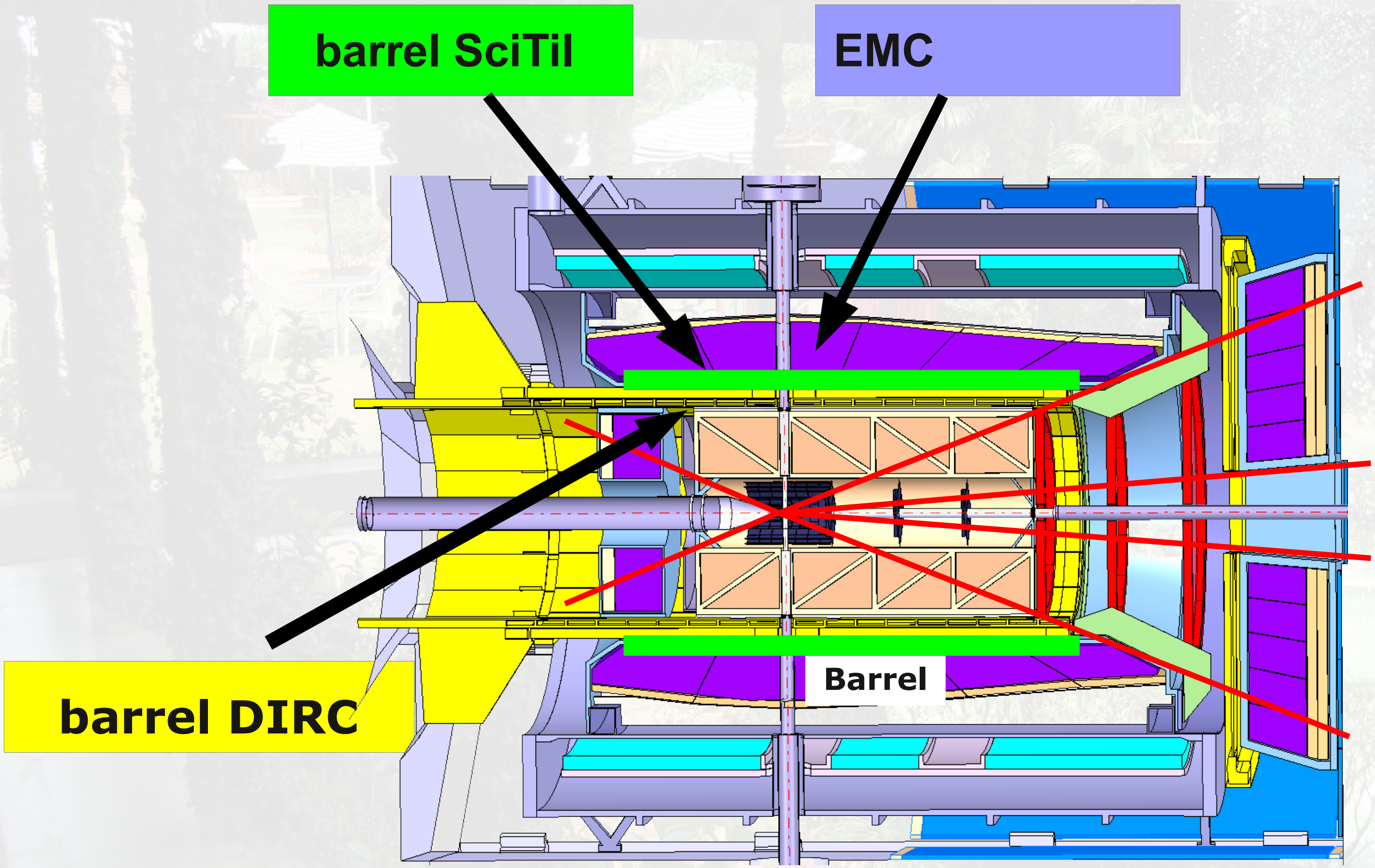
The Scintillating Tile Detector

Carsten Schwarz, GSI

- Motivation
- Setup
- Scintillator
- Photon Detector
- Prototypes

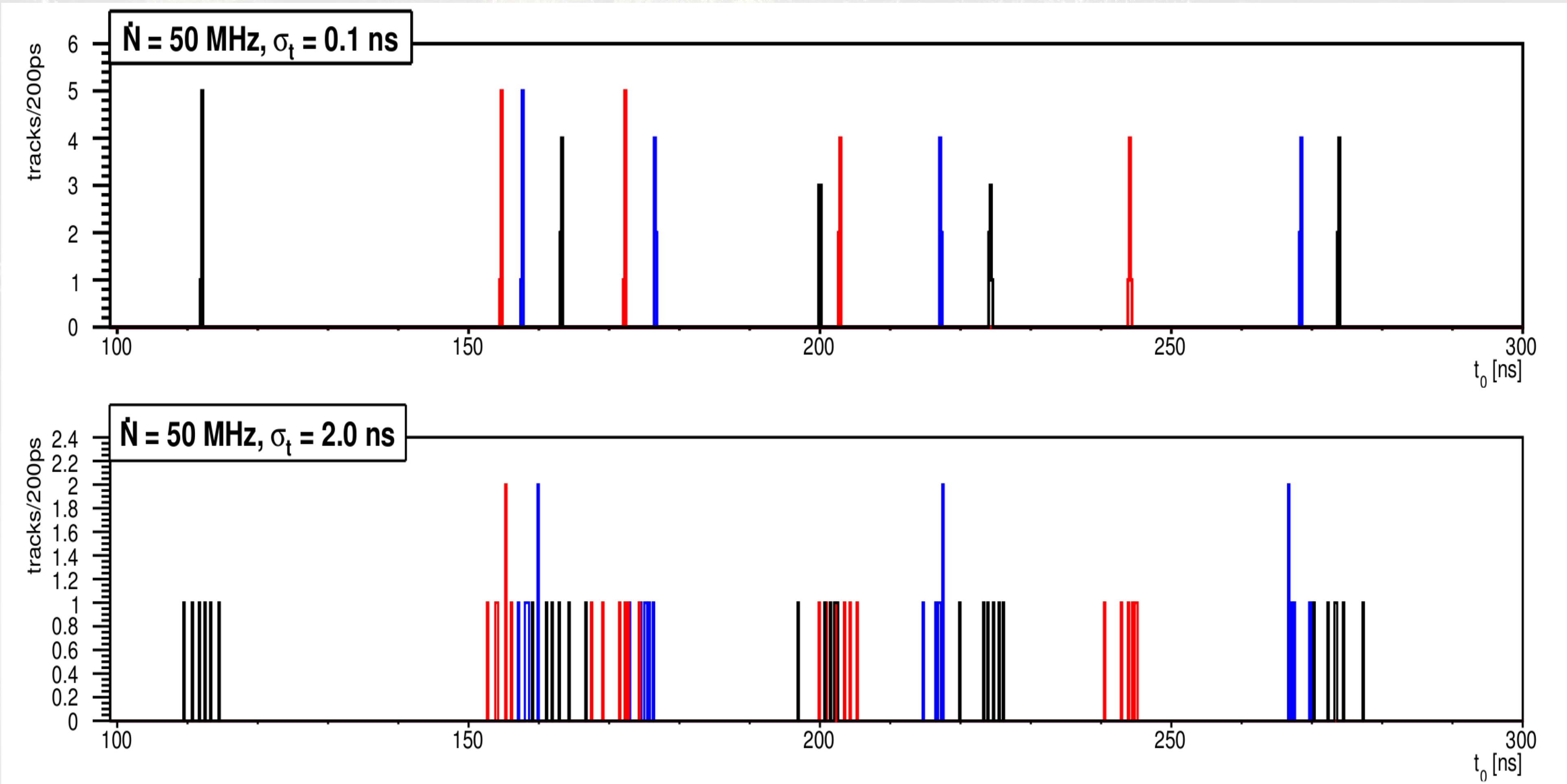
Panda Detector

PANDA interaction rate:
Average 20MHz
Peak 50-100MHz

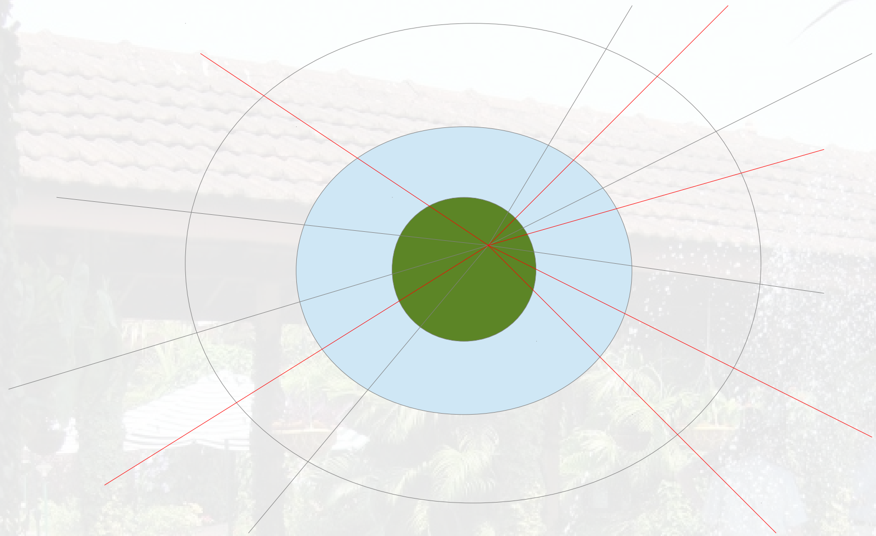


Motivation: Event Timing

Events 1,2,3,4,5,6,7,8... for 50Mhz interaction rate with 6 tracks

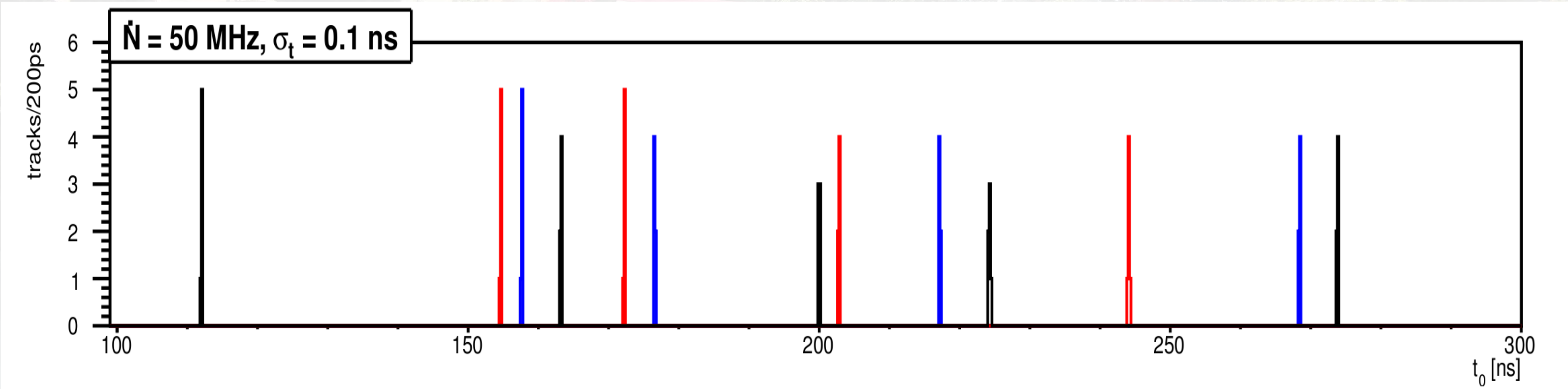


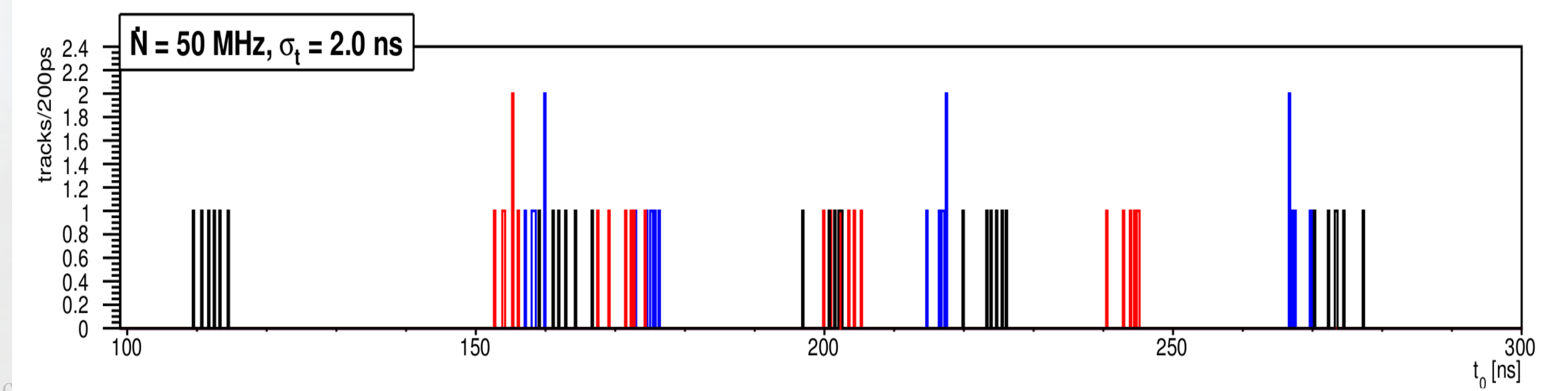
Klaus Götzen,Influence of Particle Timing on Event Building
PANDA collaboration meeting March 2011, GSI



Fast detector assigns accurate time stamps to tracks.

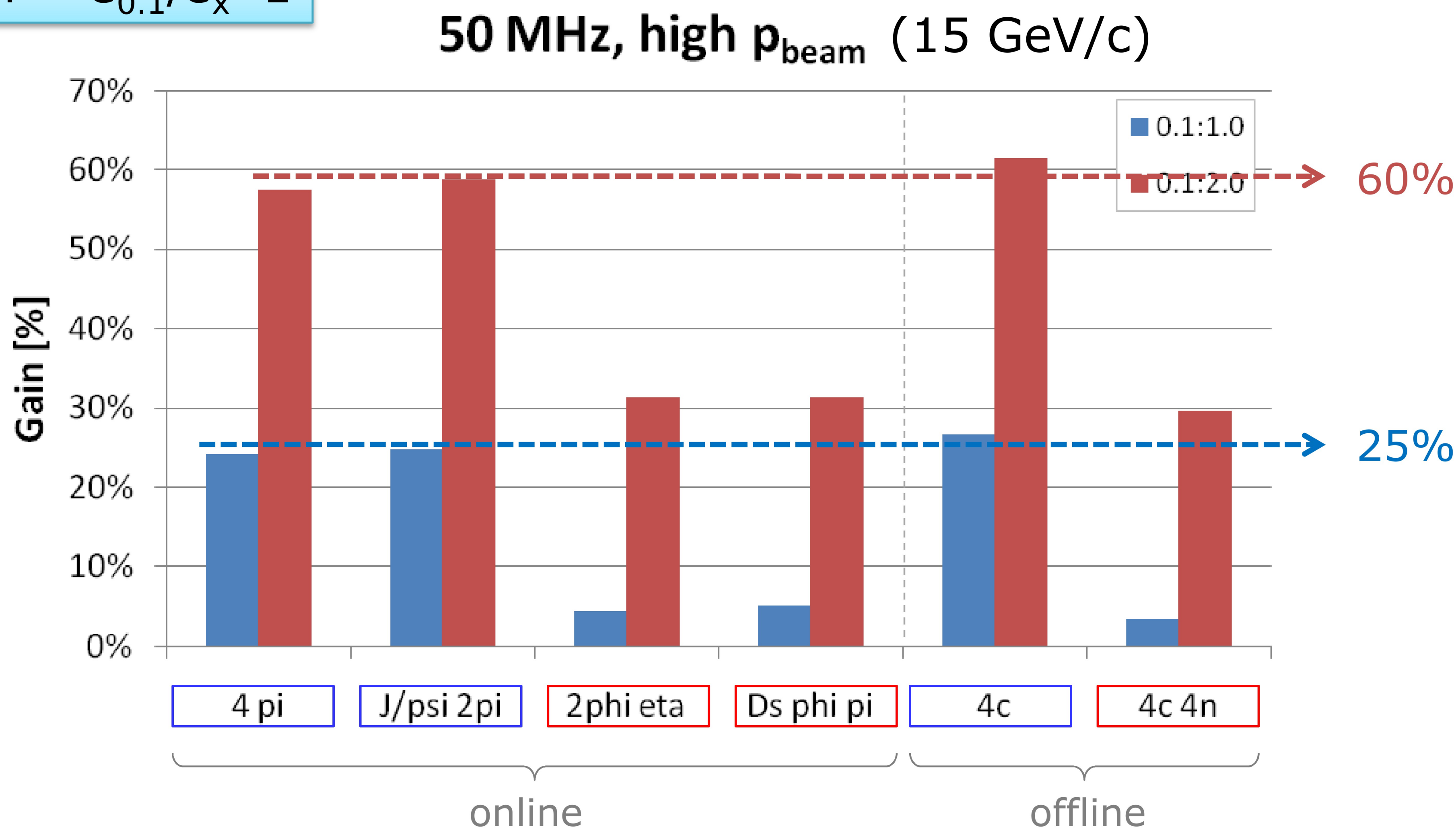
M=6





Relative Gain of 1ns/2ns → 100 ps

Gain = $\epsilon_{0.1}/\epsilon_x$ -1

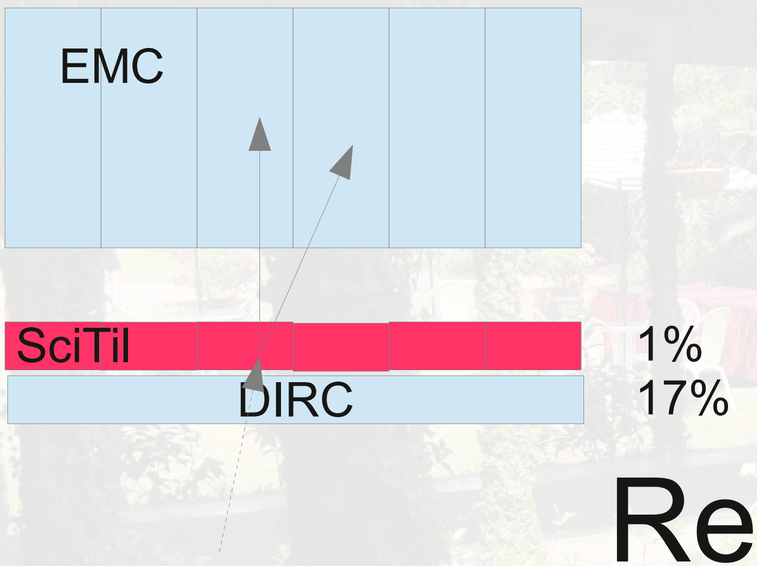


1 ns → 0.1 ns

2 ns → 0.1 ns

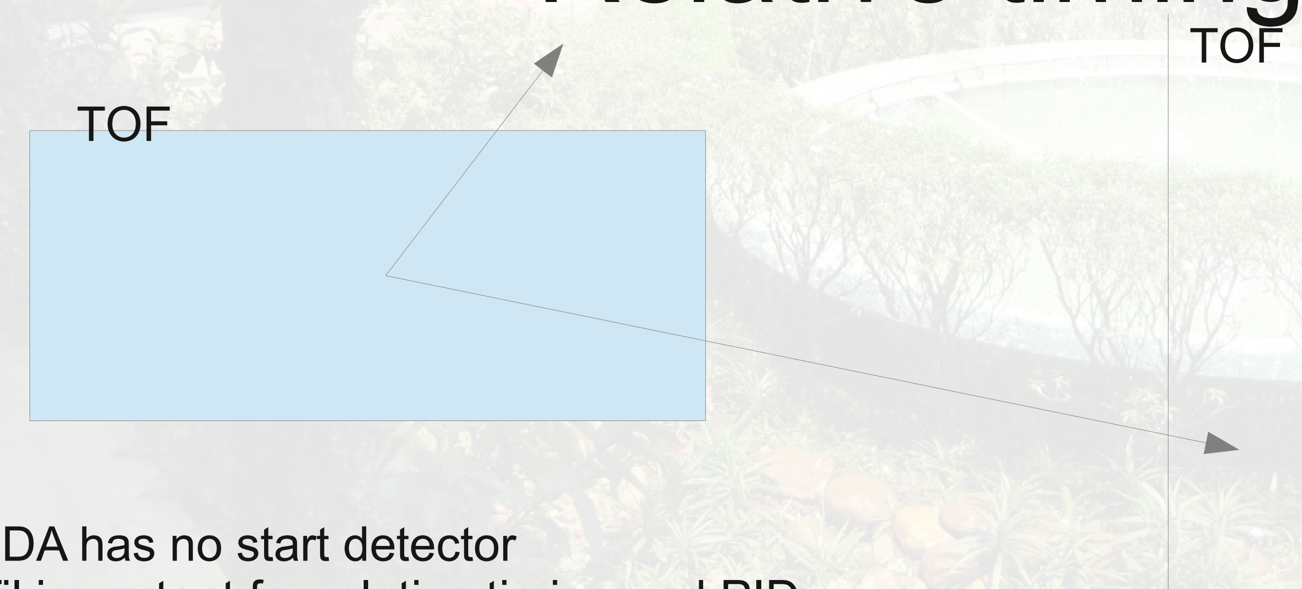
Klaus Götzen,Influence of Particle Timing on Event Building
PANDA collaboration meeting March 2011, GSI

Motivation: Conversion Detection



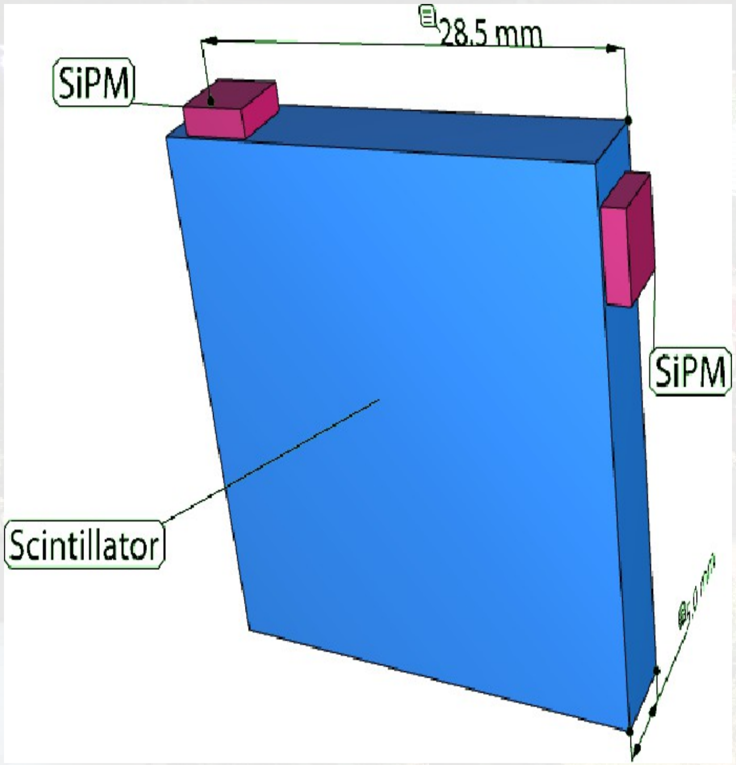
Conversion of gammas within the DIRC
can be detected with the SciTil

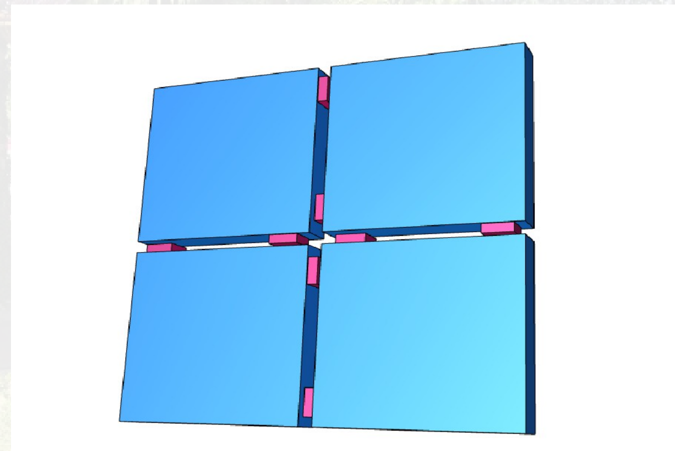
Relative timing



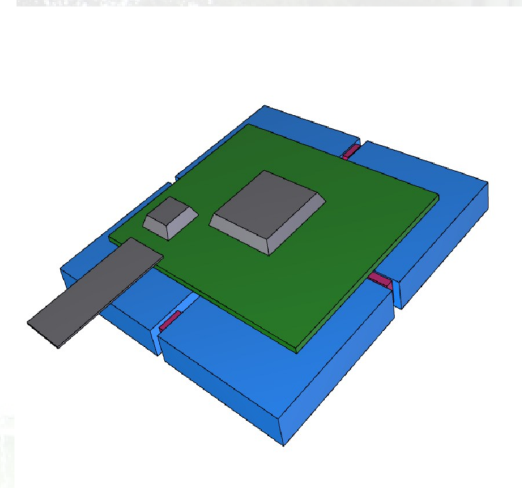
PANDA has no start detector
SciTil important for relative timing and PID

SciTil





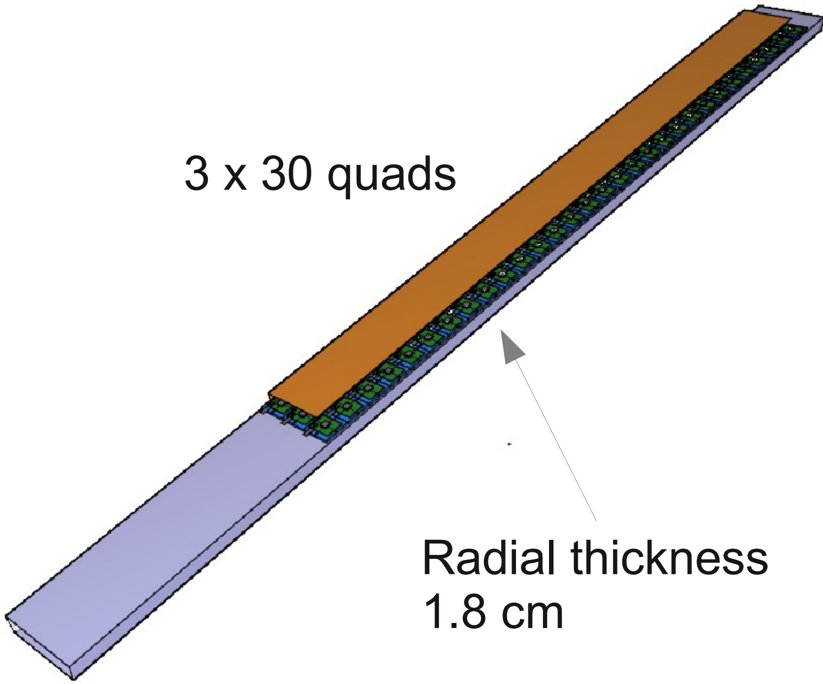
Quad module



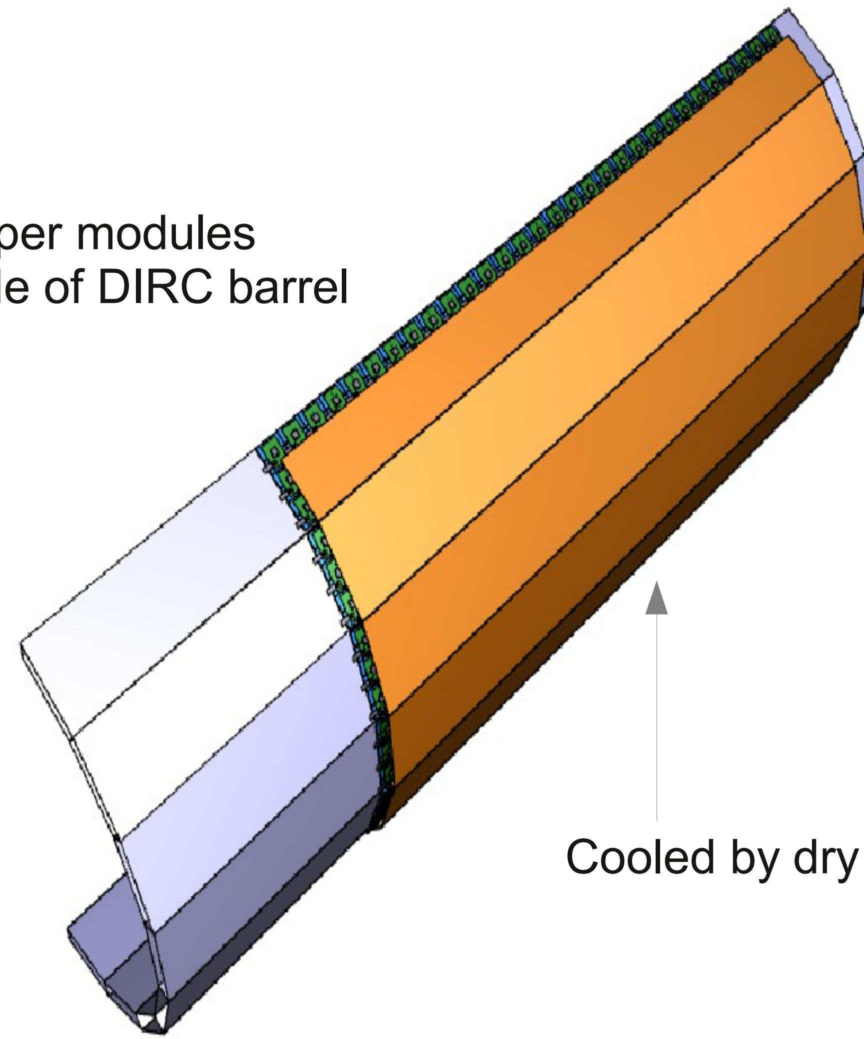
With electronics
- 8 ch. ASIC
- data transfer IC

Readout at two positions
- more photons
- less light path fluctuations
- larger detection efficiency

Super-module = 90 quad modules

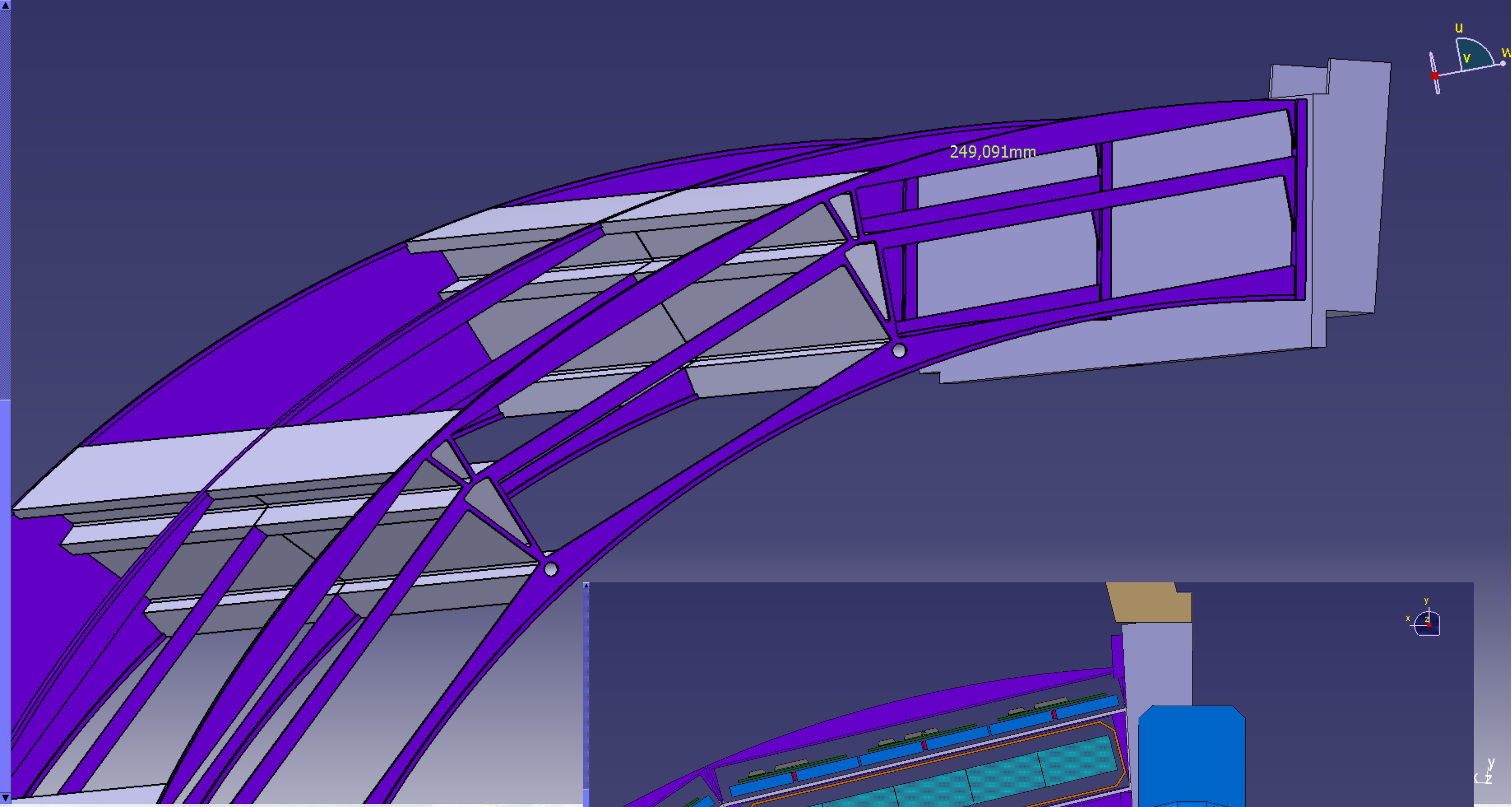


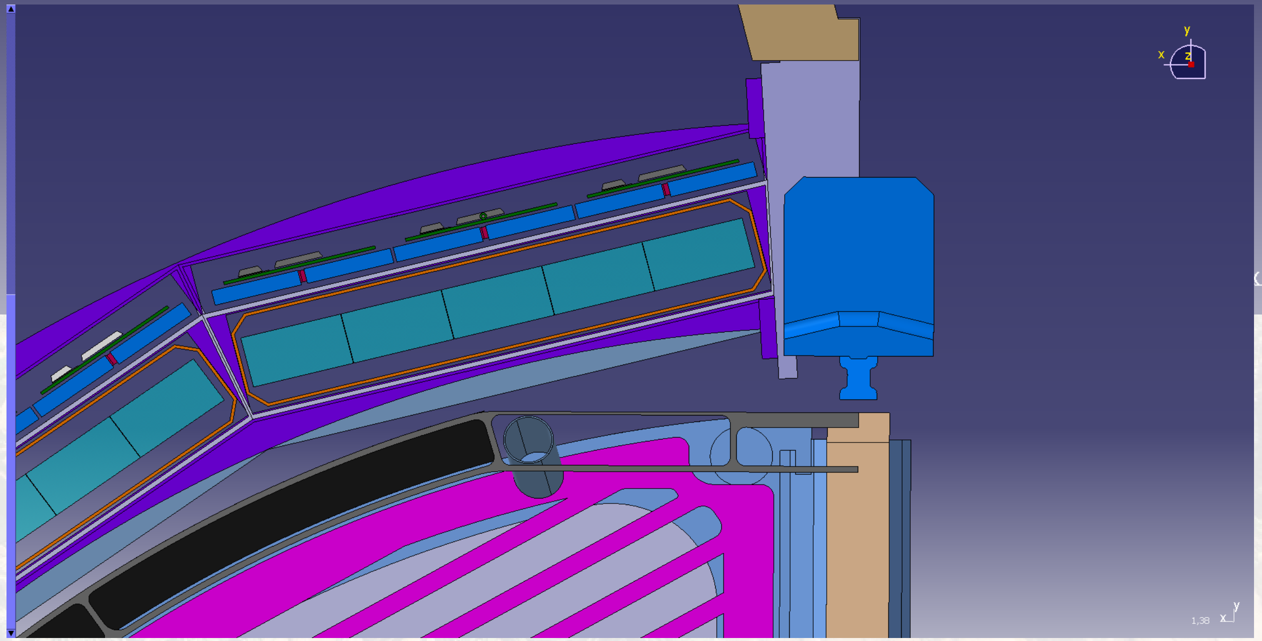
16 super modules
outside of DIRC barrel

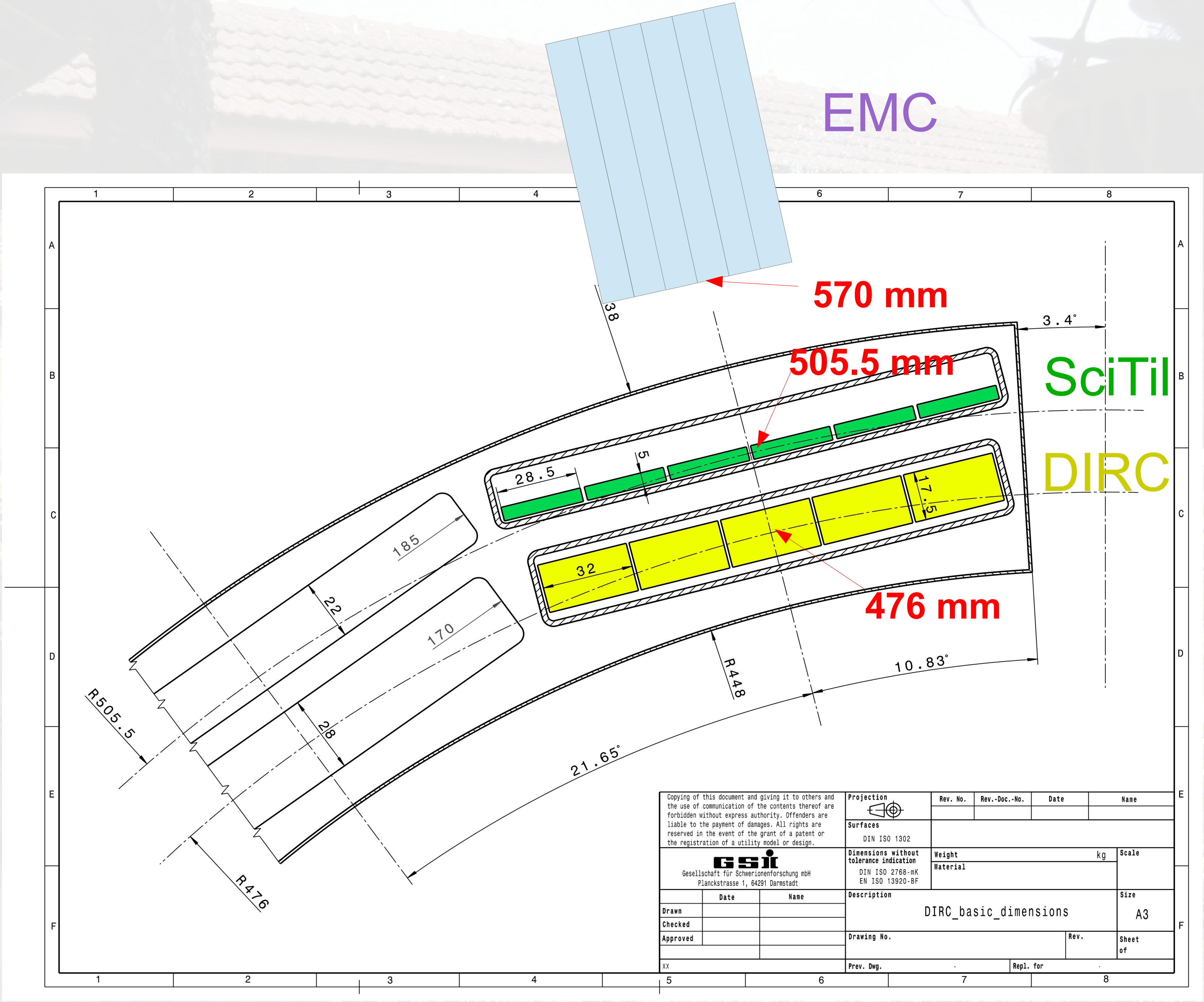


Total

5760 SciTils


249,091mm





EMC
570 mm
505.5 mm
SciTil
DIRC
476 mm
38
3.4°
28.5
5
17.5
32
185
22
170
28
R505.5
R476
R448
10.83°
21.65°
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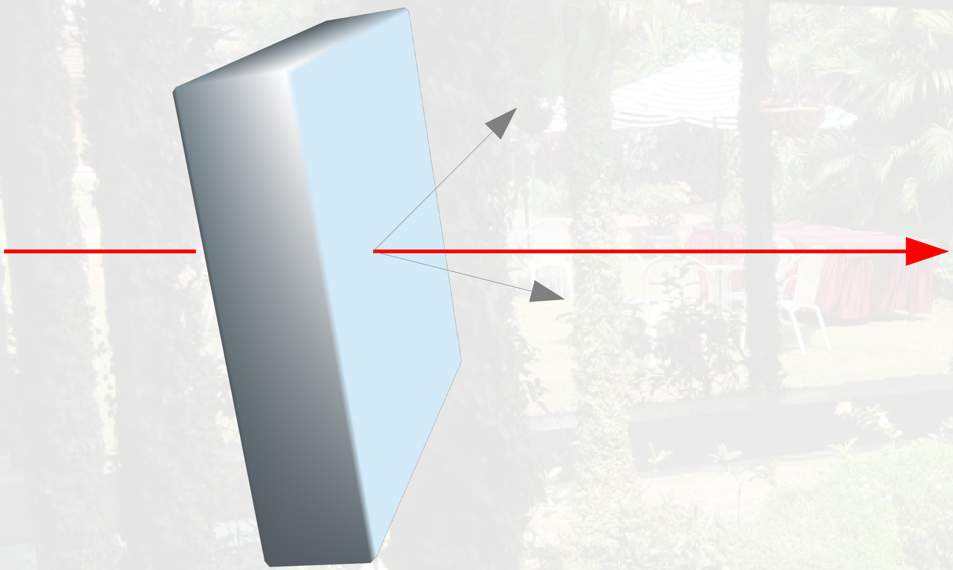
GSI
Gesellschaft für Schwerionenforschung mbH
Planckstrasse 1, 64291 Darmstadt
Projection
Surfaces
DIN ISO 1302
Dimensions without tolerance indication
DIN ISO 2768-mK
EN ISO 13920-BF
Rev. No.
Rev.-Doc.-No.
Date
Name
Weight
kg
Scale
Material
Description
DIRC_basic_dimensions
Size
A3
Drawn
Checked
Approved
Drawing No.
Rev.
Sheet
of
Prev. Dwg.
Repl. for

Photon number

Tile 30 x 30 x 5 mm^3



Minimum ionizing particle

ΔE = 1 MeV
= 10^4 photons — generated

70% hit rim
= 7000 photons — on rim

PD area = 18 mm^2
rim area = 600 mm^2

= 210 photons — geometry

55% PD efficiency — PDE

= 115 photons

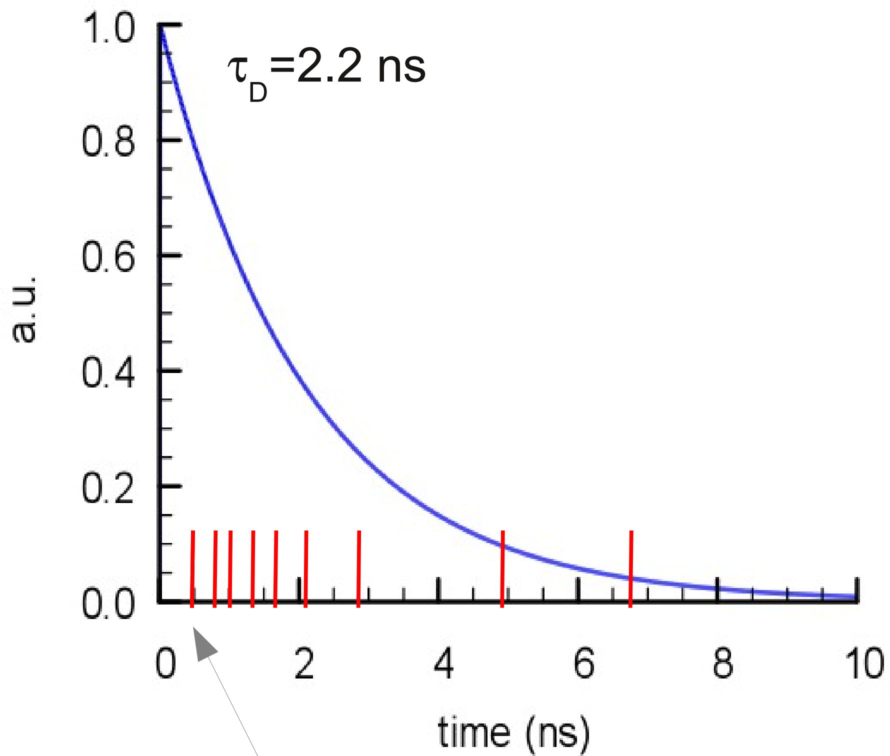
30 x 30 x 5 mm^3 → 115 photons
20 x 20 x 5 mm^3 → 180 photons

Scintillator Material

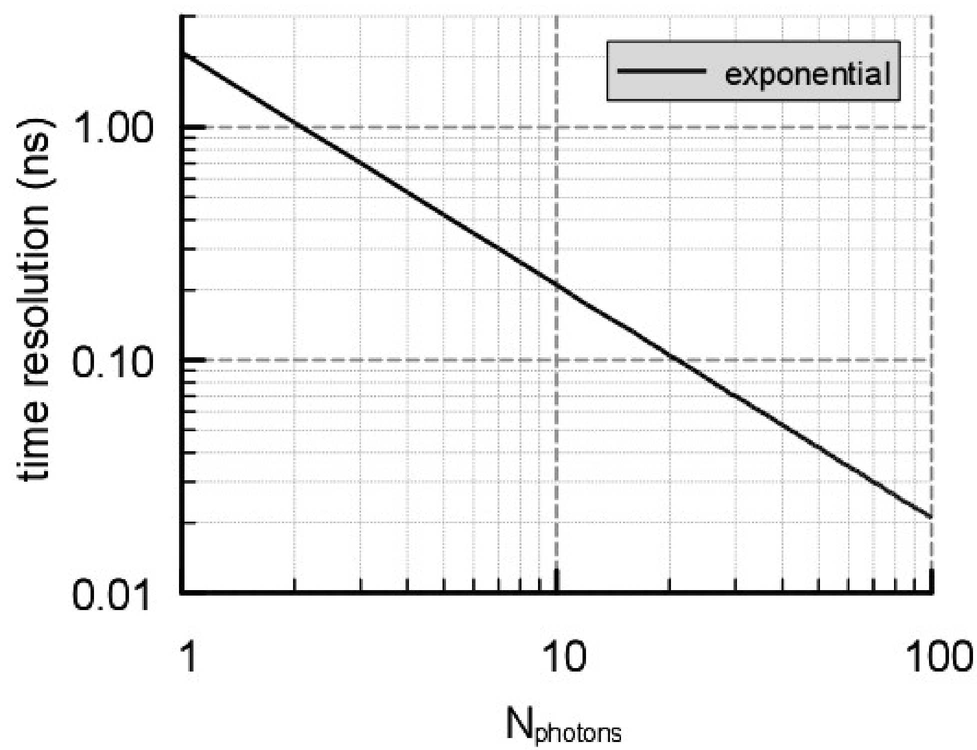
For subnanosecond timing: timing on first arriving photon

→ Time resolution depends on number of photons.

Pure exponential:



Simulation



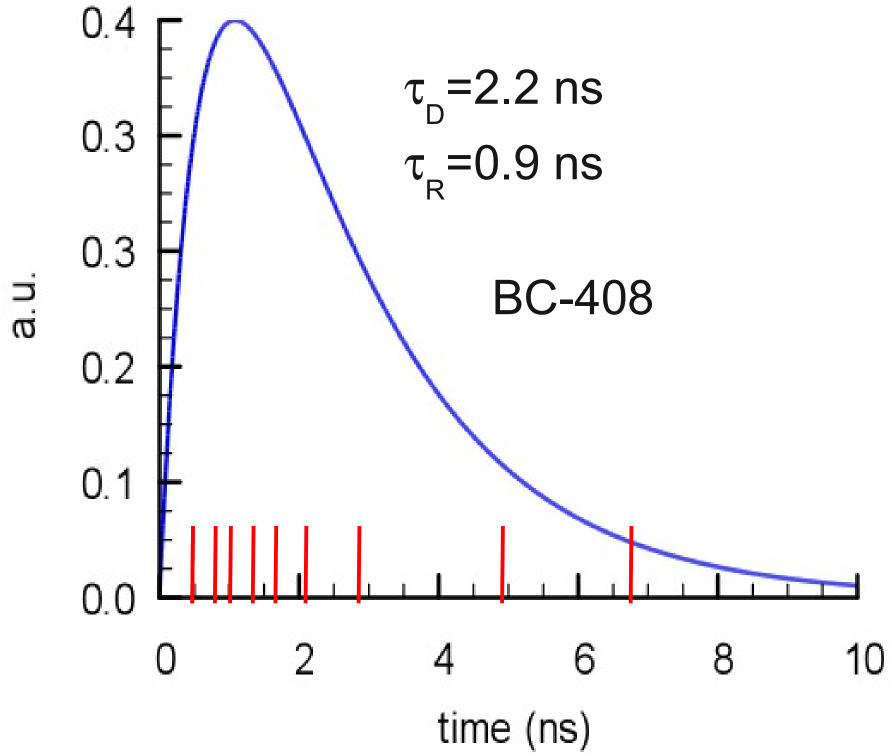
Time spread of first photon (RMS) for many events ~1/N

Unfortunately
→ not so simple...

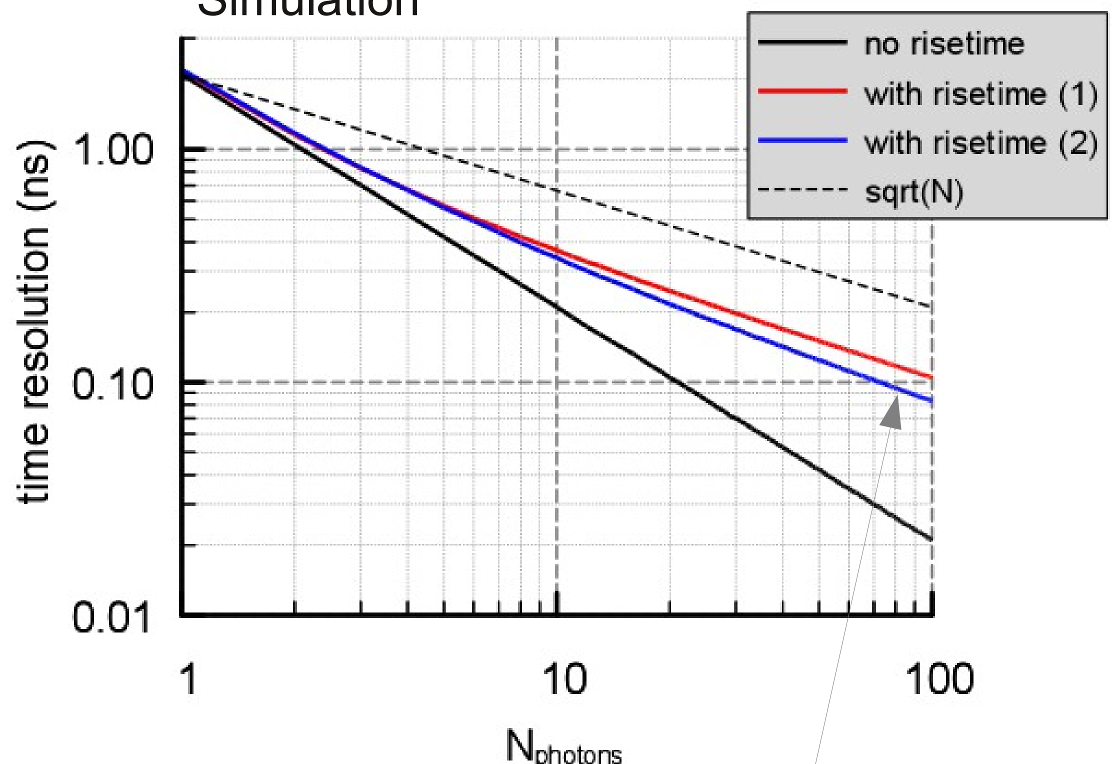
Rise time comparable to wanted time resolution

→ Additional smearing of first photon

Rise time + exponential:



Simulation



Time spread of first photon (RMS) for many events ~1/sqrt(N)

BC-408: 100 ps
100 photons

Saint Gobain Scintillators (Bicron)

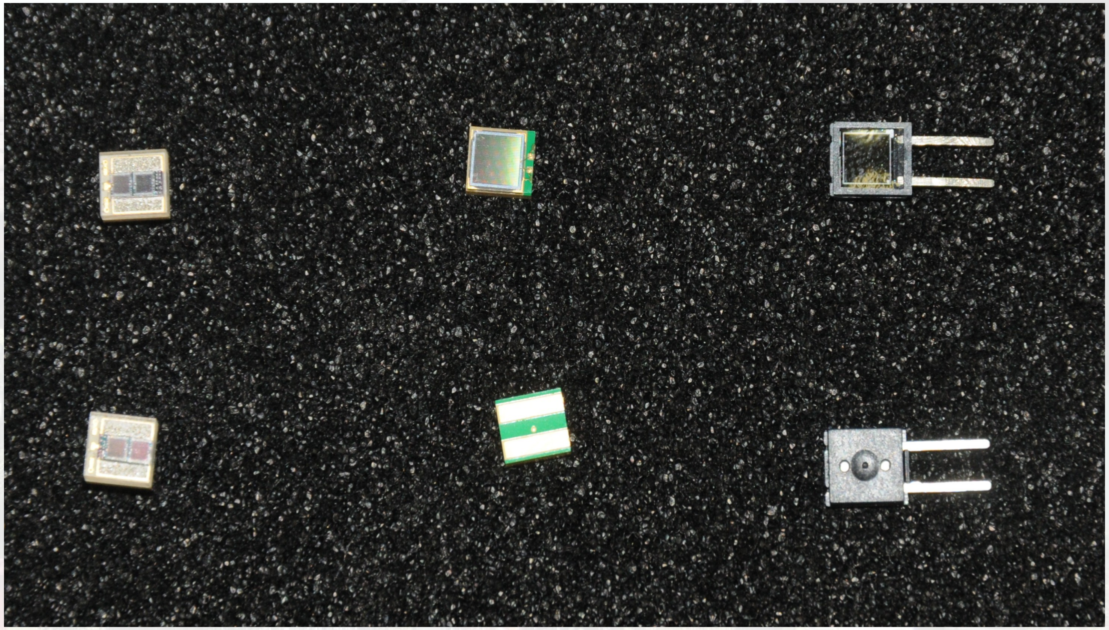
Scintillation Properties –	BC-400	BC-404	BC-408	BC-412	BC-416	BC-418	BC-420	BC-422
Light Output, %Anthracene	65	68	64	60	38	67	64	55
Rise Time, ns	0.9	0.7	0.9	1.0	–	0.5	0.5	0.35
Decay Time (ns)	2.4	1.8	2.1	3.3	4.0	1.4	1.5	1.6
Pulse Width, FWHM, ns	2.7	2.2	~2.5	4.2	5.3	1.2	1.3	1.3
Wavelength of Max. Emission, nm	423	408	425	434	434	391	391	370
Light Attenuation Length, cm*	160	140	210	210	210	NA**	140	NA**
Bulk Light Attenuation Length, cm	250	160	380	400	400	100	110	8

Up to now BC408 was used.

Other producer Eljen (ordered) and Dubna (planned)

GSI (H.O), Dubna

Photon Detector

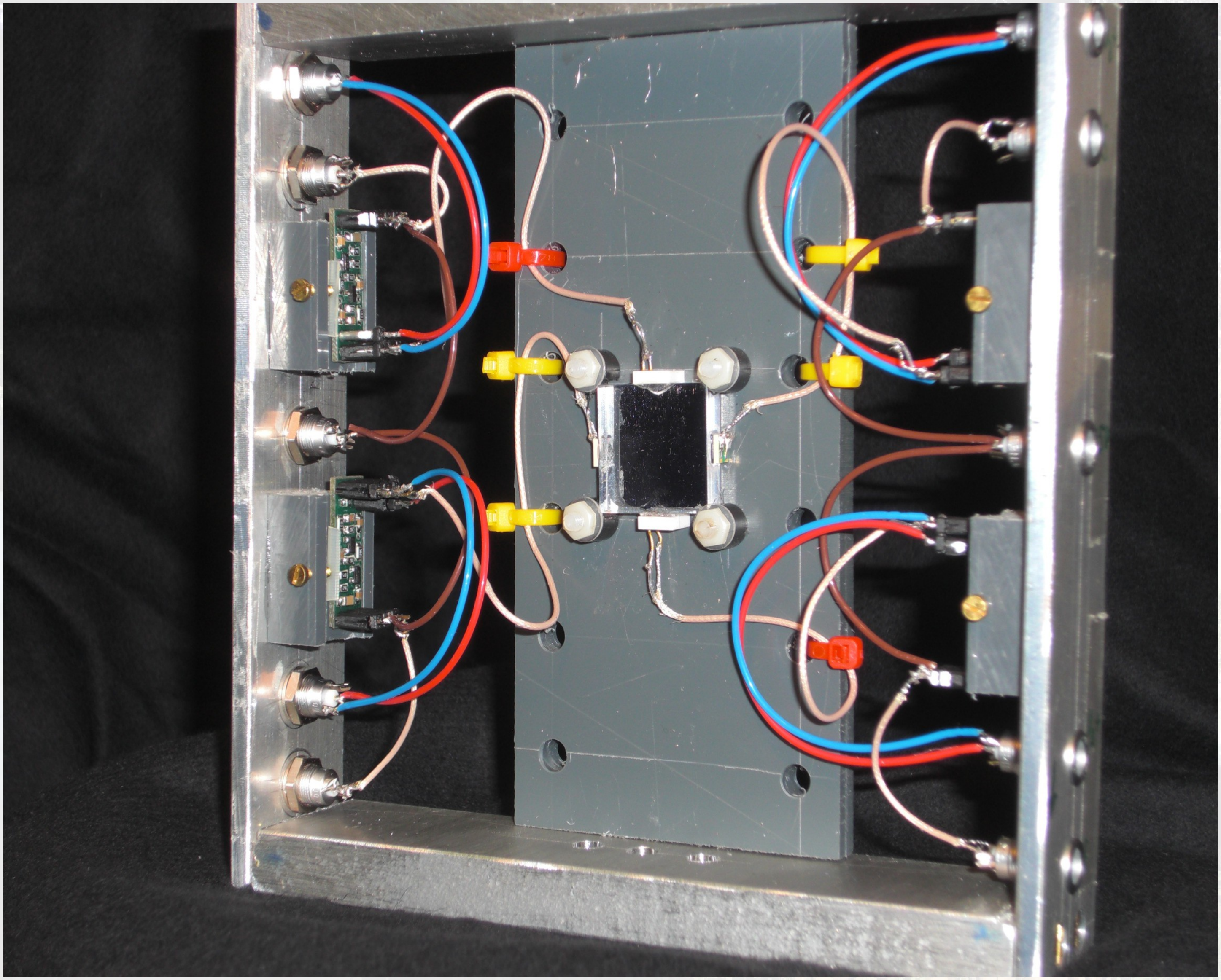


- Silicon Photomultiplier
  - High PDE
  - Good timing resolution
  - High rate capability
  - Work in high magnetic fields
  - Small, robust, low bias voltage

  - Noisy
  - Temperature dependent

→ Remember previous talk of Herbert Orth

Prototype 1 (20x20x5mm^3)



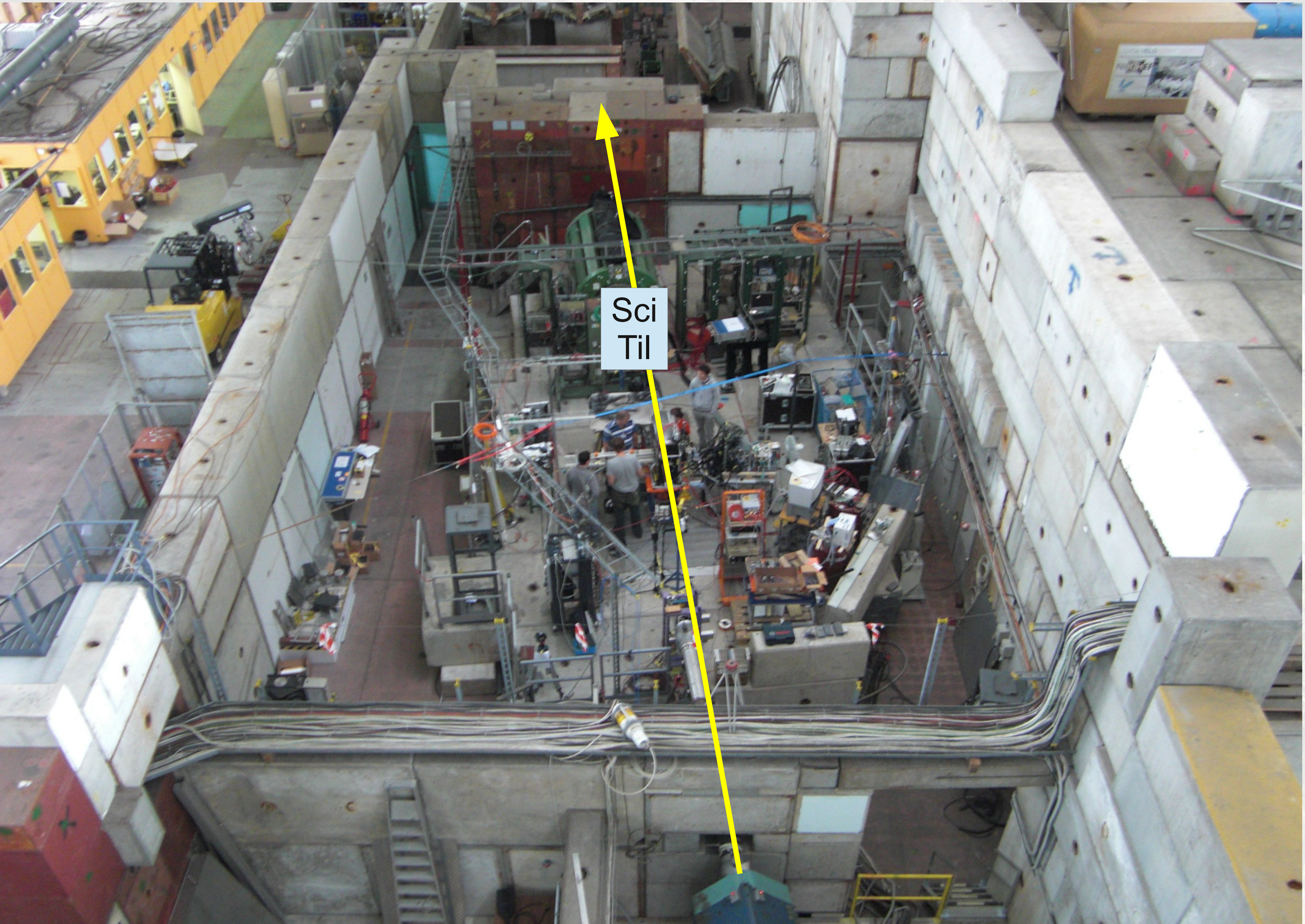
BC408
+ Superglue

Hamamatsu SiPM
S10931-050P
S10362-33-050C

Photonique
Fast amplifier 611

Readout
NINO + HADES TRB

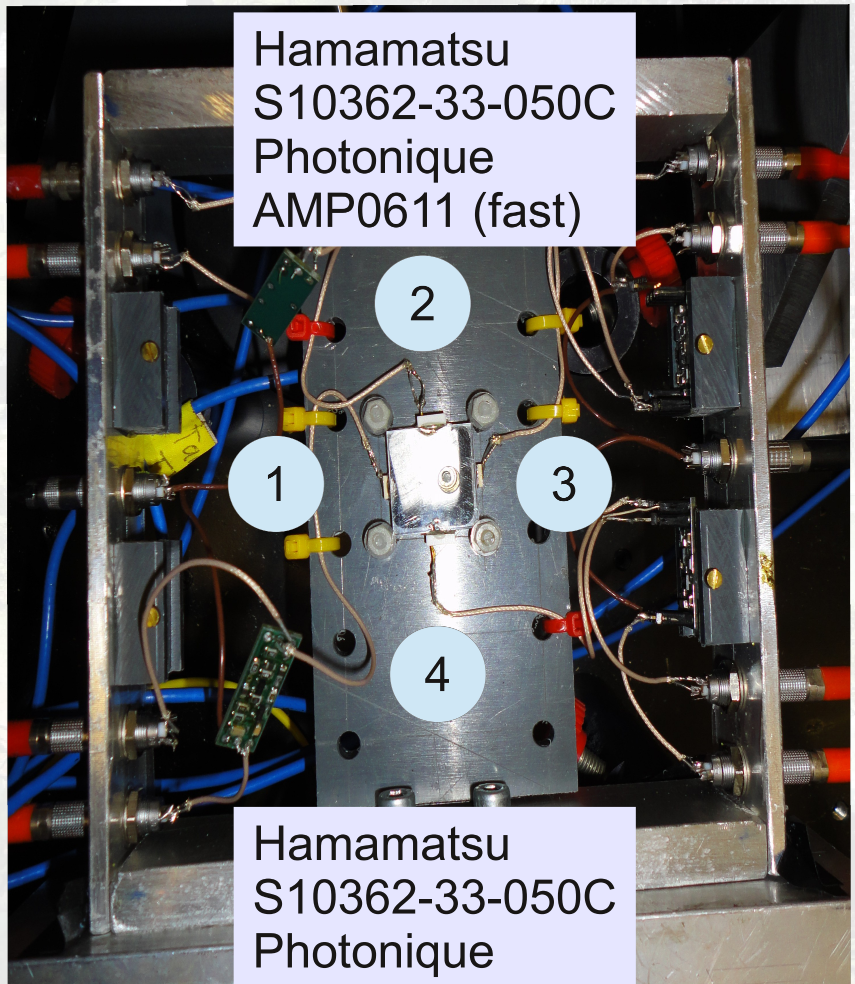
GSI, CERN DIRC prototype beam times
---> SciTil time resolution of 600ps :(



Test Stand

GSI Summerstudent program 2011: Stefan Diehl, Giessen
→ more systematic search for missing time resolution

Trigger done by
majority coincidence (=4)
CFD set to 1 photon



Hamamatsu
S10931-050P
Photonique
AMP0611 (fast)

Hamamatsu
S10931-050P
Photonique
AMP0604 (high)

Shielded bias/5V

Timing resolution of 3 detectors

$\sigma^2_1 = \sigma^2_{electr.}$

Measure t_1-t_2, t_1-t_3, t_2-t_3 , $t_1 \rightarrow$ σ^2_{12} σ^2_{13} σ^2_{23} σ^2_1

And subtract $2\sigma^2_{electr.}$ $\rightarrow$ $\sigma^{2'}_{12}$ $\sigma^{2'}_{13}$ $\sigma^{2'}_{23}$

$$\sigma^{2'}_{12} + \sigma^{2'}_{13} - \sigma^{2'}_{23} = (\sigma^2_1 + \sigma^2_2) + (\sigma^2_1 + \sigma^2_3) - (\sigma^2_2 + \sigma^2_3)$$
$$= 2\,\sigma^2_1$$

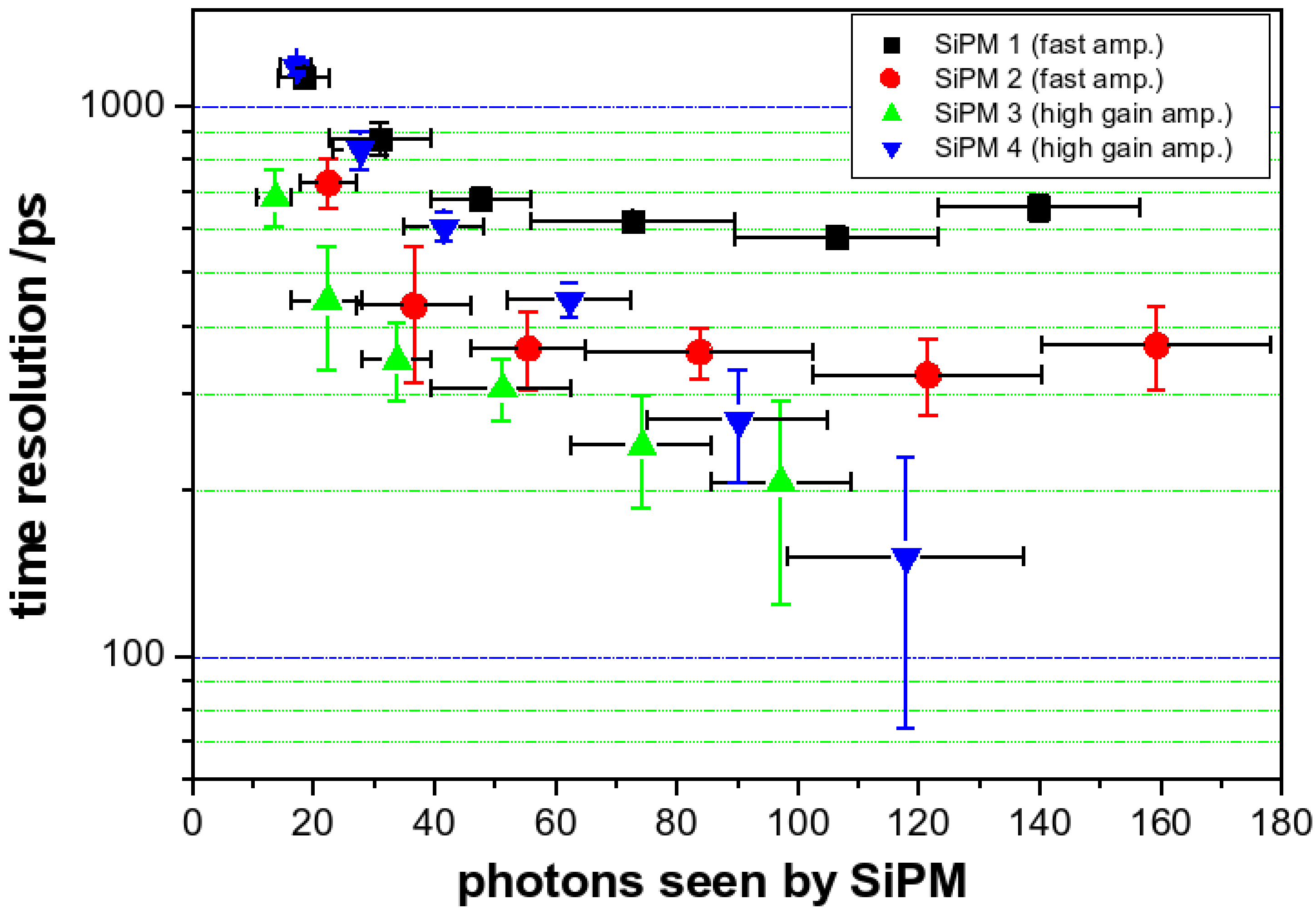
For 4 detectors each σ^2 can be determined several times
→ error bars

GSI Summerstudent program 2011:
Stefan Diehl, Giessen

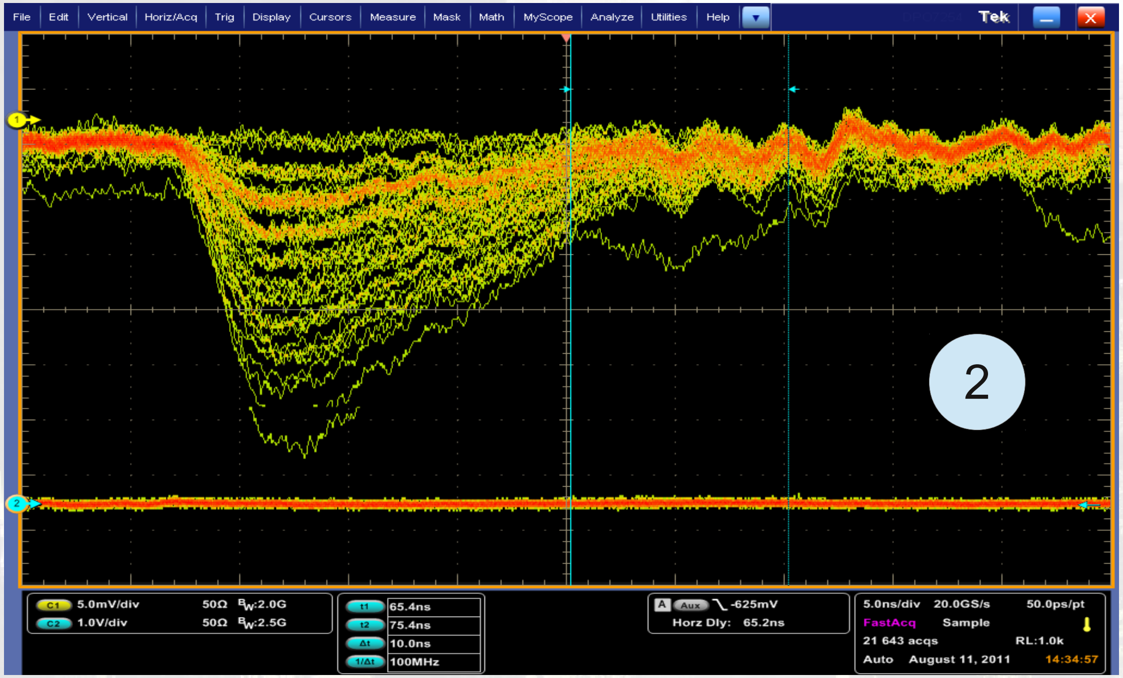
σ_{i-el}	time resolution /ps
σ_{1-el}	368 ± 29
σ_{2-el}	135 ± 30
σ_{3-el}	210 ± 54
σ_{4-el}	115 ± 30

Electronic time Resolution (FTA820/CFD/ NIM-ECL converter)

^{90}Sr source, results corrected for electronic time resolution



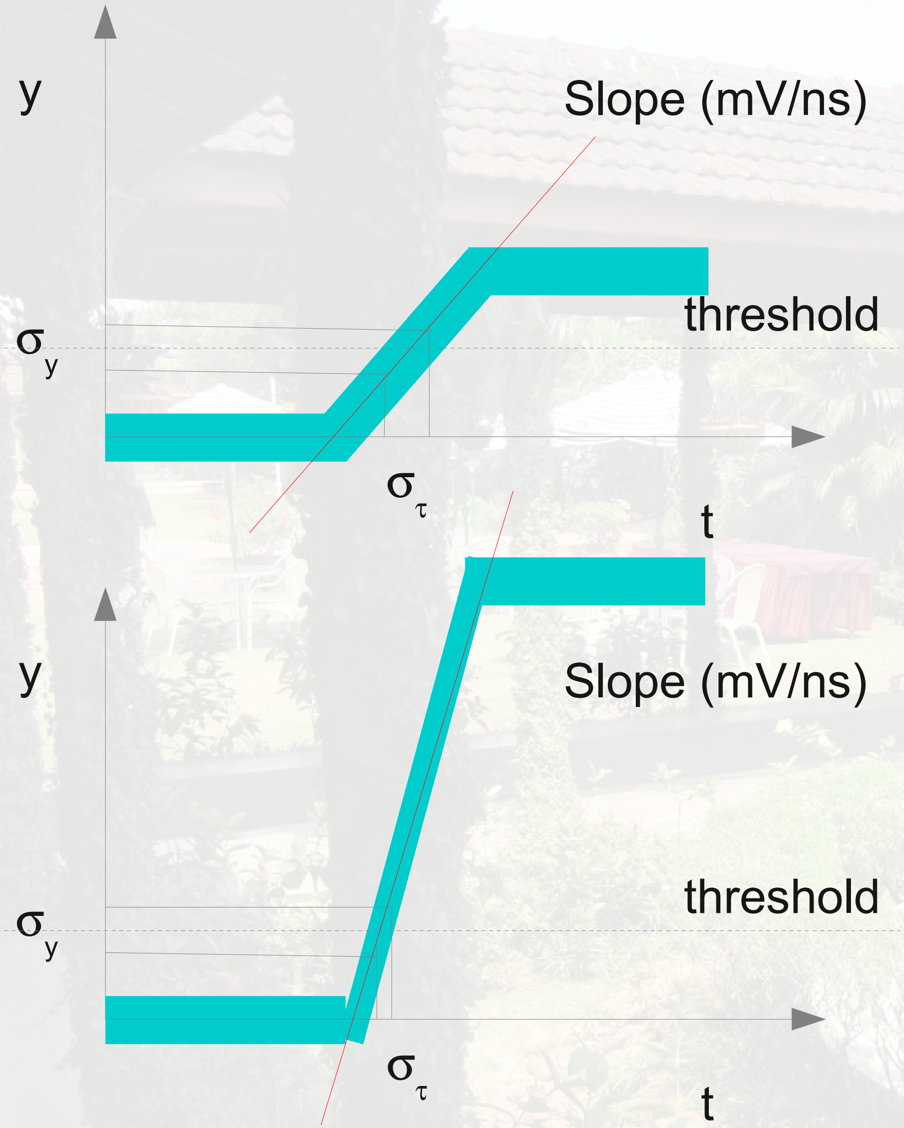
High gain AMP604 most promising



Fast
AMP611

SiPM	Rise-time [ns]	Decay-time [ns]
1 (fast amp.)	1,1 +- 0,05	11,1 +- 0,5
2 (fast amp.)	1,1 +- 0,5	10,8 +- 0,5
3 (high gain amp.)	1,2 +- 0,05	18,4 +- 1,0
4 (high gain amp.)	1,3 +- 0,3	23,9 +- 3,0

X 5



AMP611 fast low gain 1 ns x 5
AMP604 “slower” high gain 1.3 ns x 30

---> **slew rate is important**

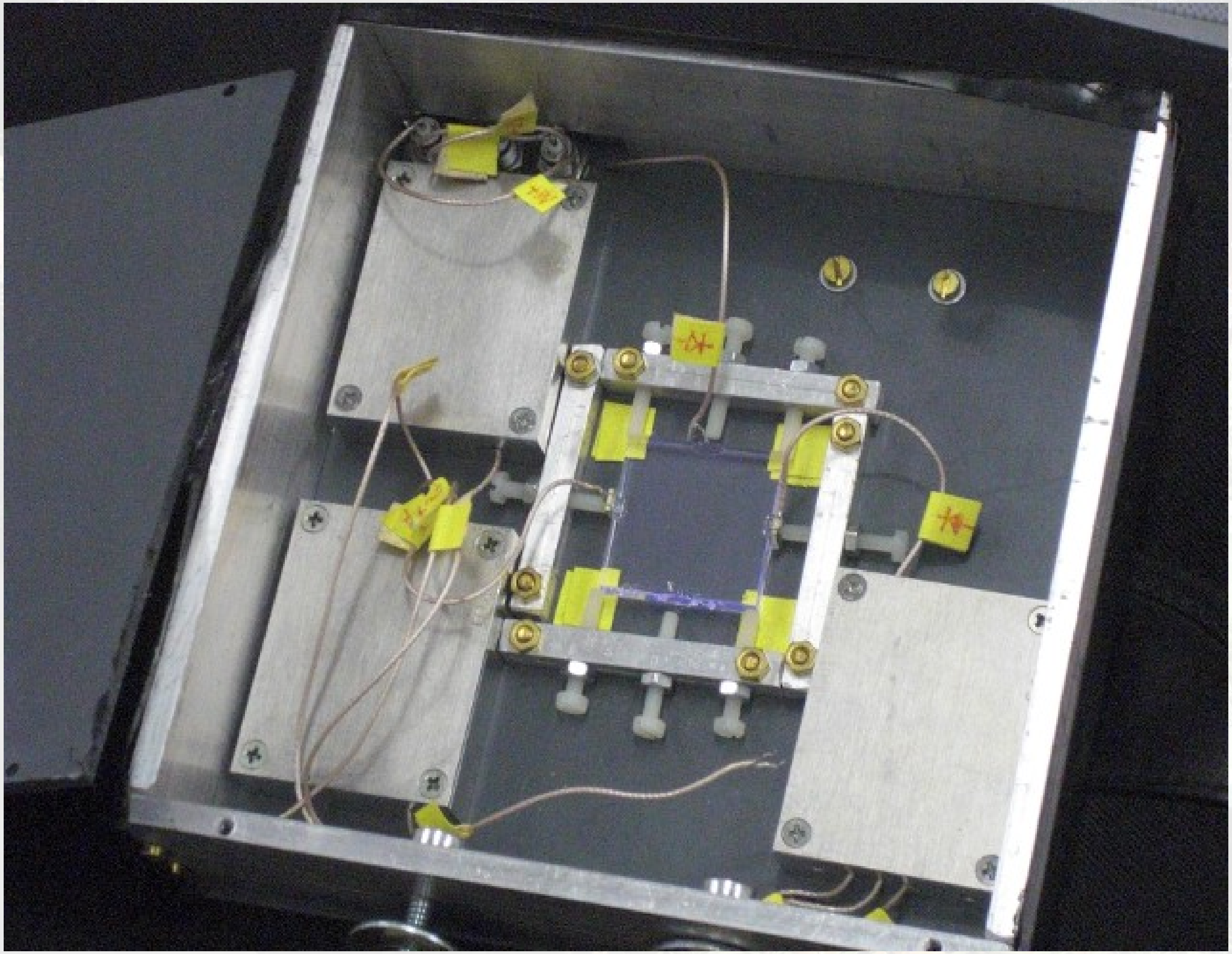
Good results with fast amplifier
(F. Guber, INR Moscow)
5ns, x200

Vienna amplifier, based on AMP604

Noise: $\sigma_\tau = \frac{\sigma_y}{\text{slope}}$

Total time resolution: $\sigma_m^2 = \sigma_d^2 + \left(\frac{\sigma_y}{\text{slope}}\right)^2$

Prototype 2 (30x30x5mm^3)



BC408
Coupled with BC606

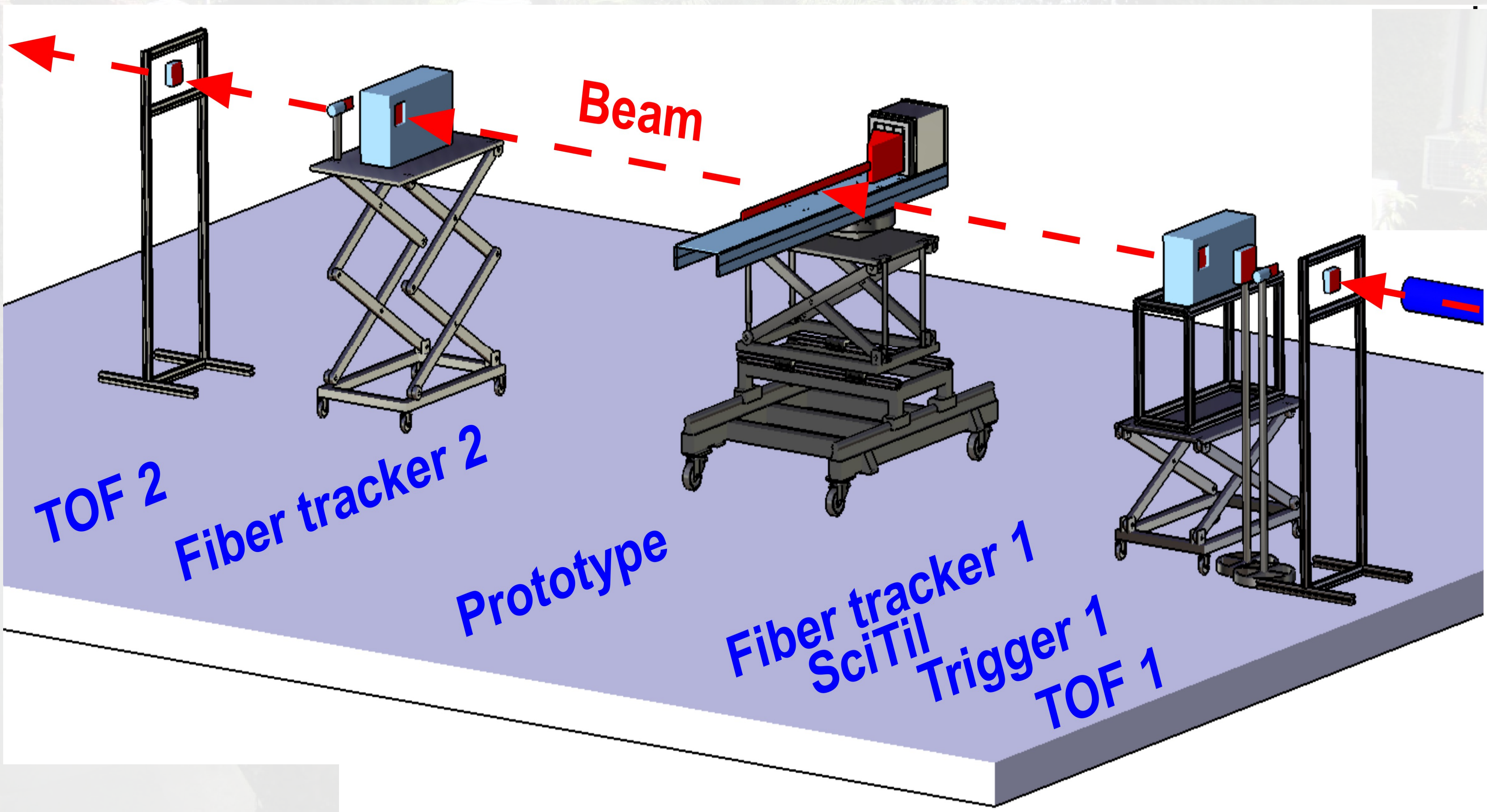
Hamamatsu SiPM
2x S10931-050P
1x S10362-33-050C
1x Ketek 3x3 60A2

Photonique
Slow amplifier 604
INR Moscow-Amplifier
(F.Guber)

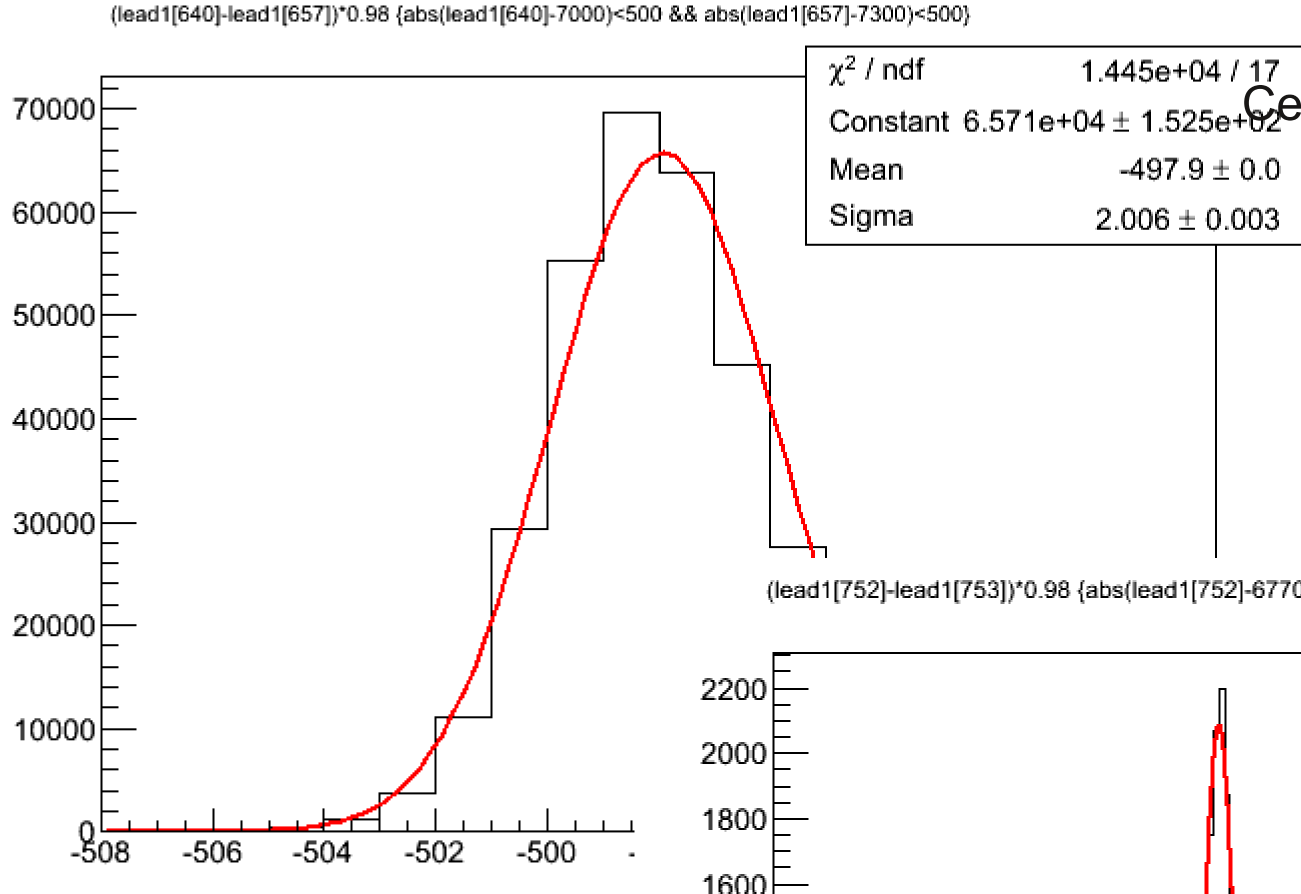
Readout
NINO + HADES TRB

CERN 2012: DIRC experiment

Beam 10 GeV pion (+ electrons)

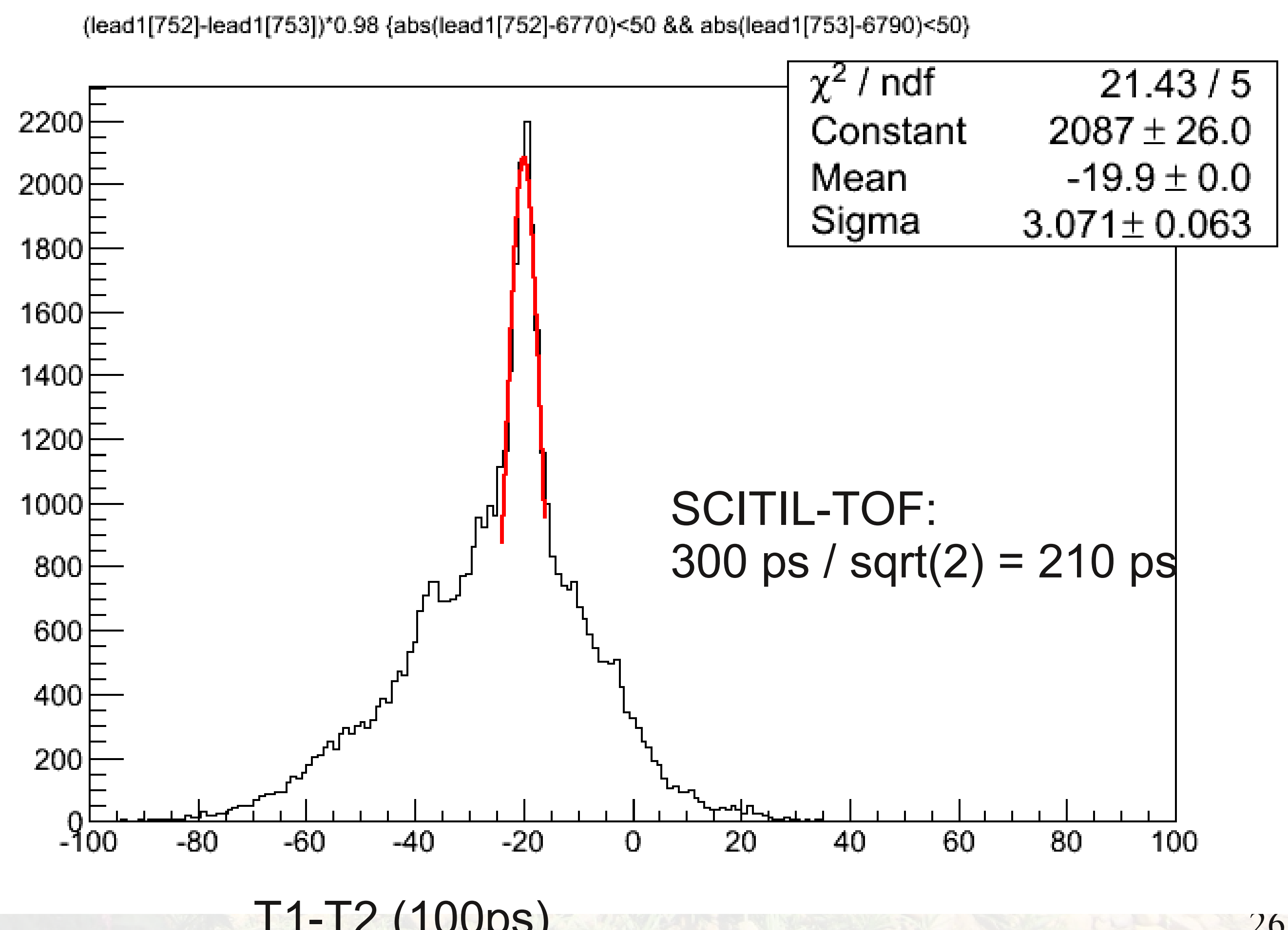


Prototype 2a



Ce12238142615

MCP-TOF:
200 ps / sqrt(2) = 140 ps



SCITIL-TOF:
300 ps / sqrt(2) = 210 ps

Including electronic
Time resolution ~70ps

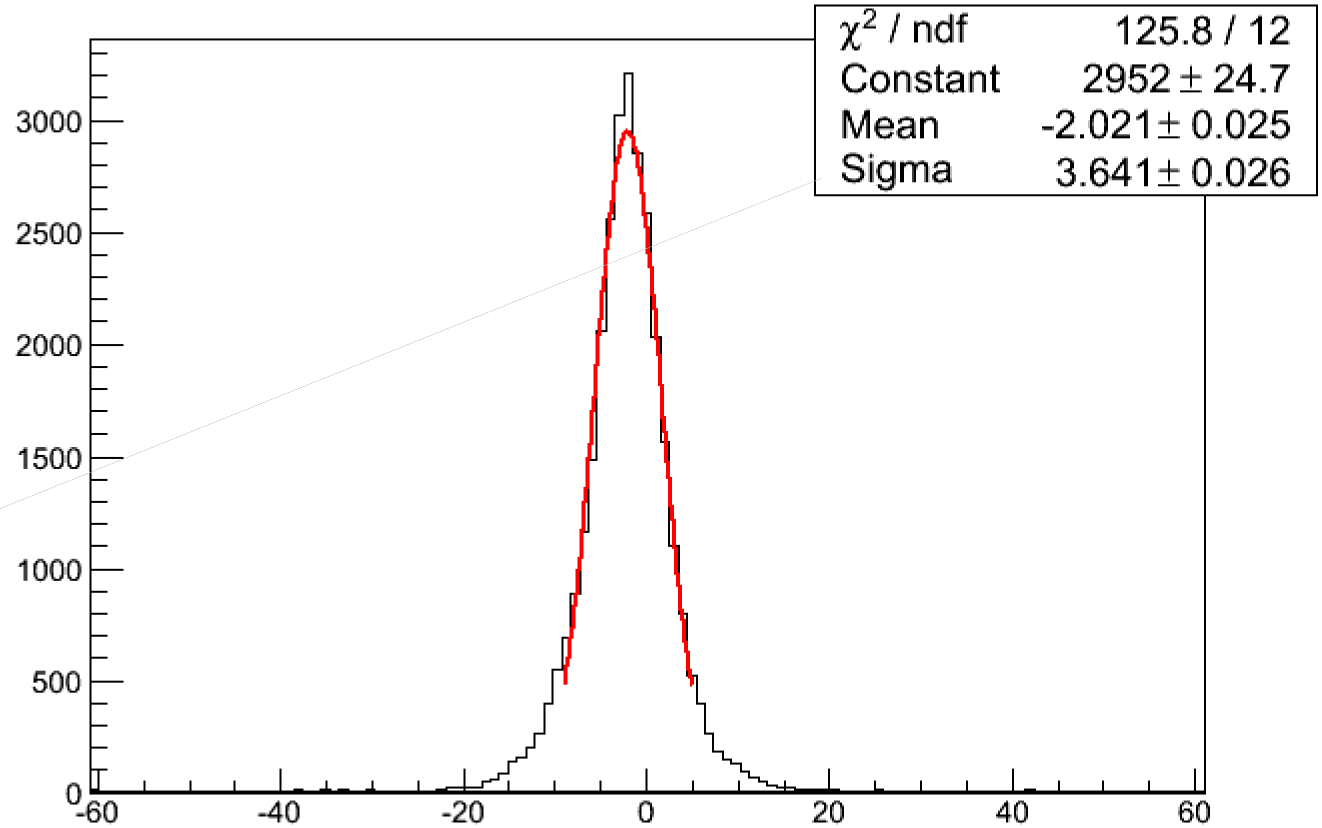
(3-10% effect)

Prototype 2b

Ce12245104147

σ_{12}	380 ± 9 ps
σ_{13}	419 ± 5 ps
σ_{14}	474 ± 7 ps
σ_{23}	364 ± 3 ps
σ_{24}	361 ± 3 ps
σ_{34}	331 ± 2 ps

Statistical errors



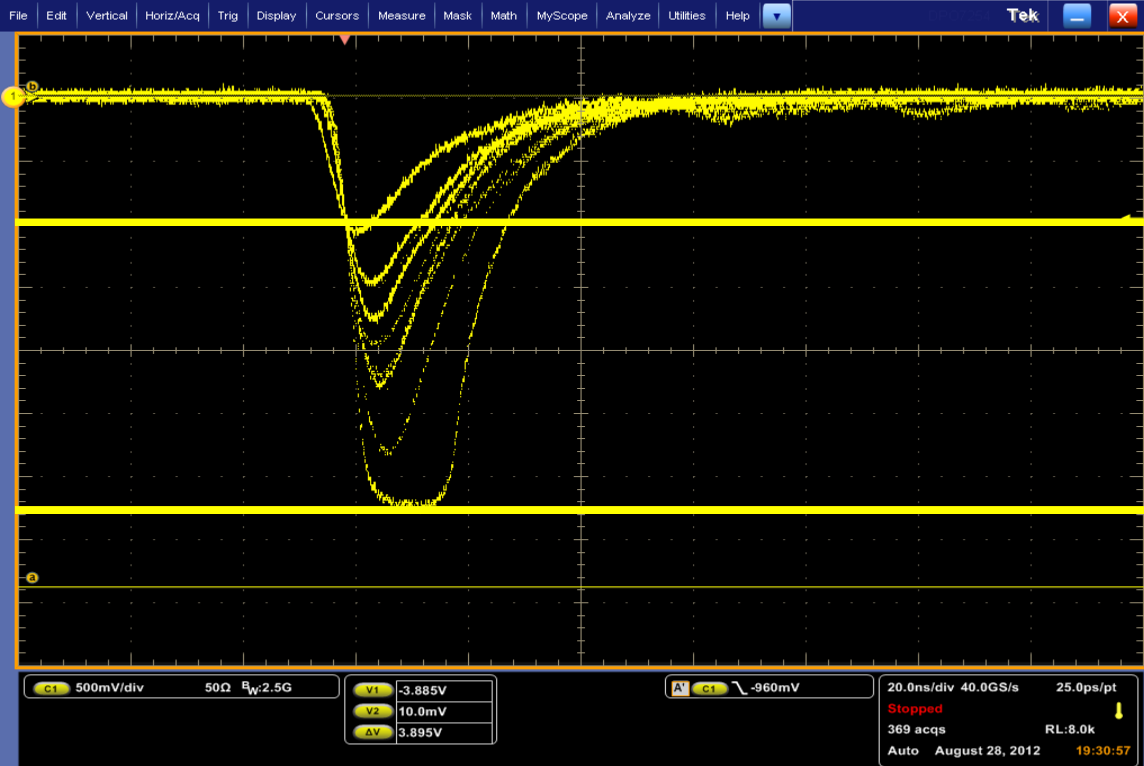
time2 – time3 (100 ps bins)

σ_1	344 ± 75 ps	S10362-33-100C
σ_2	251 ± 50 ps	S10931-050P
σ_3	230 ± 111 ps	S10362-33-100C
σ_4	302 ± 43 ps	Ketek 3x3 / 60A2

Errors from different σ_{ij} combinations → systematical

	data		Picoquant pulser run
σ_1	344 ± 75 ps	S10362-33-100C	217 ± 22 ps
σ_2	251 ± 50 ps	S10931-050P	120 ± 16 ps
σ_3	230 ± 111 ps	S10362-33-100C	86 ± 55 ps
σ_4	302 ± 43 ps	Ketek 3x3 / 60A2	194 ± 10 ps

Difference Data ↔ Pulser: Scintillator, noise on cables



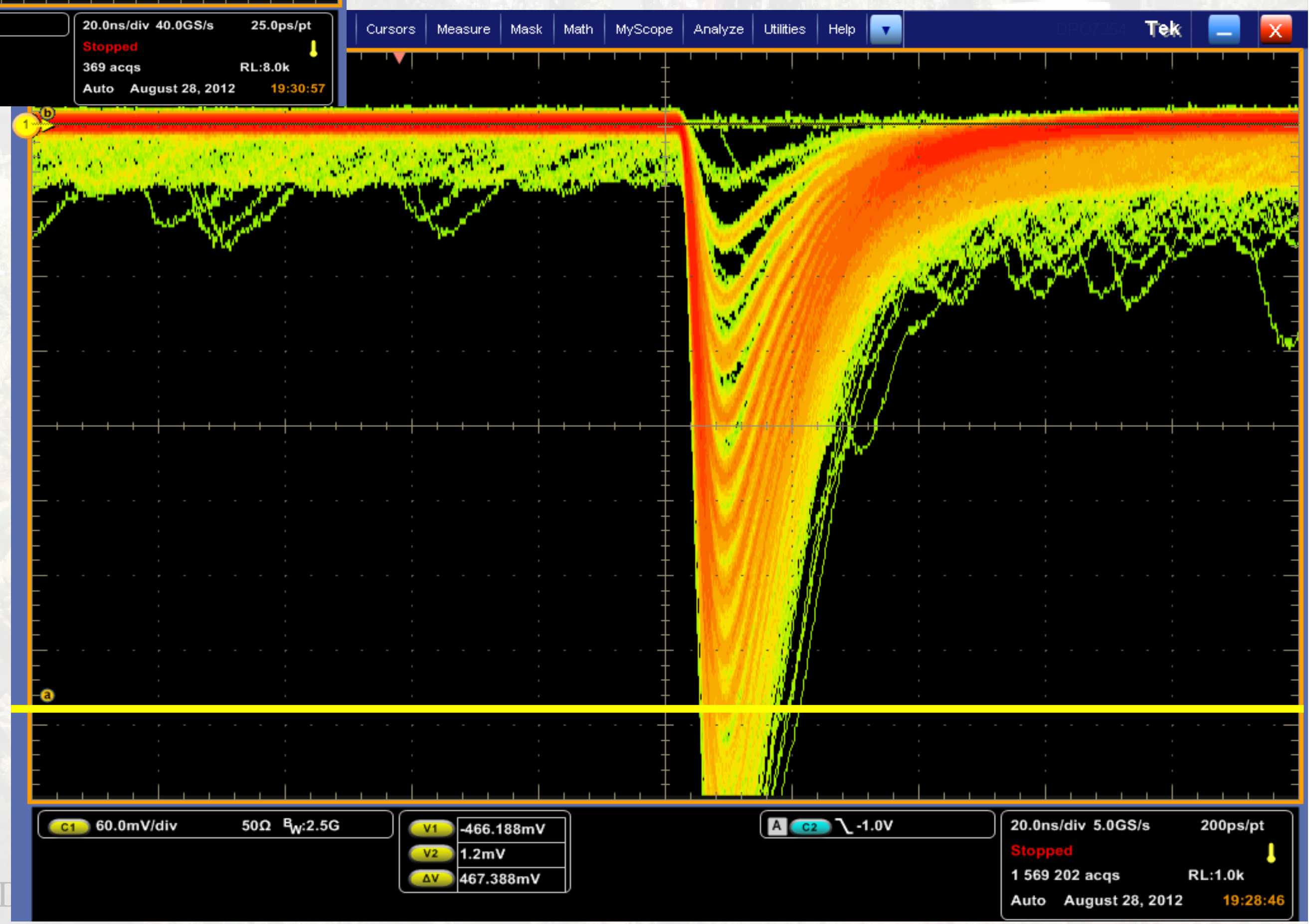
μ through beam dump (SciTil #2, west = S10931-050P)

M: > 1-3.5 V → 20-75 photons (50 expected)

U_{BIAS} = 71.8 V (reduced bias)

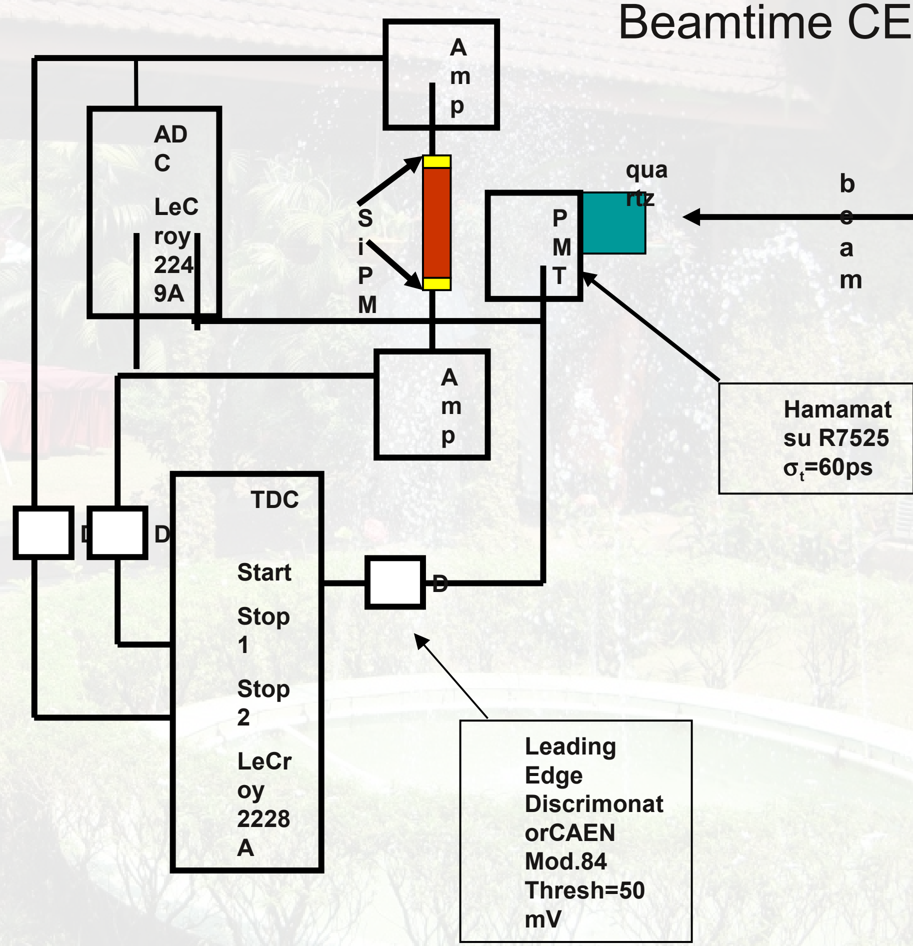
Photon number is reasonable

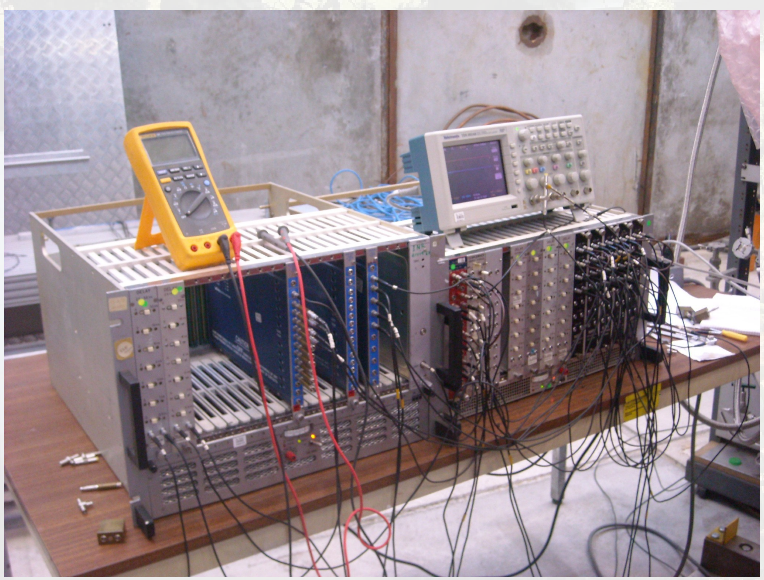
Laser: 10γ = 0.47V



Prototype “Guber” Experimental Setup

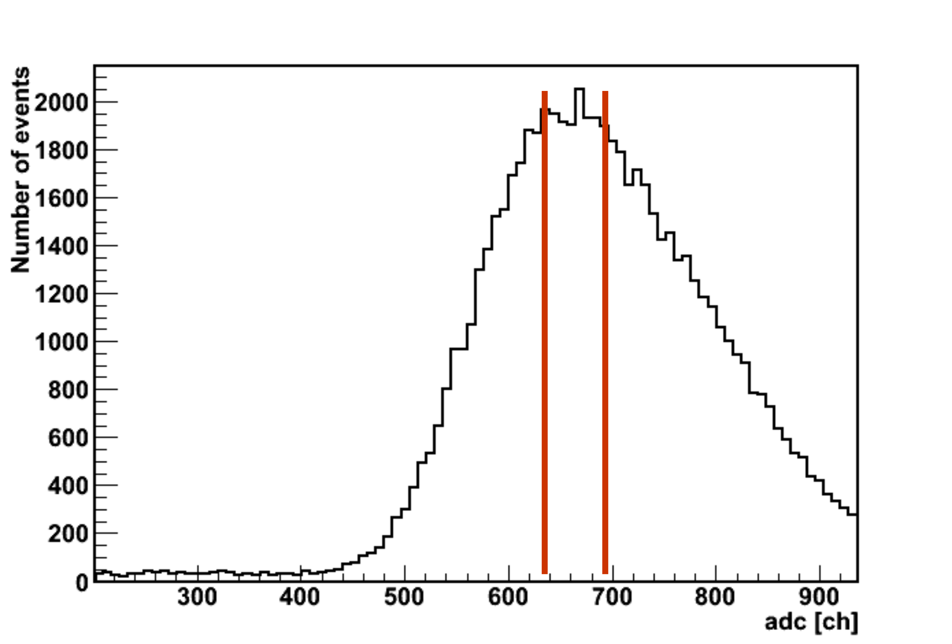
Fedor Guber, CBM
Beamtime CERN 2012

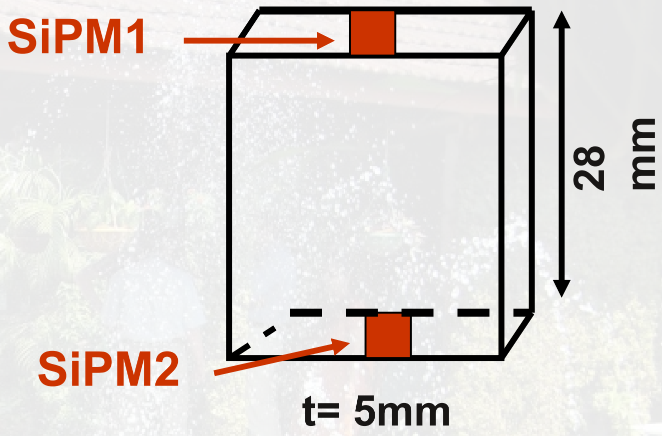




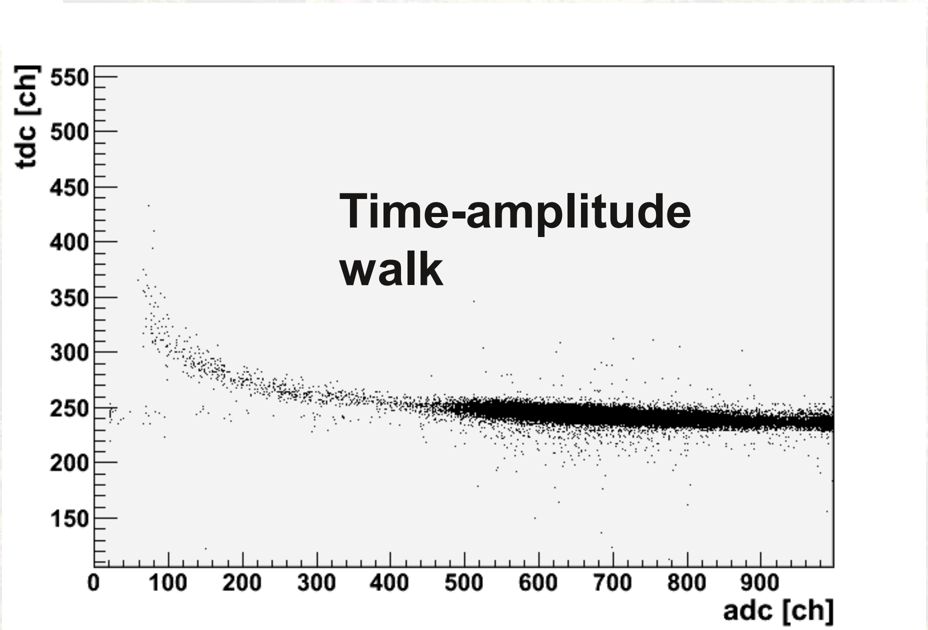
SiPM Workshop EU-FP7(HP3), Vienna, 16 Feb. 2013 F.G. H.O.

Amplitude spectra for KETEK SiPMs at small side



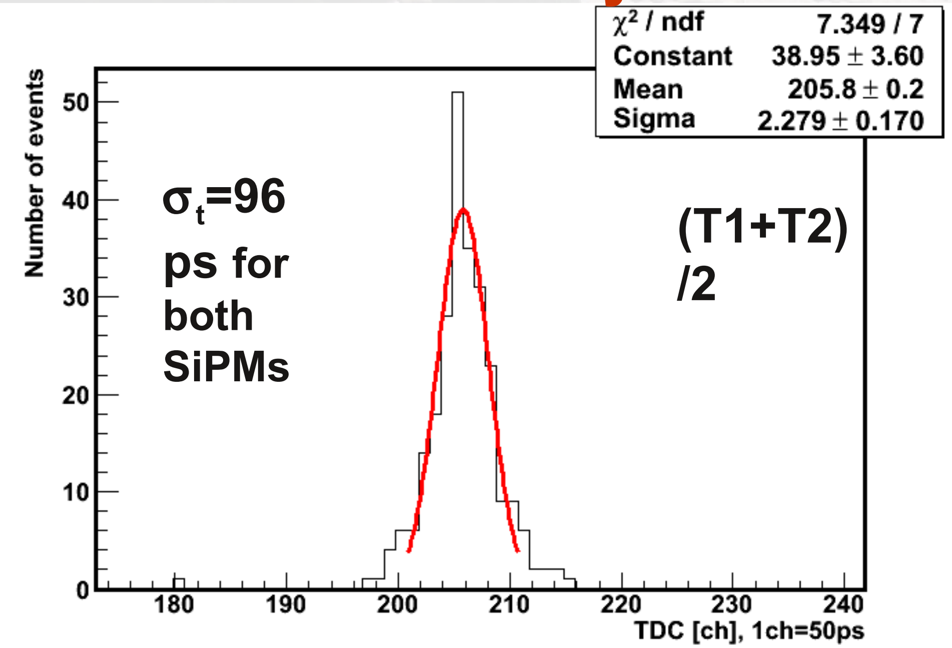


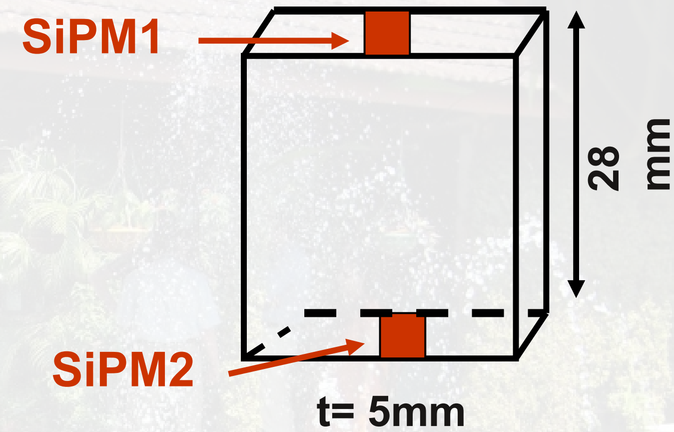
Time resolution was calculated for narrow ADC bin to avoid T-A walk



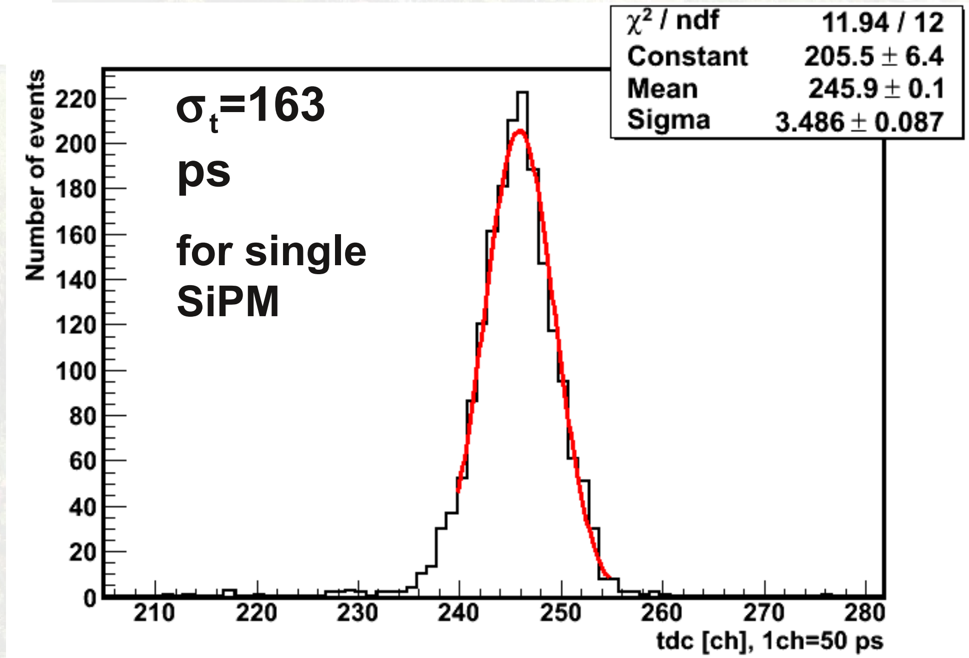
SiPM Workshop EU-FP7(HP3), Vienna, 16 Feb. 2013 F.G. H.O.

Time spectra for KETEK SiPMs at small sides for very narrow ADC bin=20 ch





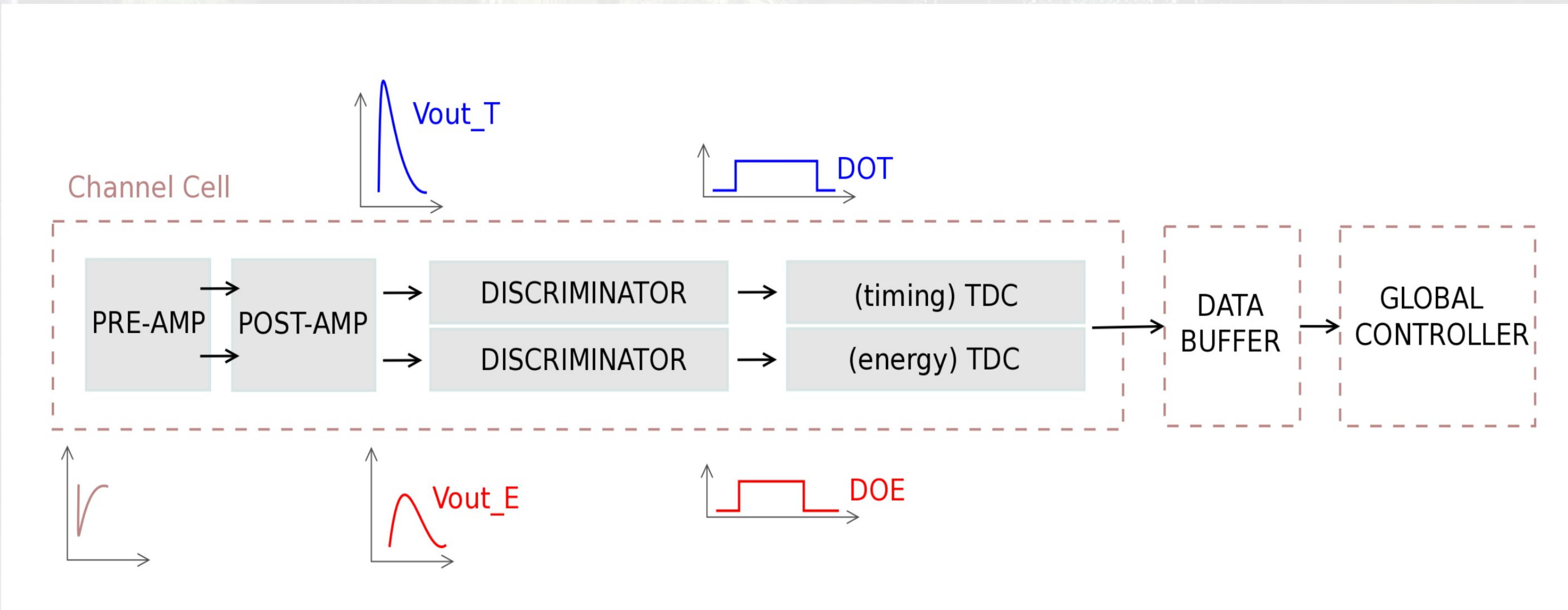
Measurement were done for very narrow ADC bin= 20 ch



SiPM Workshop EU-FP7(HP3), Vienna, 16 Feb. 2013 F.G. H.O.

ASIC for SiPM readout

TOF-PET ASIC for PET applications
M.D. Rolo JINST 8 C02050



Per channel:
100 kHz
7 mW

12000 tiles: → 84 Watts

2nd threshold
validation of events (i.e. dark count rejection) and provision of a second time stamp used for time-over-threshold measurement.
→ walk correction?

Conclusions

- SciTil time resolution 200-300ps
  - Little amplitude information
  - Probably caused by noise on cables

- Fedor Gubers experiment yields ~150ps
  - Narrow amplitude window selected
  - There is “walk”

- More R&D (test experiments) necessary
  - Integrated electronics like Torino PET-TOF (double threshold discriminator)

Outlook

Work package	Interested institutes
Simulation	BARC
Module design	GSI, BARC
Scintillator	Dubna, Gatchina
Silicon PM	EU HP3, BARC, Dubna, Gatchina
Readout design	EU HP3, BARC
Mechanical design	GSI
Prototype production	BARC

construction

R&D

Status:DAE - BRNS Workshop on Hadron Physics – 2011

New: Vienna, Mainz, Erlangen for R&D with test stands

SIPM Kick Off Meeting October 2011
→ https://indico.gsi.de/conferenceDisplay.py?confId=1367

Work Package	Interested Institutes
SiPM test facility	BARC

construction

R&D
- Prototype
- Electronic readout (TOF-PET)

>1year

Testing and documentation of 12000 sensors
- Dark current
- Bias
- Temperature dependence of bias

>1year

Testing and documentation of 6000 tiles
- Material
- Coupling of sensors

Assembly of 6000 tiles
- tiles
- electronics