previous study.

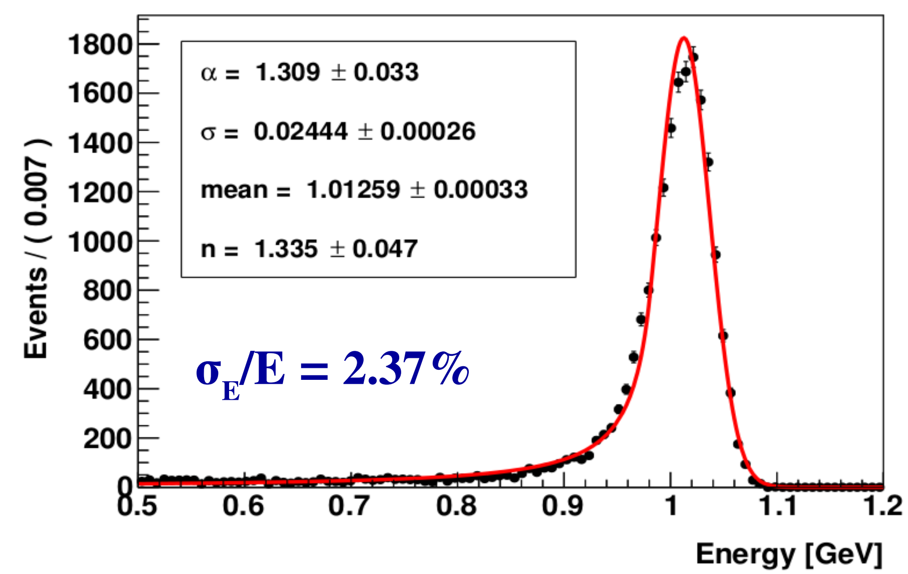
K. Dutta

Quantitative comparison w/, w/o DIRC material

NON PRESHOWER



NON PRESHOWER + PRESHOWER



$$f(x;\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} \exp(-\frac{(x-\bar{x})^2}{2\sigma^2}), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot (B - \frac{x-\bar{x}}{\sigma})^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leqslant -\alpha \end{cases}$$

$$A = \left(\frac{n}{|\alpha|}\right)^n \cdot \exp\left(-\frac{|\alpha|^2}{2}\right) \qquad B = \frac{n}{|\alpha|} - |\alpha|$$

K. Dutta

01-12-2015 PANDA LV. Collaboration Meeting, Wein. 13

Much smaller influence than previously told

Radiation Hardness

SiPM radiation studies – literature

Y. Musienko et al. 2009 [12]

82 MeV protons at PSI
Up to 1 x 10^{10} protons/cm^2 –> ~ equivalent to 2 x 10^{10} 1 MeV neutrons/cm^2
SiPMs (1x1 mm^2) from CPTA/Photonique, MePhI/Pulsar, FBK-IRST, Zecotek, Hamamatsu
SiPM parameters were measured before and 90 days after irradiation
Results:
– significant increase in leakage current and dark count rate for all devices
– no change of breakdown voltage and quenching resistor
– relative change of PDE < 10%
– significant reduction (> 10%) of signal amplitude for some devices

P. Bohn et al. 2009 [13]

212 MeV protons at Massachusetts General Hospital
Up to 3 x 10^{10} protons/cm^2 –> ~ equivalent to 2.4 x 10^{10} 1 MeV neutrons/cm^2
SiPMs (1 mm^2 to 6.2 mm^2) from CPTA, FBK, Hamamatsu
SiPM current was measured continuously during irradiation
Other parameters were measured during pauses in between irradiation steps
Results:
– significant increase in leakage current and dark count rate for all devices
– reduced gain under large bias currents after irradiation
– significant reduction (4% – 49%) of signal amplitude
– loss of photon counting capability at max fluence
– SiPMs remained functional as photon counters
– annealing at room temp –> reduction of leakage current by factor 2 in 100 days

SiPM radiation studies – literature

T. Matsumura et al. 2009 [14]

53.3 MeV protons at Research Center for Nuclear Physics, Osaka
Up to 2.8 x 10^8 protons/**mm^2** –> ~ equivalent to 4.8 x 10^8 1 MeV neutrons/**mm^2**
SiPMs (1x1 mm^2) from Hamamatsu (MPPC S10362-11-050C)
SiPM current was measured continuously during irradiation
Other parameters were measured during pauses in between irradiation steps
Results: – significant increase in leakage current
– loss of photon counting capability at highest fluences
– no significant change in the gain up to 9.1 x 10^7 1 MeV neutrons/**mm^2**

Y. Musienko et al. 2007 [15]

28 MeV positrons at PSI
Up to 8 x 10^{10} positrons/cm^2 –> ~ equivalent to 2.7 x 10^9 1 MeV neutrons/cm^2
SiPMs (1 mm^2 to 4.41 mm^2) from CPTA, Dubna, Hamamatsu
SiPM parameters measured before and 2 days after irradiation
Results: – significant increase in leakage current and dark count rate for all devices
– change of gain and PDE < 15%

SiPM radiation studies – literature

S. Sanchez Majos et al. 2009 [16]

14 MeV electrons at MAMI
Up to 3.8 x 10^{10} electrons/**mm²**
SiPMs Photonique
Results: – significant increase in leakage current
– loss of photon counting capability
– partial recovery after annealing at 80°C

M. Danilov 2007 [17]

200 MeV protons at ITEP synchrotron
Up to 2 x 10^{12} protons/cm² –> ~ equivalent to 1.6 x 10^{10} 1 MeV neutrons/cm²
SiPMs 1.1 x 1.1 mm² from MEPhI/Pulsar
Results: – significant increase in leakage current
– loss of photon counting capability after 10^{10} protons/cm²
– SiPMs still operable after highest fluence but much more noise

Y. Musienko NDIP 2011 [18]
A. H. Heering NDIP 2011 [19]

1 MeV neutrons at CERN IRRAD facility
Up to 3 x 10^{12} neutrons/cm²
New SiPMs from Hamamatsu with different pixel sizes (15U – 50U)
Results: – SiPMs with high cell density and fast recovery time can operate up to 3 x 10^{12} n/cm²
– gain change < 25%

Radiation test at PSI

We plan to do a radiation hardness test of SiPMs at PSI in Villigen, Switzerland in the first half of 2015.

The Proton Irradiation Facility (PIF) there is well suited for such tests.

- Proton energy up to 230 MeV
- Max. intensity at 230 MeV: 2 nA
- Max. flux at 230 MeV: ~ 2 x 10^9 p/s/cm²

http://pif.web.psi.ch/pif.htm

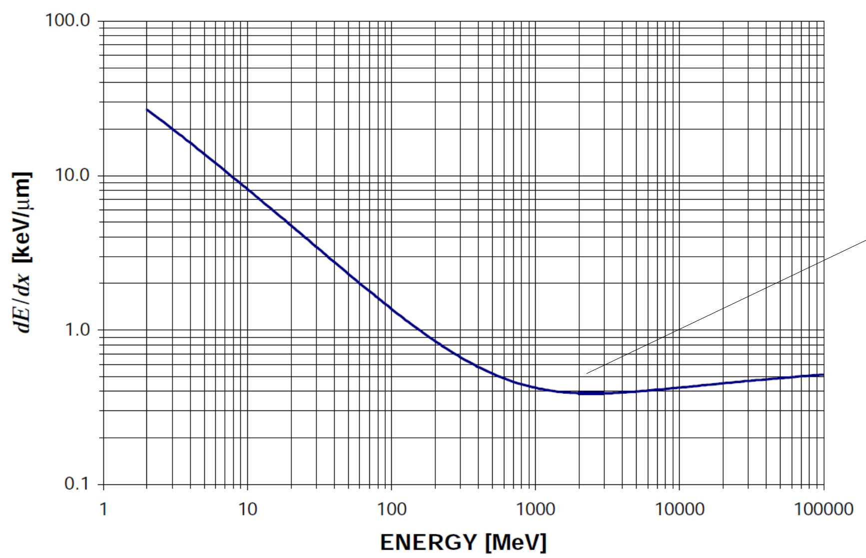
We know the facility from previous test beam experiments. We are in contact with the responsible person. A radiation hardness test in April 2015 seems feasible.

The idea is to test several SiPMs from different vendors and compare the performance before, during and after irradiation.

Irradiation time

Estimation: 10 years of SciTil in PANDA: ~ 1 x 10^{12} MIPs/cm^2

dE/dx vs. E of protons in silicon



Minimum ionization: ~ 2 GeV

SciTil: hardness factor 2 GeV protons: 0.62 (tabulated value)

PIF: hardness factor 230 MeV protons: 0.95 (tabulated value)
PIF: max intensity: 2 x 10^9 p/cm^2/s
Time needed to achieve roughly same damage as expected in PANDA: 325 s ~ 5.5 min

L. Gruber, Feb. 2015

Irradiation test, early 2016, also with the new Hamamatsu sensors

TDR

System	Submission *Expected*	M3 (Approval) *Expected*
Target Spectrometer EMC		08/08/2008
Barrel EMC		08/08/2008
Backward Endcap EMC		08/08/2008
Forward Endcap EMC		08/08/2008
Solenoid		05/21/2009
Dipole		05/21/2009
Micro Vertex Detector (MVD)		02/26/2013
Straw Tube Tracker (STT)		01/29/2013
Cluster Jet Target		08/28/2013
Muon System		09/22/2014
Forward Shashlyk Calorimeter	17/6/2015	*1/2016*
Luminosity Detector	*3/2016*	*9/2016*
Forward TOF	*3/2015*	*9/2016*
Forward Tracking	*3/2015*	*9/2016*
Barrel DIRC	*6/2016*	*12/2016*
Hypernuclear Setup	*6/2016*	*12/2016*
Pellet Target	*6/2016*	*12/2016*
Controls	*6/2016*	*12/2016*
Planar GEM Trackers	*9/2016*	*3/2017*
Barrel Time of Flight (TOF)	*9/2016*	*3/2017*
DAQ	*6/2017*	*12/2017*
Endcap Disc DIRC	*6/2017*	*12/2017*
Computing	*9/2017*	*3/2018*
Silicon Lambda Disks	tba	tba
Forward RICH	tba	tba
tba: to be announced		Status 3/11/2015

For the items "Interaction Region", "Supports" and "Supplies" no TDRs are planned, only specification documents.

ON SCHEDULE

Summary and Outlook

- minor geometry update
- (much) better time resolution
- make more use of SciTil in your simulations (high/low level)
- Irradiation test early next year
- On schedule

Backup

Development in Sensor

sensitive area size (0.1 mm)

pixel size (μm)

package

S13360-[13|30|60][25|50|75][CS/PE]

S12571

Status

- with Mainz group (C. Sfienti, M. Hoek)
- Working on concept
- Testing the TOF-PET chip
  - An evaluation kit of TOF-PET chip originally purchased by Carsten/Herbert
  - 64ch/chip
  - rate capability: 100 kHz = 10 μs?

Evaluation kit