"SciRods": An Alternative to SciTils?

A. Lehmann, S. Motz, et al.

- Motivation for "SciRods"
- Setup for Time Resolution Measurements
- Results

Motivation for SciRods

- **Problem:** 30 x 30 x 5 mm^3 SciTils read out with 3x3 mm^2 MPPCs show only a moderate time resolution (>200 ps) up to now

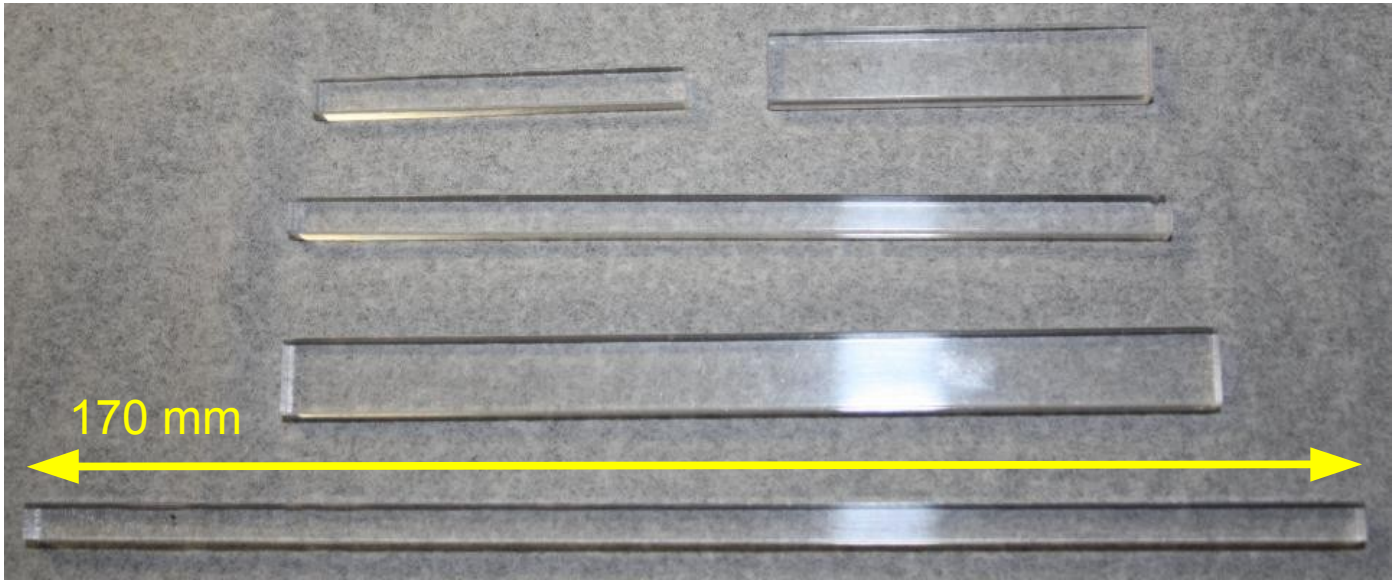
- Possible cause:
  - Many reflections in all directions before photons hit MPPC
  - Detected photons are distributed over a rather wide time interval
  - Only few photons arrive "prompt" → time resolution suffers

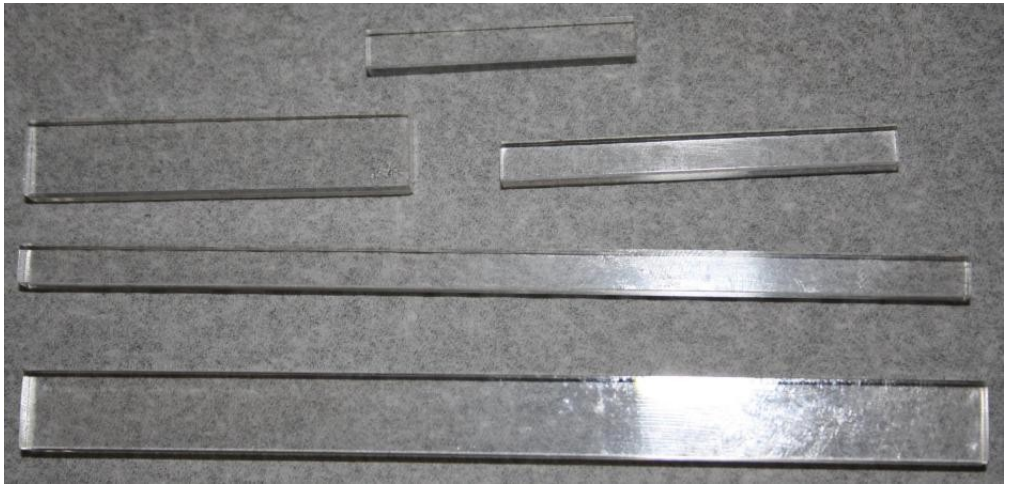
- Advantages of SciRods (e.g., 5 x 5 x 120 mm^3):
  - Use only photons totally reflected inside scintillator
    → collected photons at MPPCs arrive within a short time window
  - Read out at both scintillator ends with 3x3 mm^2 MPPCs
    → good solid angle coverage for scintillation photons
    → many "prompt" photons
  - Read out at both ends → position resolution along SciRod

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



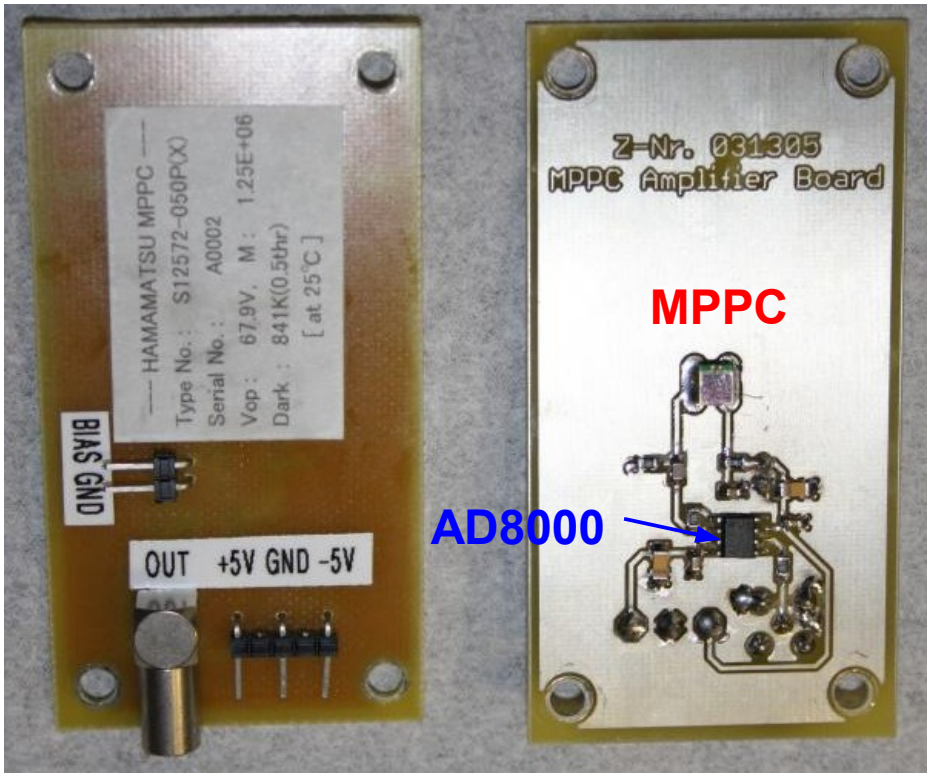


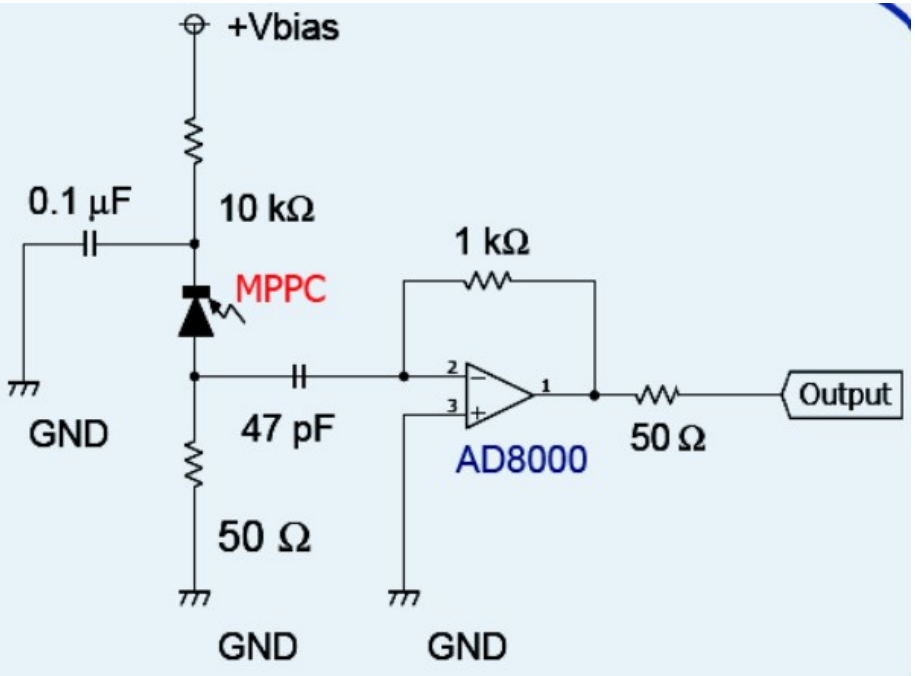
BC420 (τ = 1.5 ns)

- 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

Readout

- Readout circuit taken from a talk of H. Kanda given at PhotoDet 2012
  - Inverting amplifier circuit with AD8000 high speed chip (1.5 GHz)
  - Capacitive coupling with 47 pF



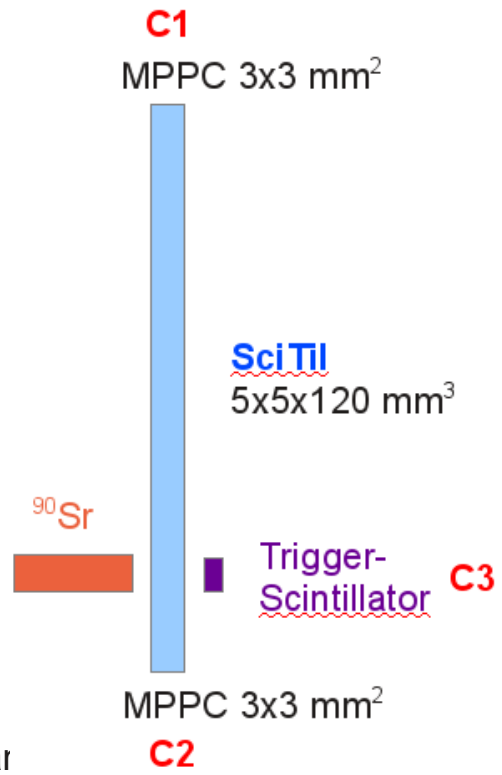


- MPPCs (3x3 mm^2)
  - Hamamatsu standard
    - S10362-33-100P
    - S10362-33-050P
  - Hamamatsu lower afterpulsing
    - S12572-33-050P
    - S12572-33-015P

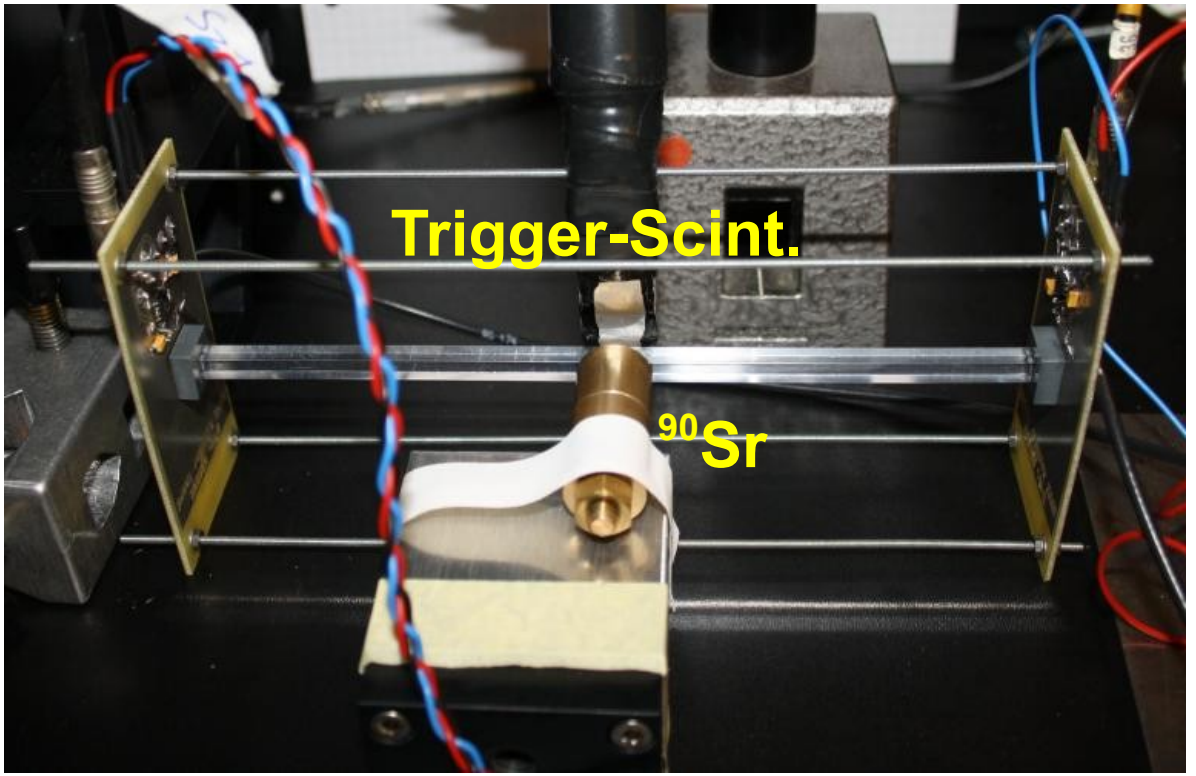
Measurement Setup

- Scintillator rod read out at both sides with Hamamatsu MPPCs
  - No aluminum wrapping (→ collect only totally reflected photons)
  - Measure pulse heights (→ number of photons)
  - Measure time difference (→ time resolution)

Source: 1 mCi ^{90}Sr with 1 mm aperture



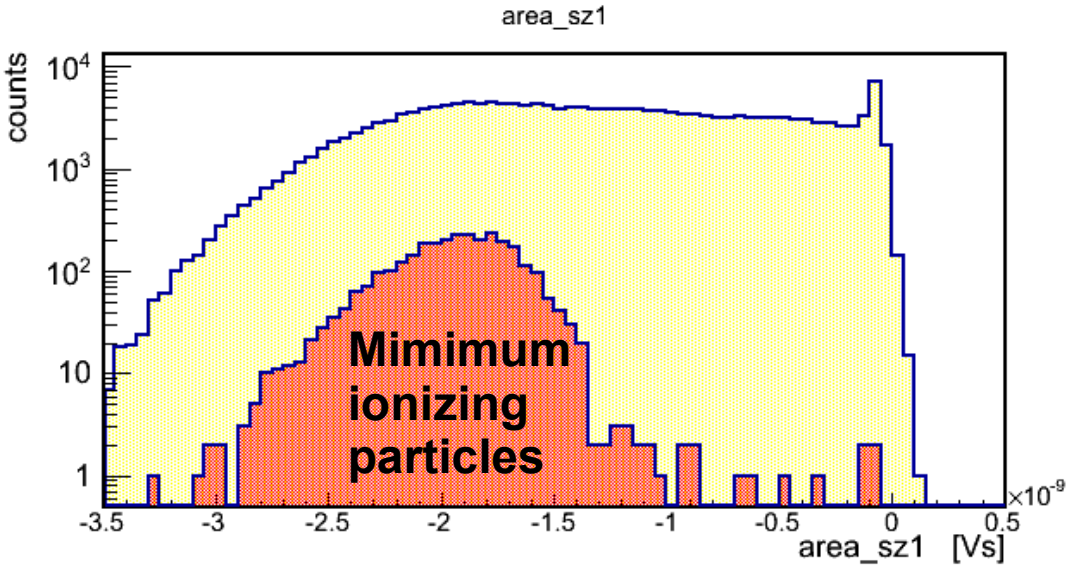
Trigger Scintillator: ~3 mm Ø from PS185

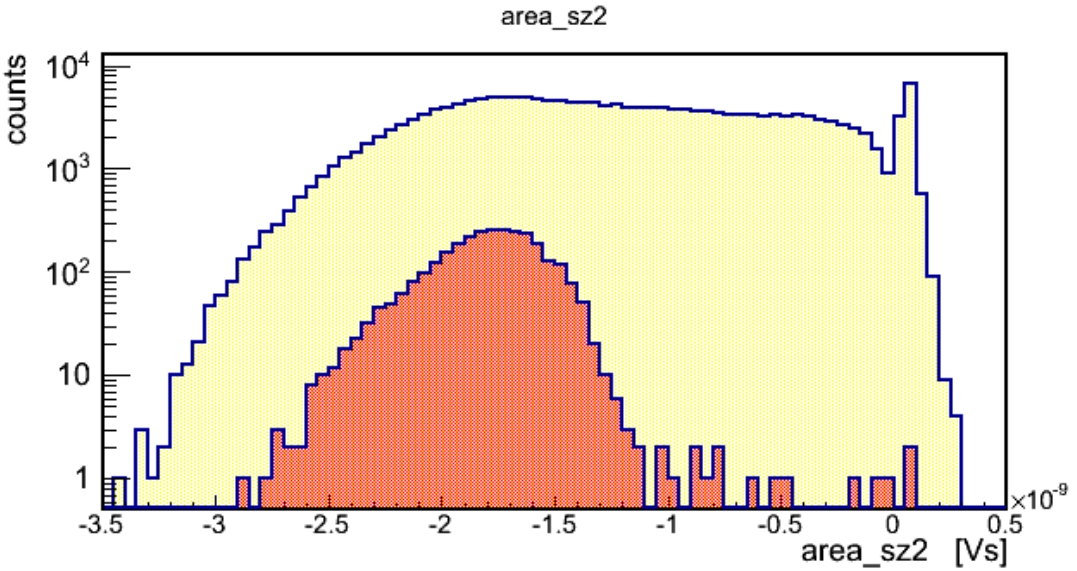


Expected Number of Photons

- Beta electrons simulate minimum ionizing particle
  - Energy loss in 5 mm thick scintillator (e.g. 5x5x120)
    - **~1 MeV** (0.92 MeV exact)
  - Number of photons created in 5mm BC408 scintillator
    - ~9000
- Number of photons at 3x3 mm^2 MPPCs
  - Assuming PDE of 25% and totally reflected photons
  - **~150 detected photons** at each side expected

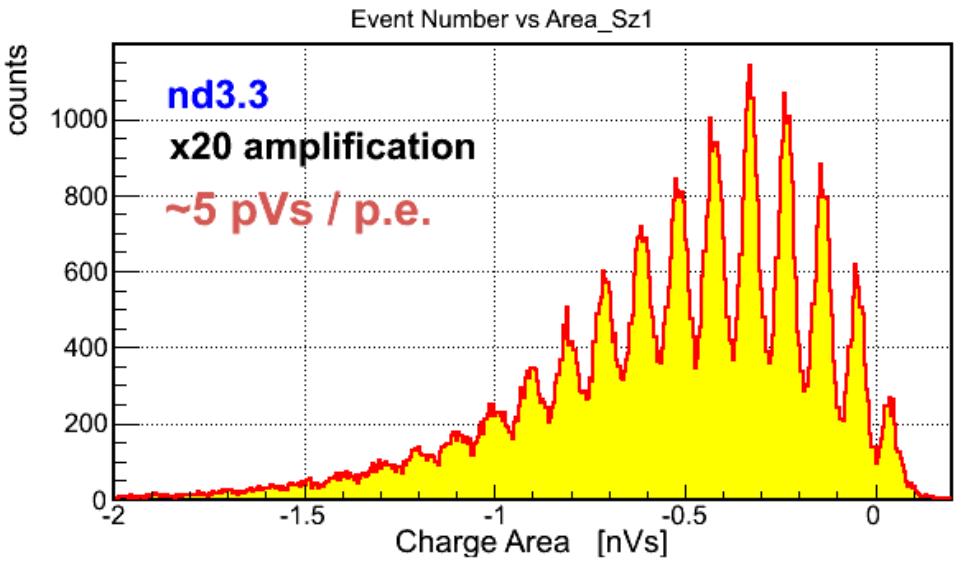
Event rate at trigger: ~350 Hz

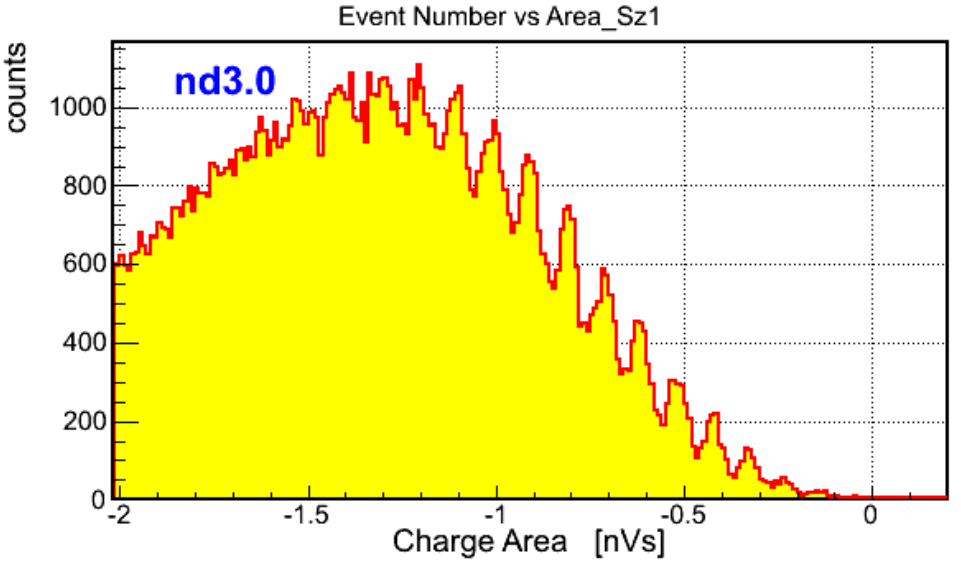




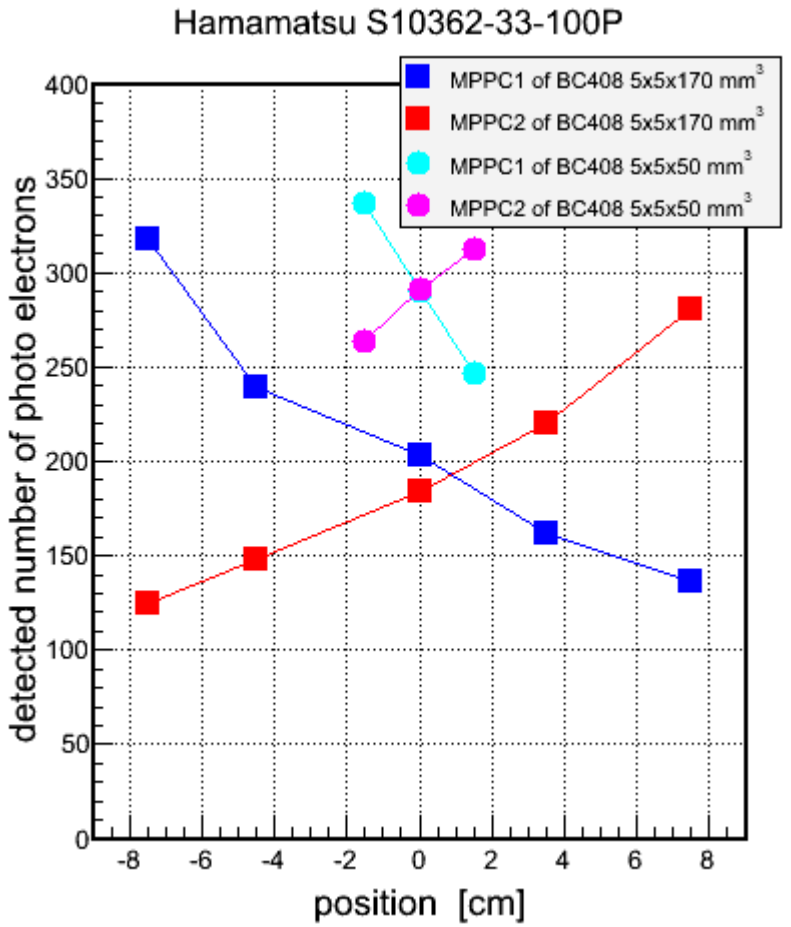
Pulse Height Calibration

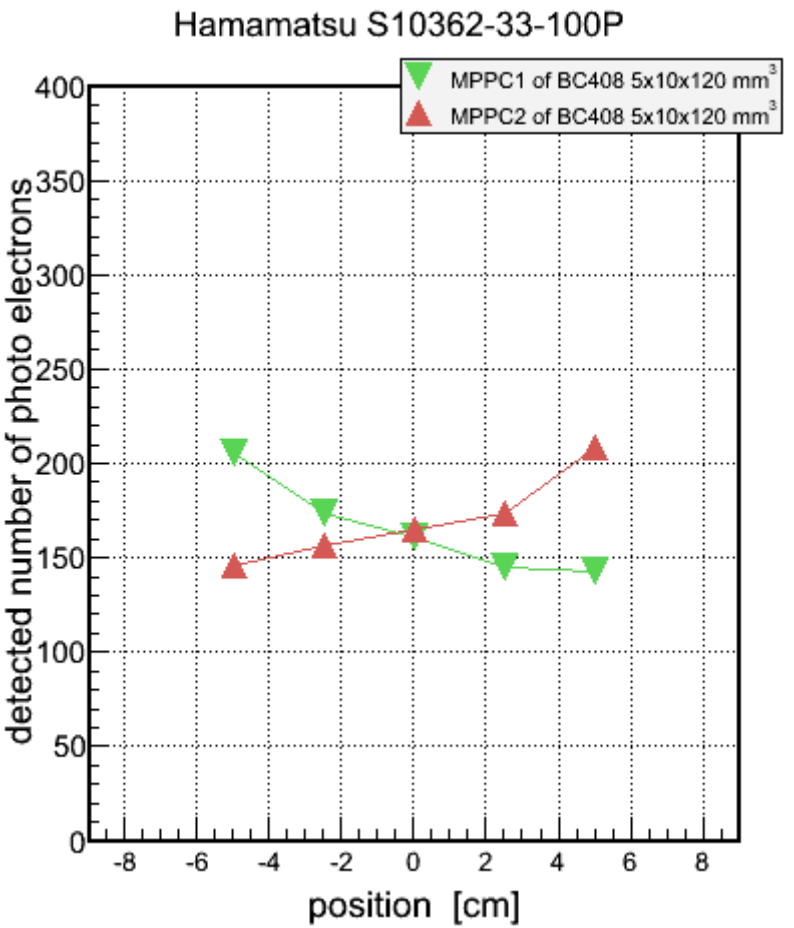
- Calibration was done with pulsed laser light (372 nm) on MPPCs (also possible with darkcount)
- Whole charge scale calibrated by using different ND filters
  - S10362-33-100P at V_{op} = 72.5 V
  - AD8000 + PS775 (x20) amplifiers
- Each peak corresponds to one photon:
  - ~5 pVs / p.e.
  - charge scale linear up to several hundred photo electrons
  - tested with different ND filters (nd3.3 to nd2.0)





Measured Number of Photons



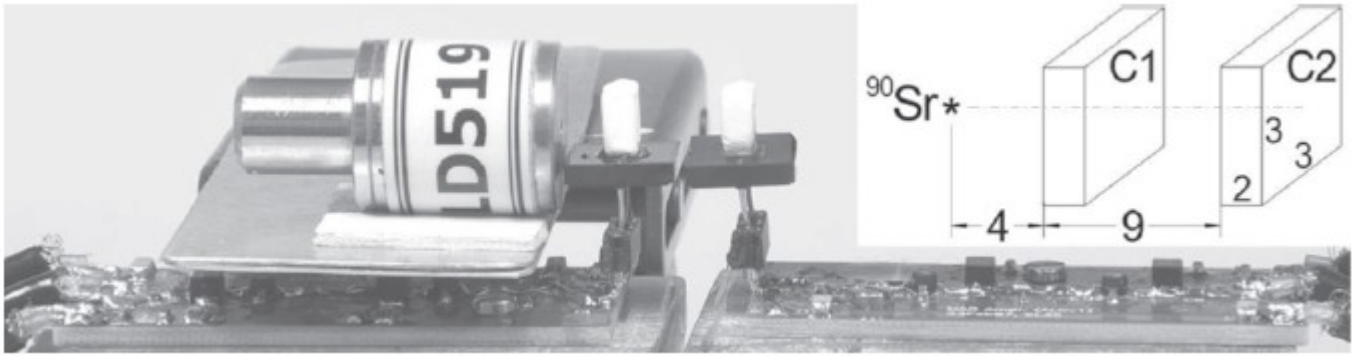


- Detect too many photons → maybe not only "prompt" photons
- Quite considerable loss of photons along the rods
- Measure less photons with 5x10x120 mm^3 rod as expected

Estimation of Time Resolution

A. Stoykov, et al.; NIM A695 (2012) 202-205; "A time resolution study with a plastic scintillator read out be a Geiger-mode Avalanche Photodiode"

Setup uses 2 samples of BC422 (3 x 3 x 2 mm^3) read out by Hamamatsu MPPCs 10362-33-050



Time resolution measured:

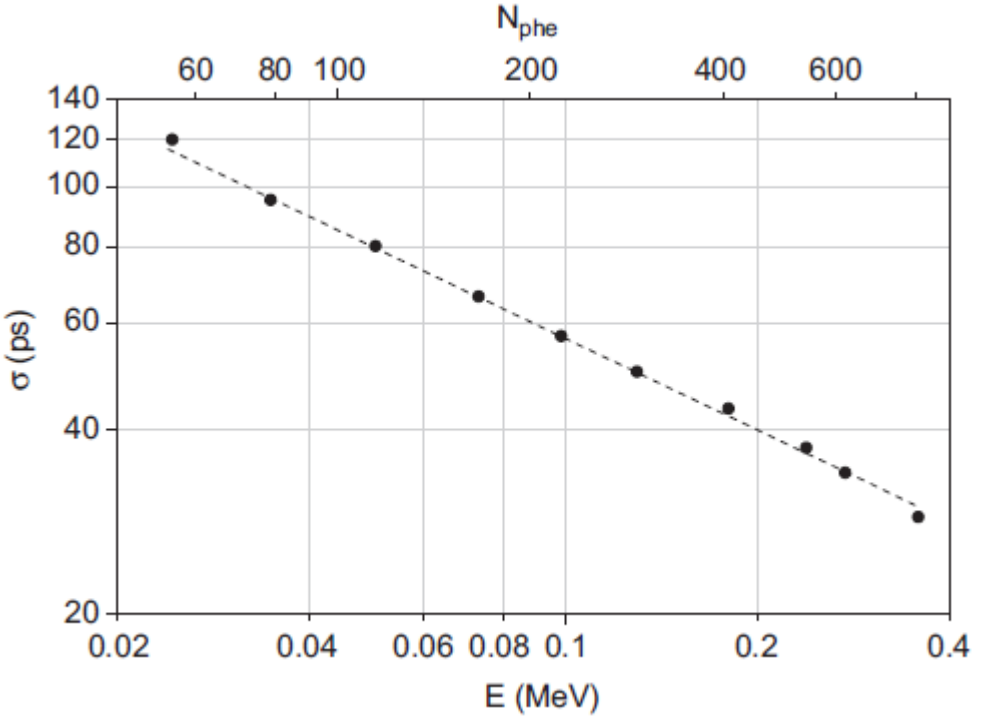
$\sigma_t = 18\ ps \cdot MeV^{0.5}$

This roughly corresponds to

100 ps with 80 photo electrons

70 ps with 150 photo electrons

50 ps with 300 photo electrons

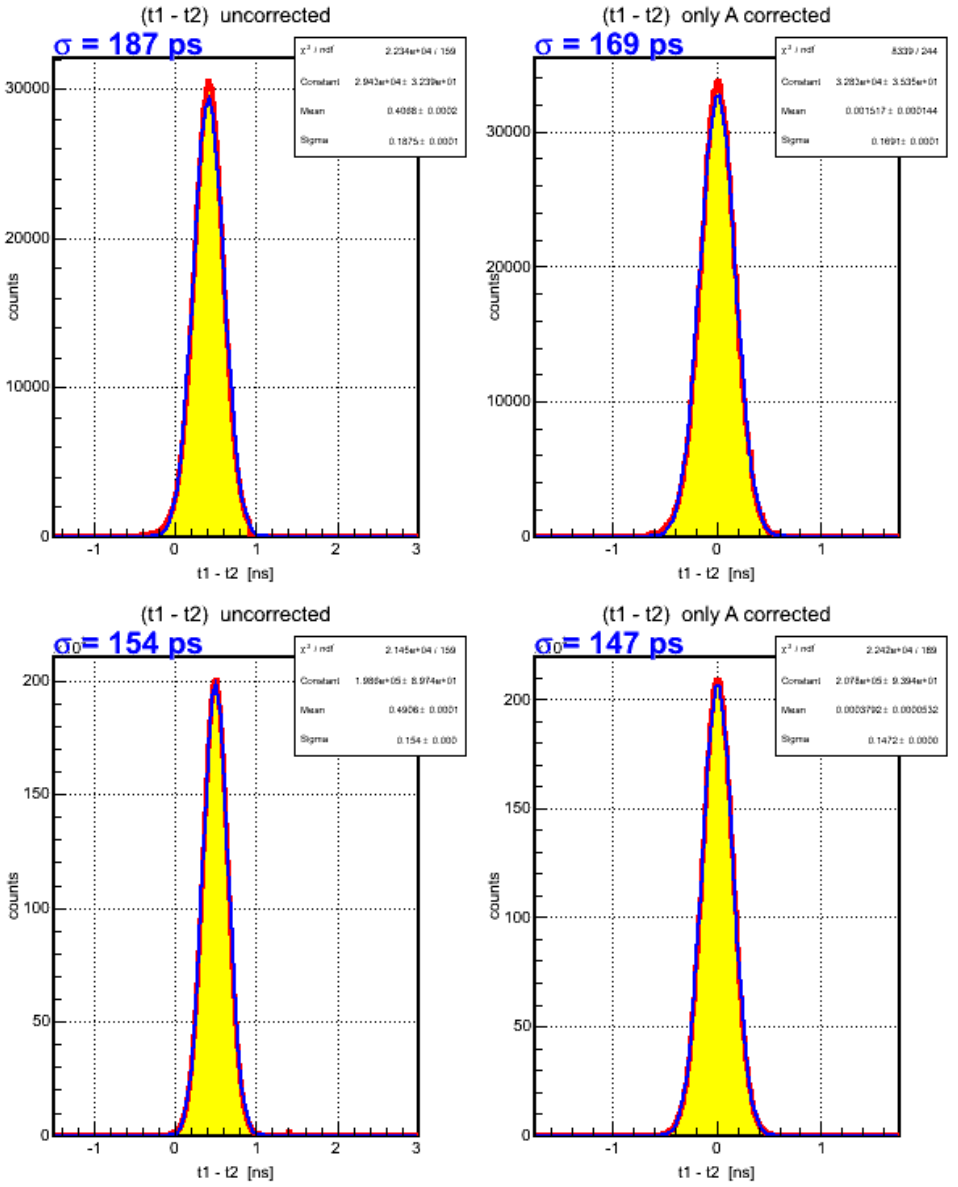


First Time Resolution Result

- **Setup:** 5 x 5 x 120 mm^3 BC408 SciRod irradiated in the center and read out by two 3x3 mm^2 MPPCs (Hamamatsu S10362-33-100P)

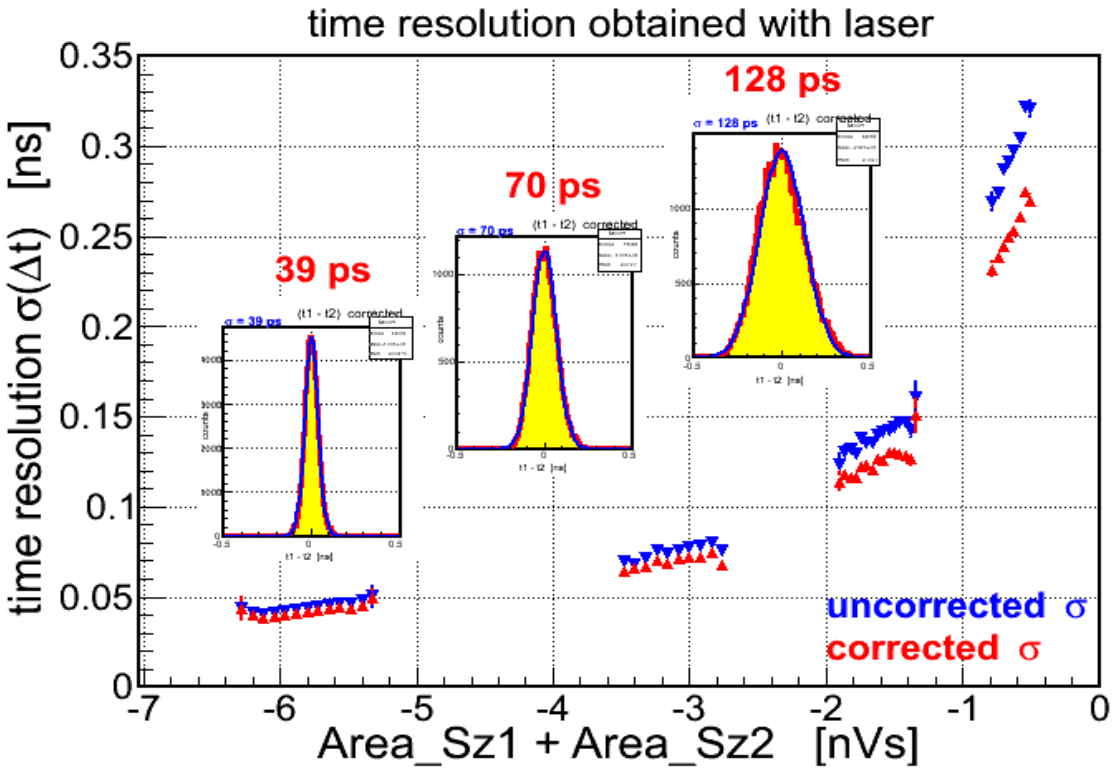
- Time difference between ends
  - with AD8000 amplifier only
  - Time signal taken with LeCroy 821 discriminator at -35 mV
  - $\sigma(\Delta t) = \sigma(t_1 - t_2) = 187$ ps
  - Improve time resolution (169 ps) with pulse height corrections

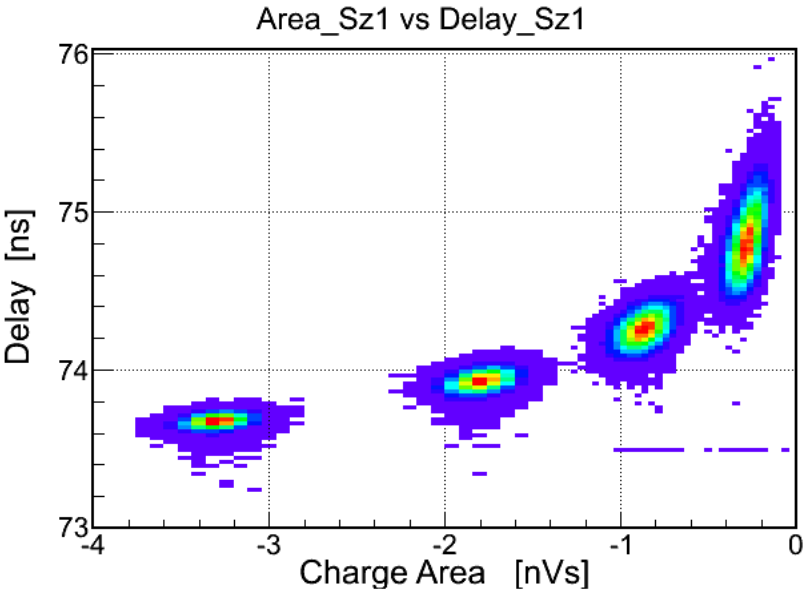
- Δt with more amplified signals:
  - AD8000 and PS776 (x10)
  - 154 ps uncorrected
  - 147 ps corrected

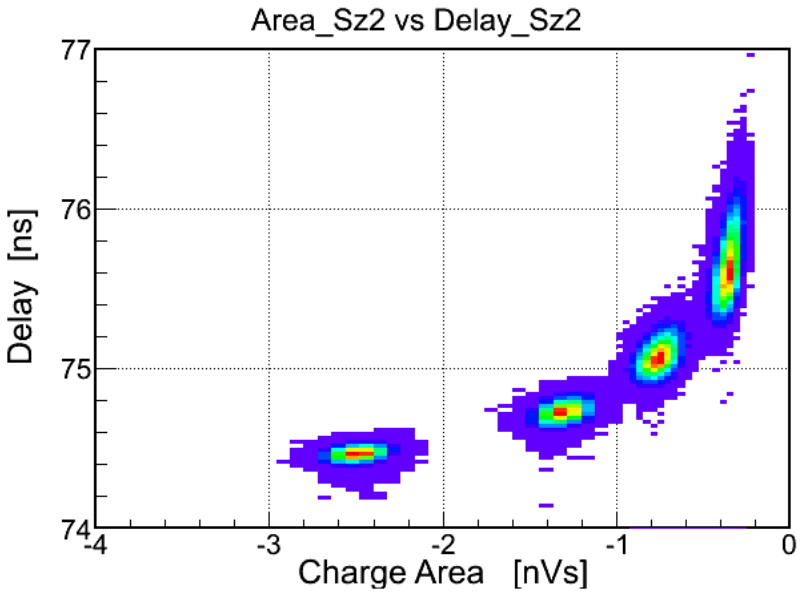


Time Resolution with Laser

- laser light (372 nm) into center of 5x10x50 mm^3 BC408 scintillator
- -1 nVs corresponds to ~200 Npe
  - expected for minimum ionising particle
  - $\sigma_{\Delta t} \approx$ **70-130 ps**

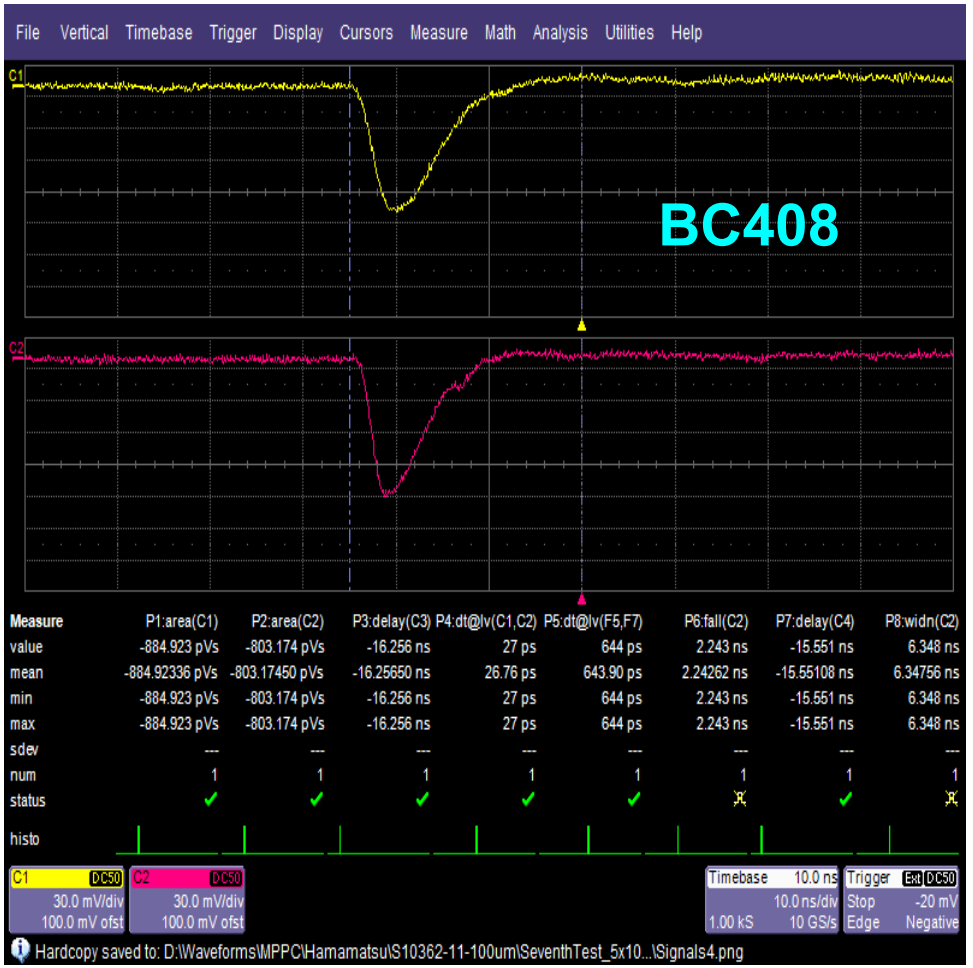






Pulse Widths

Scintillator 5x10x120 mm^3
MPPC S10362-33-100P



BC408
width(C1) = 6.7 ns
width(C2) = 6.3 ns

BC420
width(C1) = 5.9 ns
width(C2) = 5.6 ns

Time Resolutions (1)

Scintillator 5 x 5 x 120 mm^3

Scintillator	MPPC	left		center		right
		σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)
BC408	S10362-100P	175		187		202
	S10362-100P(x10)	142		154		148
	S12572-050P	143		173		148
BC420	S12572-015P	119		215		125
	S12572-050P	99	158	147	113	104

Scintillator 5 x 10 x 120 mm^3

Scintillator	MPPC	left		center		right
		σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)
BC408	S10362-100P	175	232	266	195	186
BC420	S10362-100P	150		242		164

BC420 scintillator provides better results than BC408

Time Resolutions (2)

Scintillator 5 x 5 x 50 mm^3

Scintillator	MPPC	left		center		right
		σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)
BC408	S10362-100P	136		205		148
	S12572-050P	147		134		136
BC420	S12572-050P	155		128		101

Scintillator 5 x 10 x 50 mm^3

Scintillator	MPPC	left		center		right
		σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)
BC408	S10362-100P	226		245		184

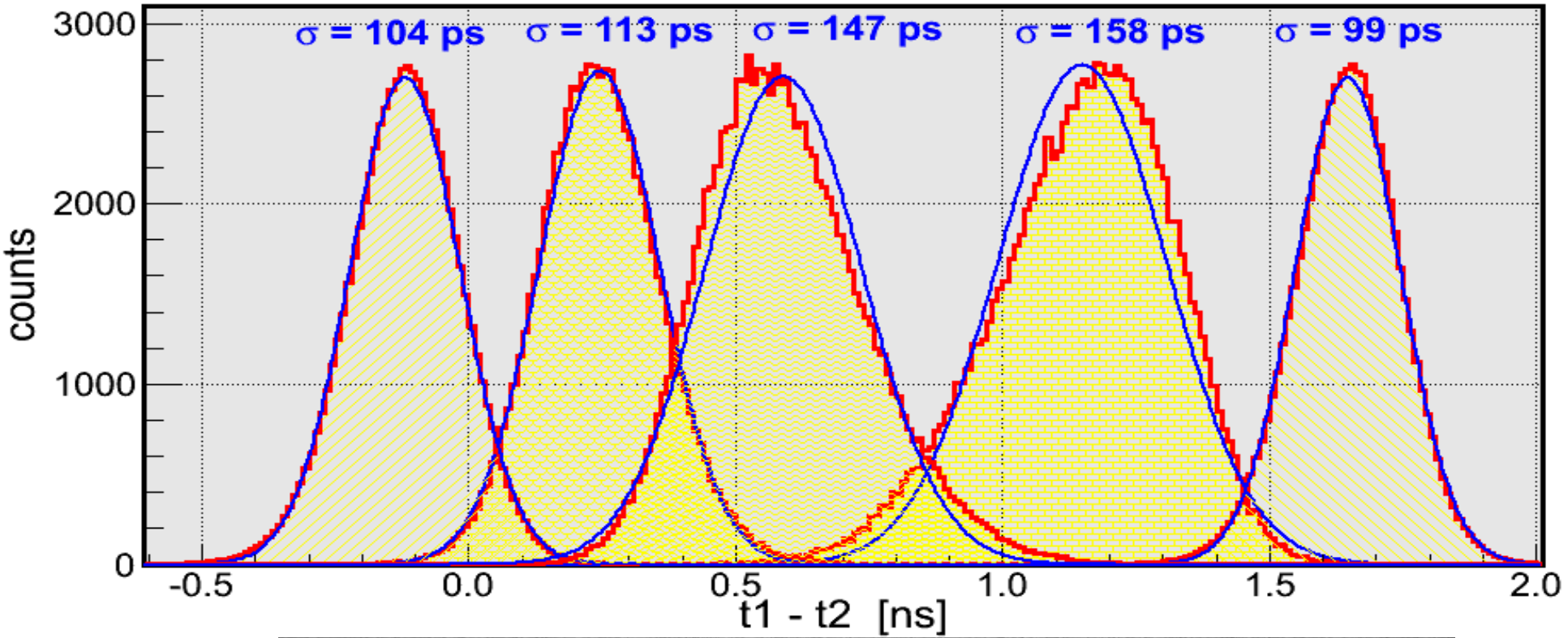
Scintillator 5 x 5 x 170 mm^3

Scintillator	MPPC	left		center		right
		σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)	σ(t1-t2)
BC408	S10362-100P	176	170	258	169	198

Longer and wider rods tend to give worse time resolution

Position Resolution

MPPC S12572-33-050P (t1 - t2) uncorrected of BC420 5x5x120 mm3



- Position resolution with σ_t = 100 ps:

  Δx(FWHM) = 100 mm * 235 ps / 1770 ps = **13 mm**

Summary and Outlook

- Various sizes of SciRods and different MPPCs tested
- First Tests with SciRods show promising results
  - number of detected photons somewhat higher than expected
    - attenuation along the rods
  - time difference (t_1-t_2) resolution varies between 100 and 200 ps
    - → **single counter resolution between 70 and 140 ps**
    - better than SciTils
    - position resolution (FWHM) down to 13 mm
- Outlook:
  - xy-scans of whole surface for σ(Δt) and N_{pe} are planned
  - other amplifier circuits will be tested
  - run readout with new TRB boards (possibly with ADCs)