Time resolution measurements of scintillation counters with SiPM readout for new NA62 trigger Charged Hodoscope (CHOD)

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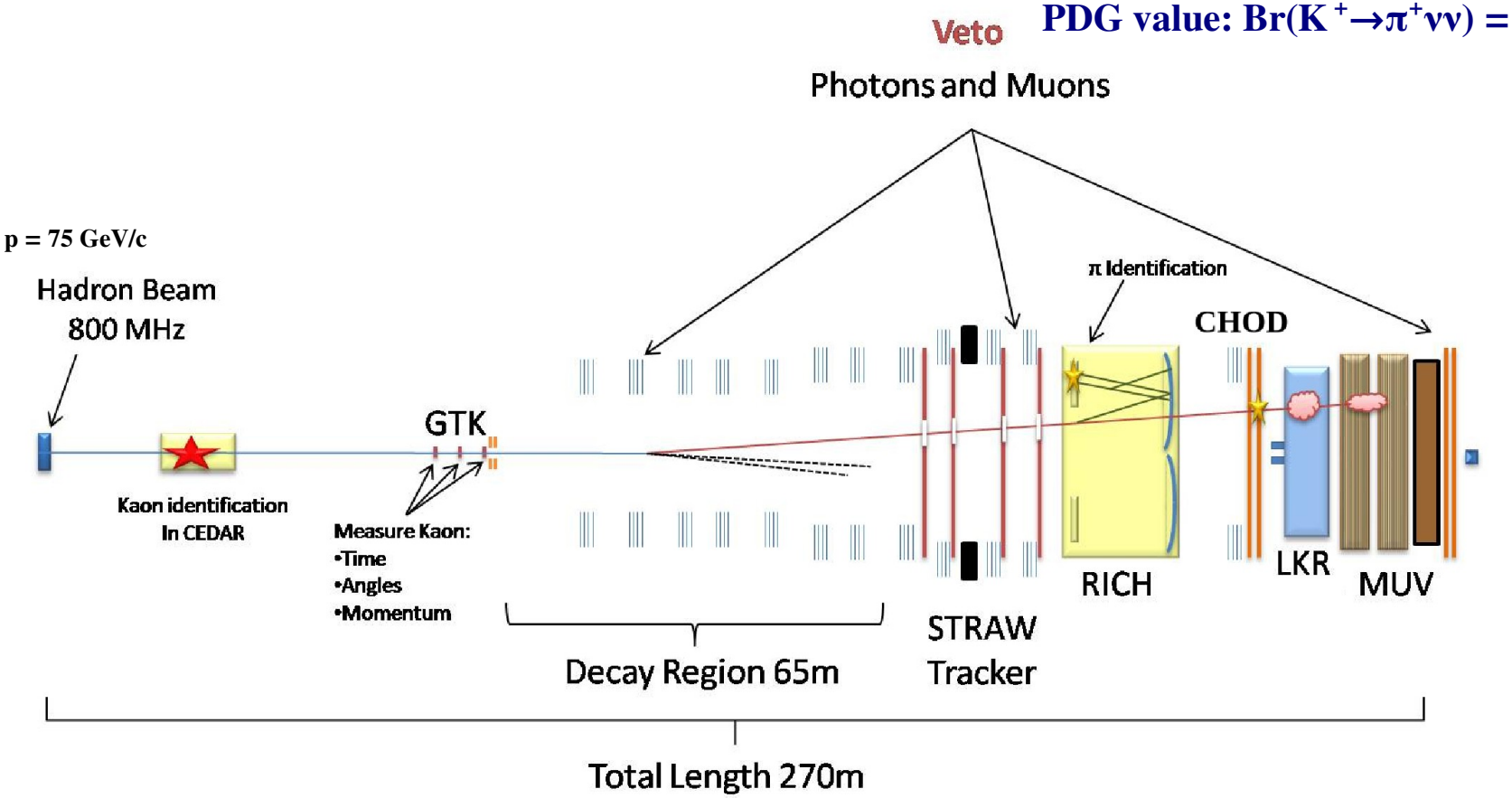
NA62 setup

Main goal: Measuring $Br(K^+ \to \pi^+ \nu\bar{\nu})$ with 10% precision

PDG value: $Br(K^+ \to \pi^+ \nu\bar{\nu}) = (1.7 \pm 1.1) \times 10^{-10}$



Kaon id & $\overline{\text{Beam killer}}$	~10 MHz
L0 (RICH, LKr, LAV, MUV, CHOD)	~1 MHz
L1 (single detector Software level)	~100 KHz
L2 (multi detector Software level)	few KHz

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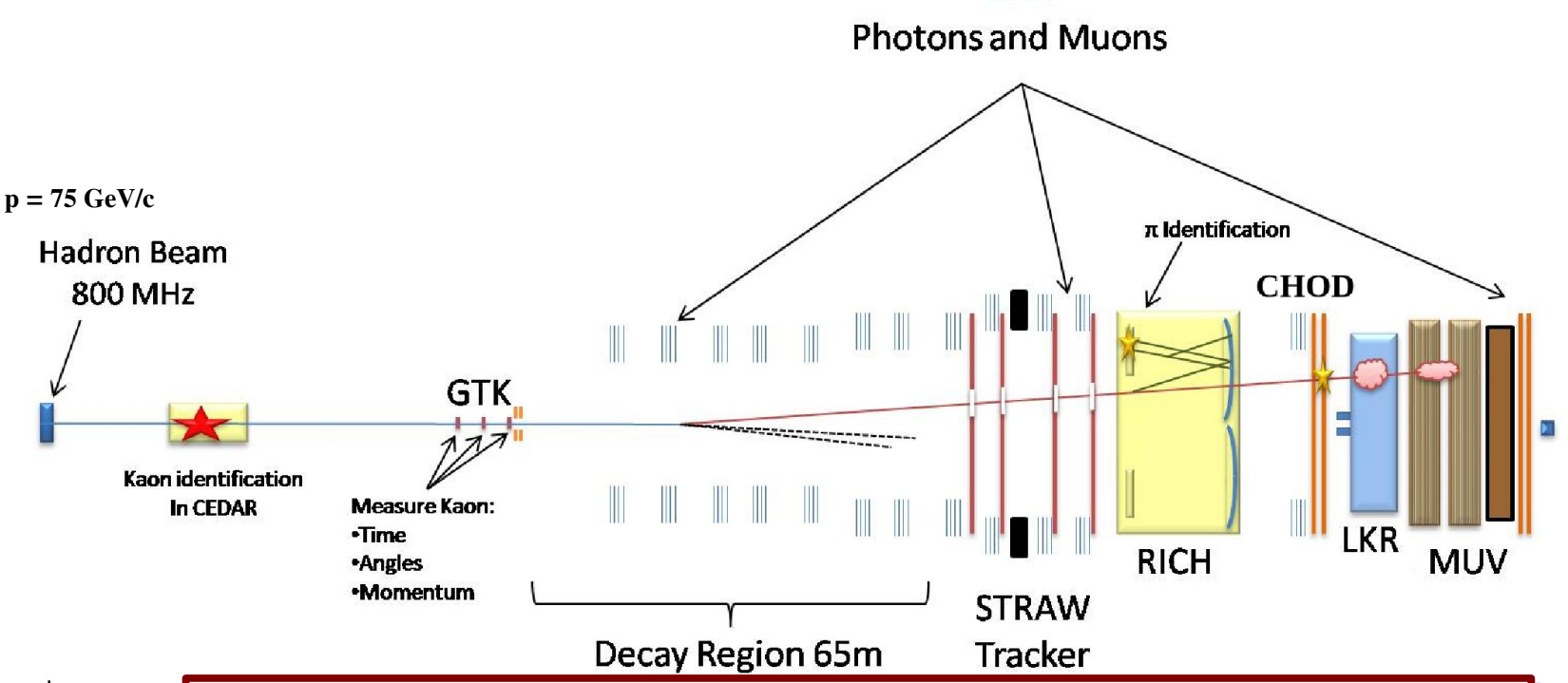
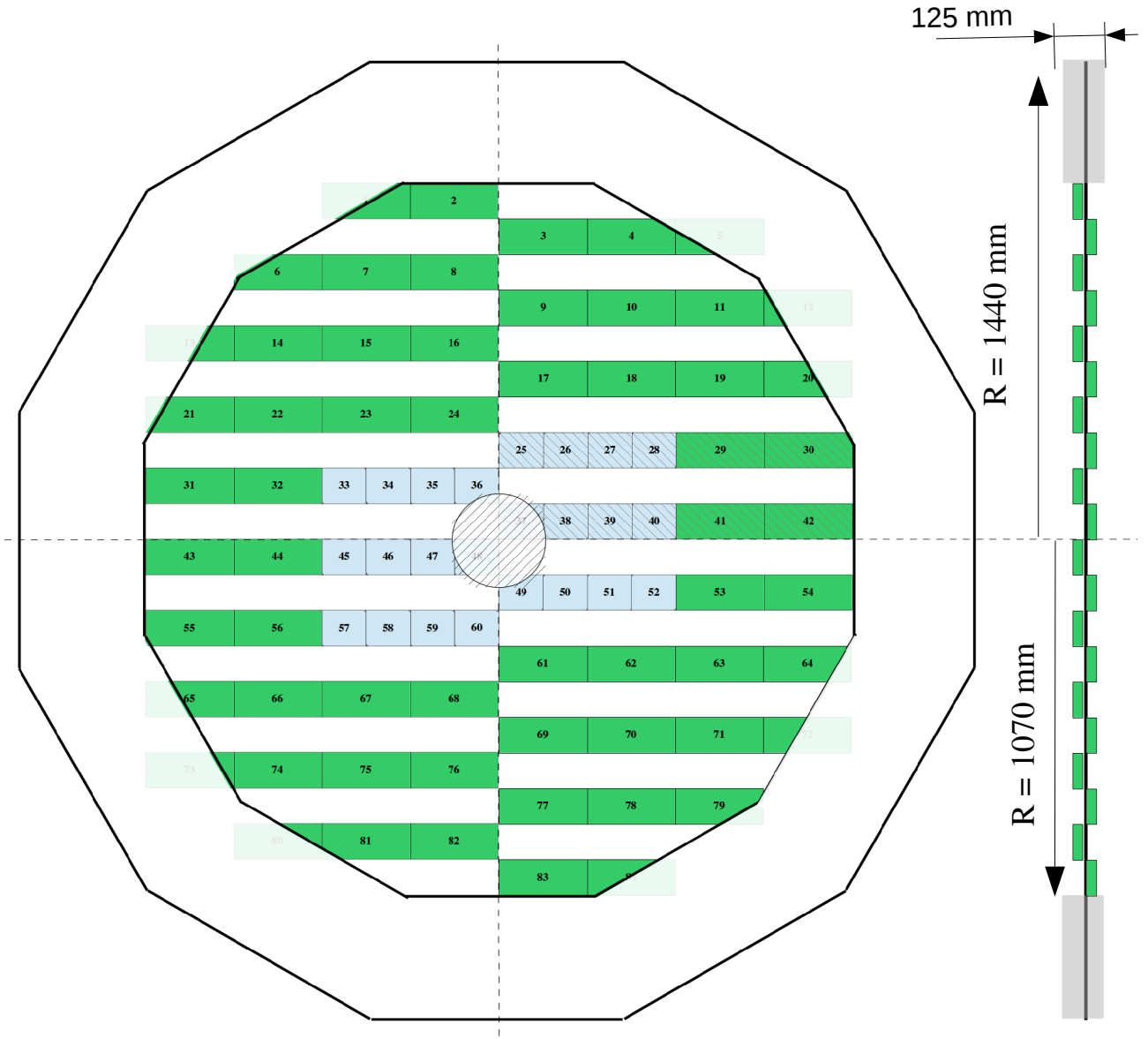


CHOD in L0 trigger:

- Trigger on multiplicity
- Detect possible photo-nuclear reaction in the RICH mirror plane
- Back-up the RICH in the L0 trigger for charged tracks.
- ...

New CHOD preliminary design



- Pad structure

148 pads / 296 electronic channels

100x Green: 265 x 107 mm^2

48x Blue: 132 x 107 mm^2

- on-line time resolution

$\sigma < 600$ ps

Trigger Gate length < 5 ns

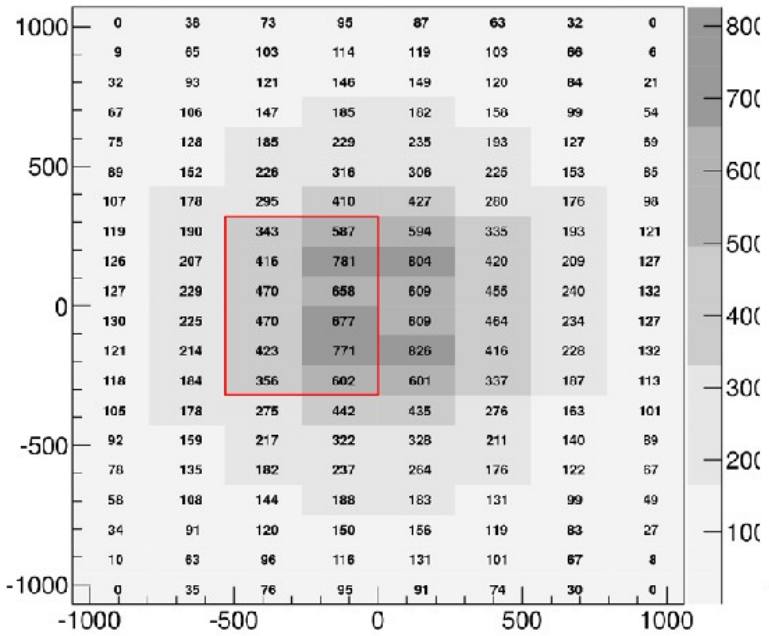
- Rate / Channel

< 400-500 KHz

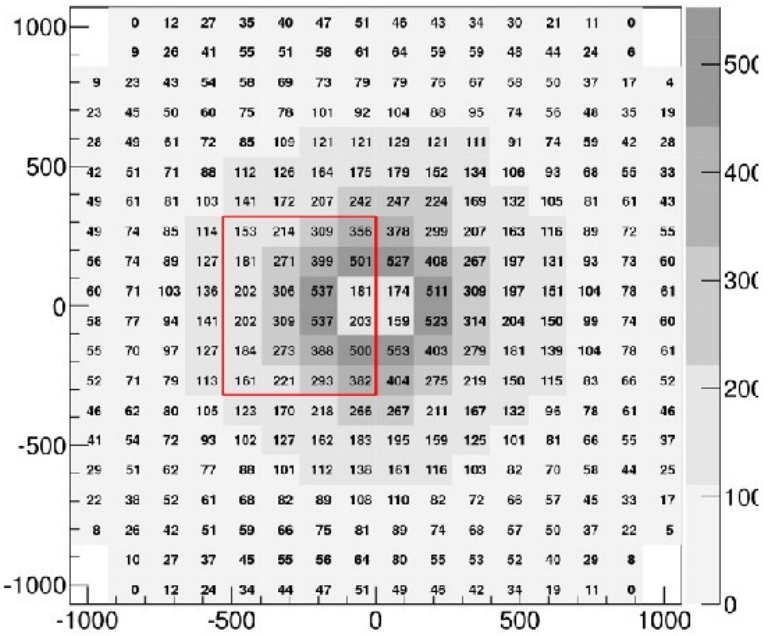
MC: CHOD rate per tile

Total rate per tile in kHz [REAL]

SMALL tiles (123.5 x 107 mm)



Total rate (OR): 32 MHz



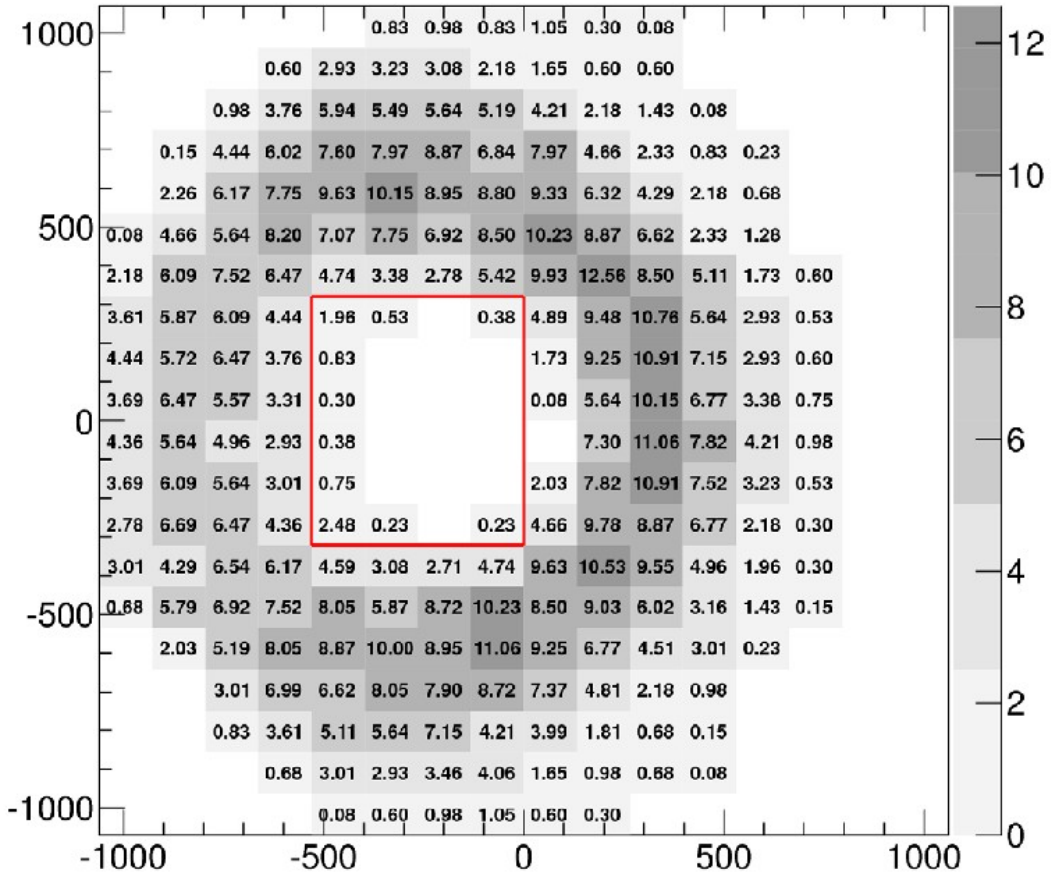
Total rate (OR): 35 MHz

Backsplashes included!

Spasimir Balev 16/05/2013

MC: CHOD K → πνν̄ acceptance

Signal acceptance in ‰ per **small tile**



πνν after all analysis cuts

Red area proposed to be excluded from main L0 trigger (this makes it possible to exclude the busiest MUV3 module with ~MHz rate)

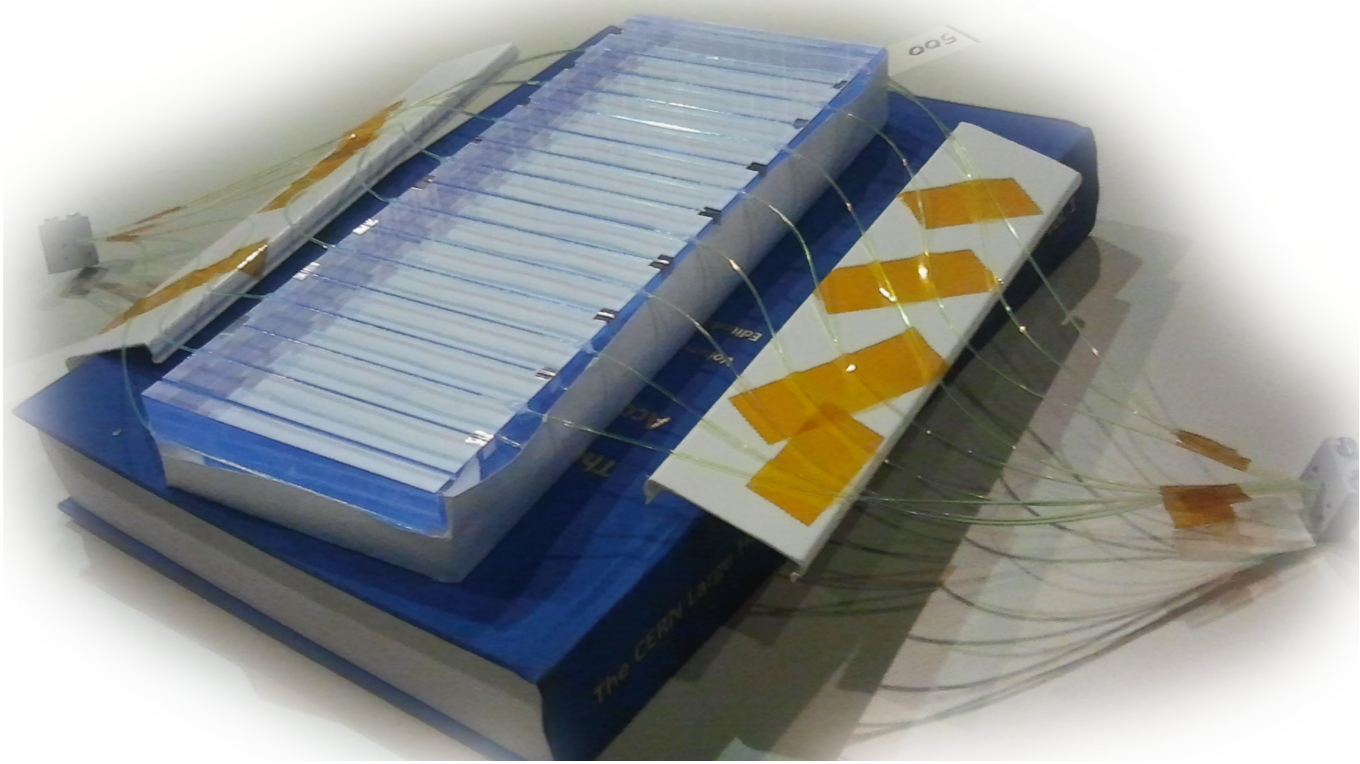
The cost:
Less than 1% signal loss

Spasimir Balev 16/05/2013

CHOD counters (prototype)

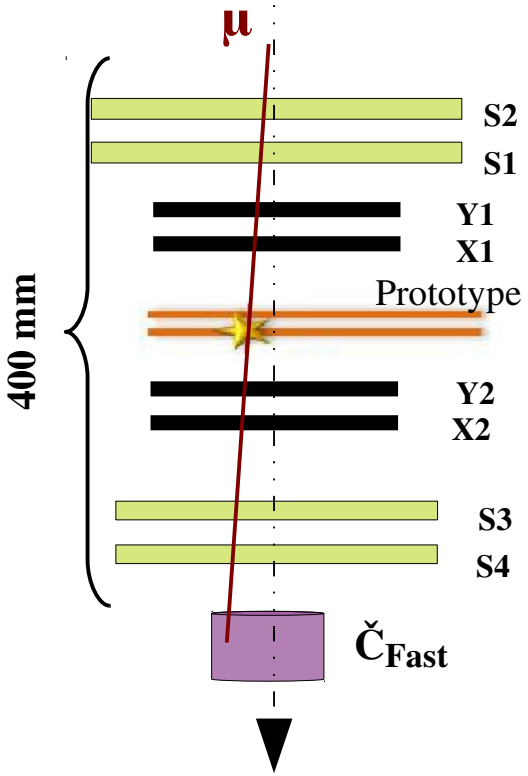
Direct readout	
Size:	132.5 x 107 x 20 mm^3
SiPM:	2x SensL MicroFB-60035

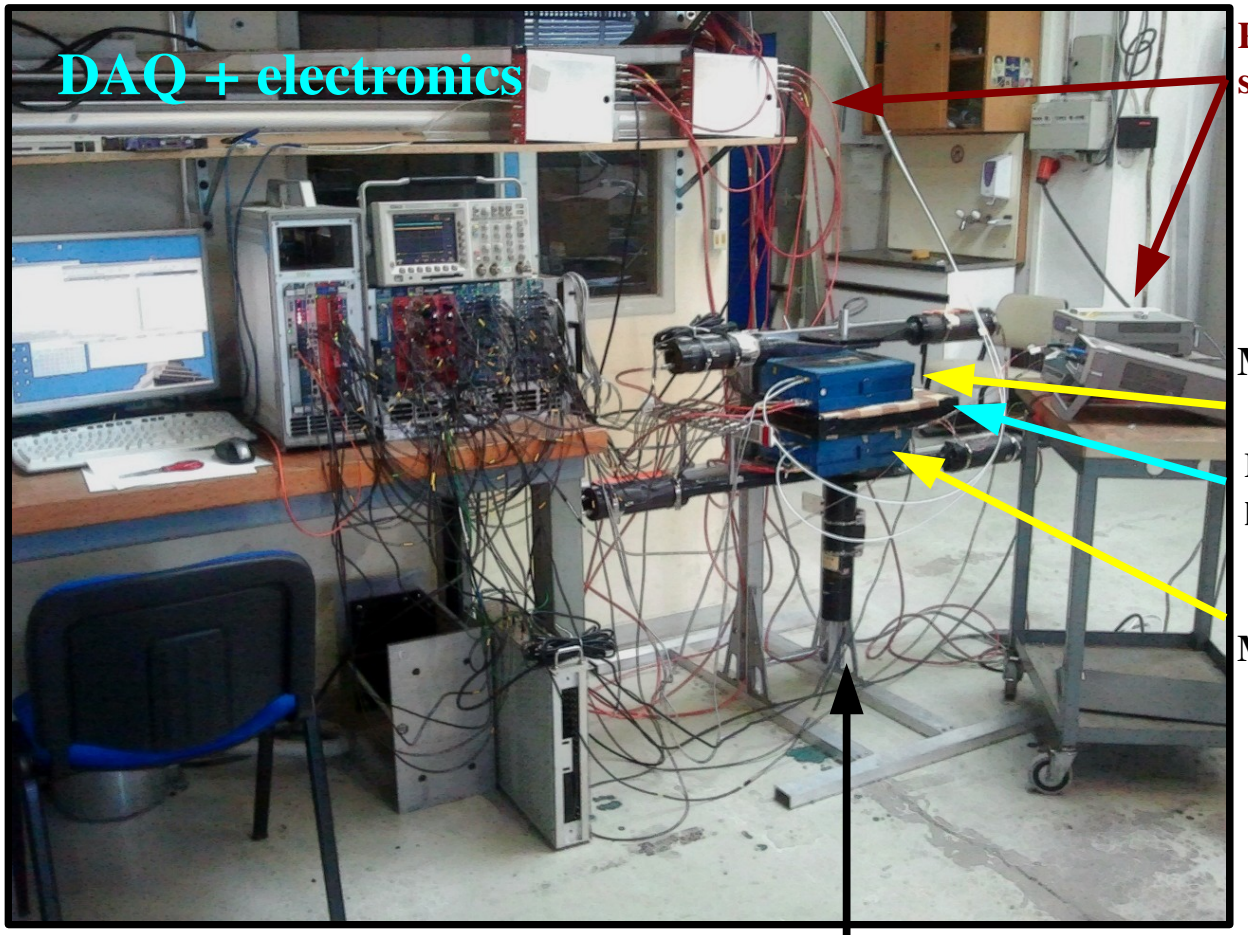
WLS-Fiber readout	
Size:	265 x 107 x 30 mm^3
SiPM:	2x Hamamatsu S10931-05P
2x 9 BCF-92 ∅1mm, length = 40cm	



Polymerized scintillator produced in Protvino (similar to BC-408)

Setup (1)



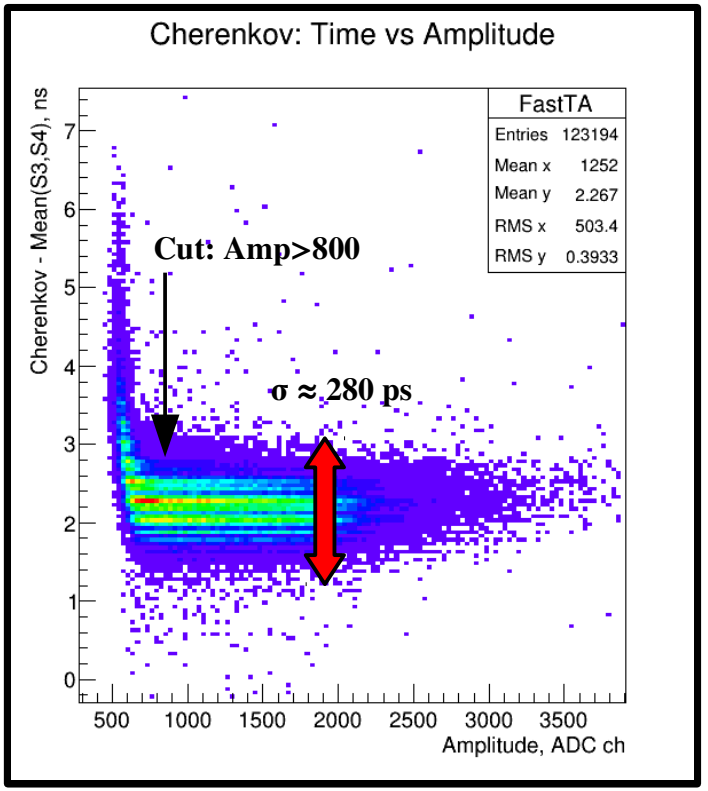


CFD:

CAEN Mod N253: SiPMs, $\check{C}_{Fast}$

ORTEC 934 Quad: S3, S4

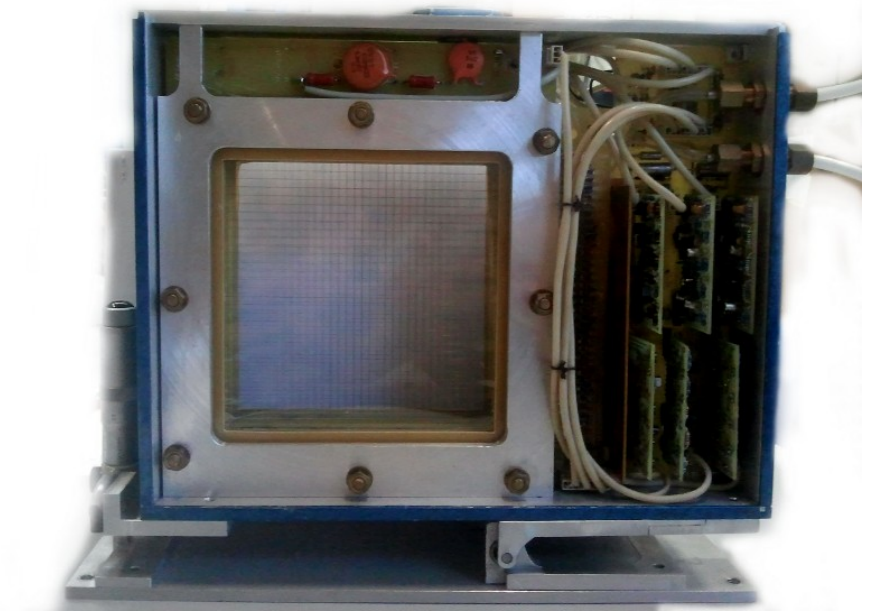
Setup (2)



Time setting counter $\check{C}_{Fast}$: Cherenkov counter based on XP2020 PMT and ∅ 40mm x 45mm cylinder made of Plexiglas above with no grease.

Time resolution ≈ 175 ps

Multi-Wired Proportional Chambers with cathode readout. 4mm step between wires. Each wire delayed on 10ns. For each plane we have two signals. Coordinate ~ time difference between signals.



WLS Fibers readout

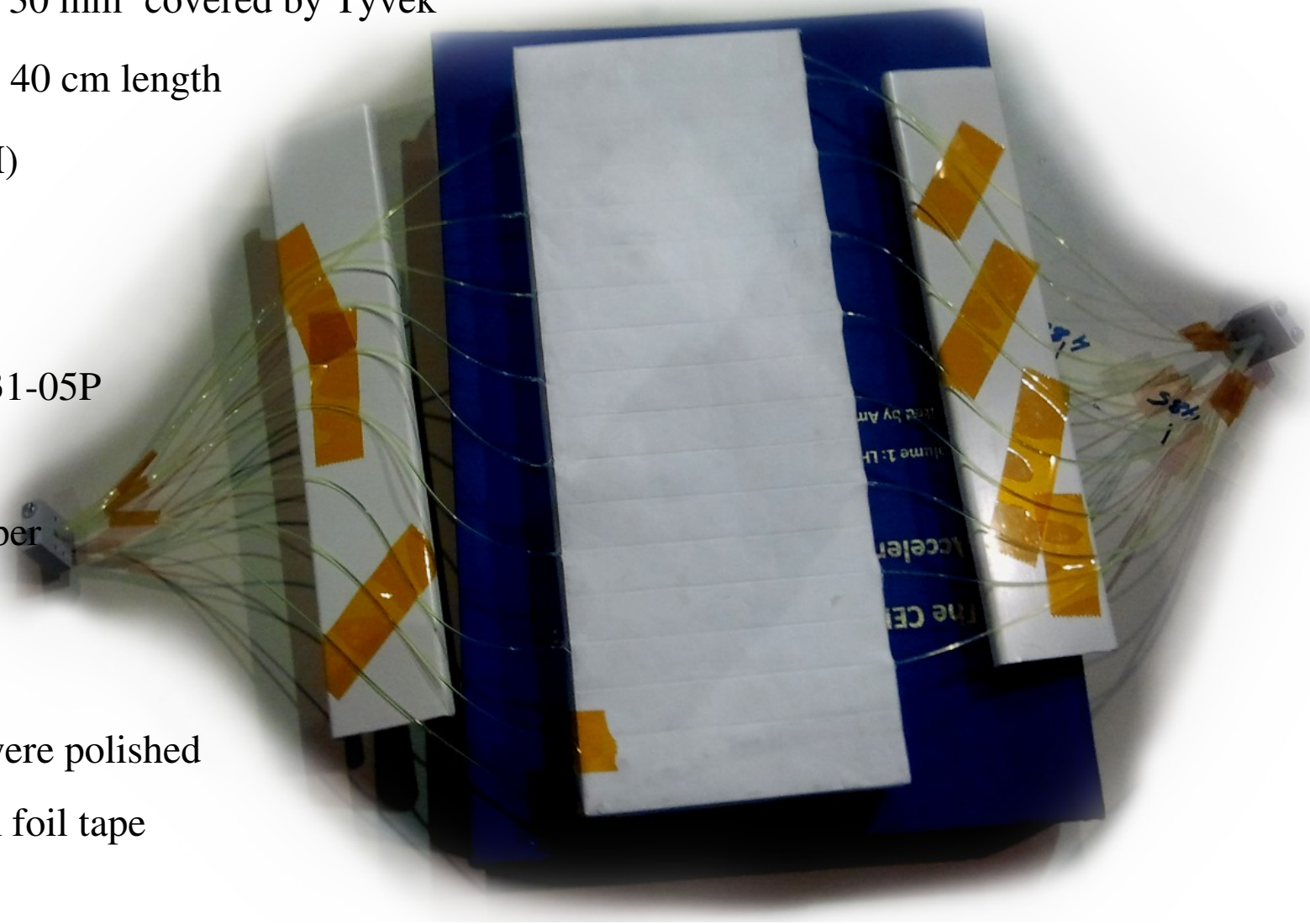
- Scintillator: 265 x 100 x 30 mm^3 covered by Tyvek
- BCF-92 Fibers ∅ 1 mm, 40 cm length

(9 to each 3 x 3 mm^2 SiPM)

- SiPMs 3 × 3 mm^2:

  2x Hamamatsu S10931-05P

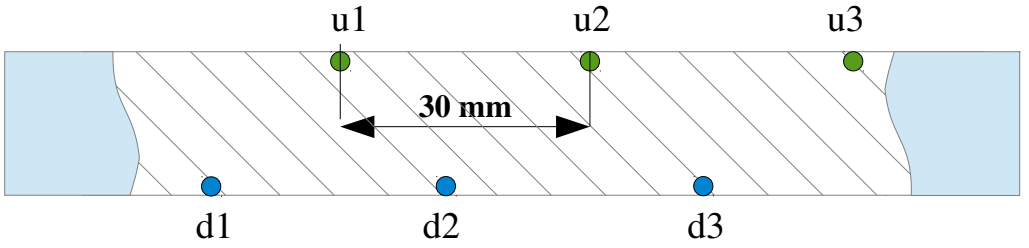
  Vbr + 1.9V
- CPTA amplifiers + shaper



- Opposite end of fibers were polished

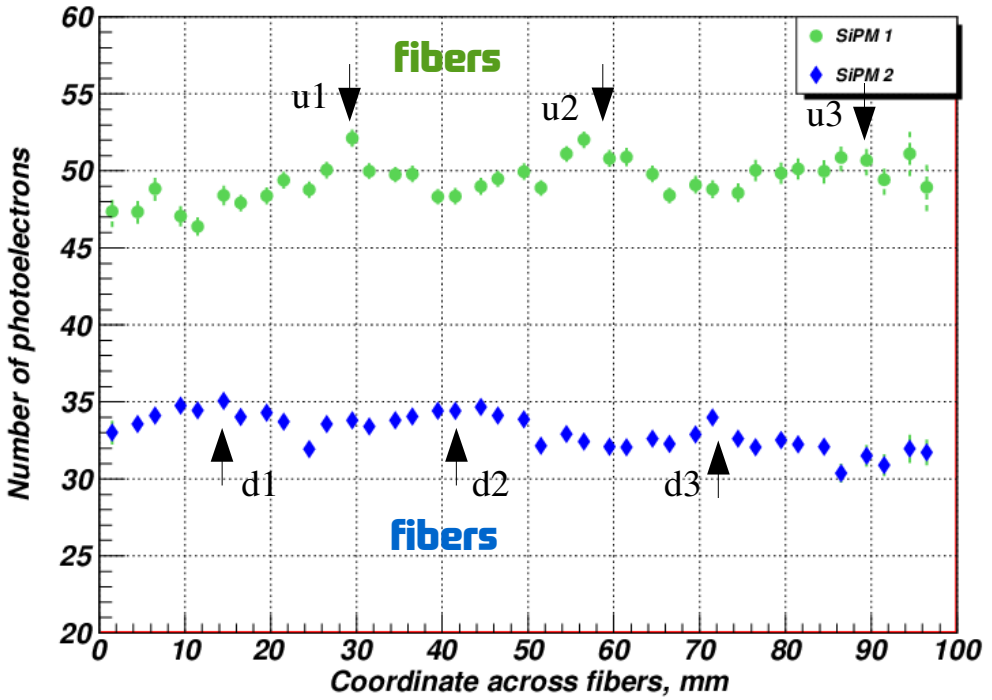
and mirrored by aluminum foil tape

WLS Fibers readout – across fibers

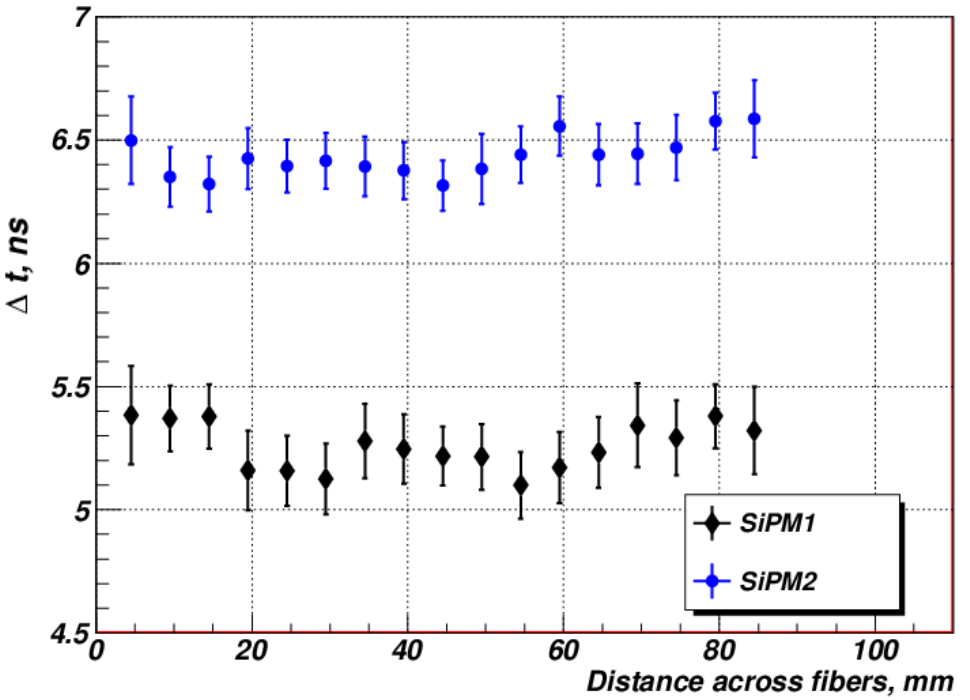


Δt = time difference between start signal from Cfast and signal from SiPM.

Amplitude across fibers for SiPM1



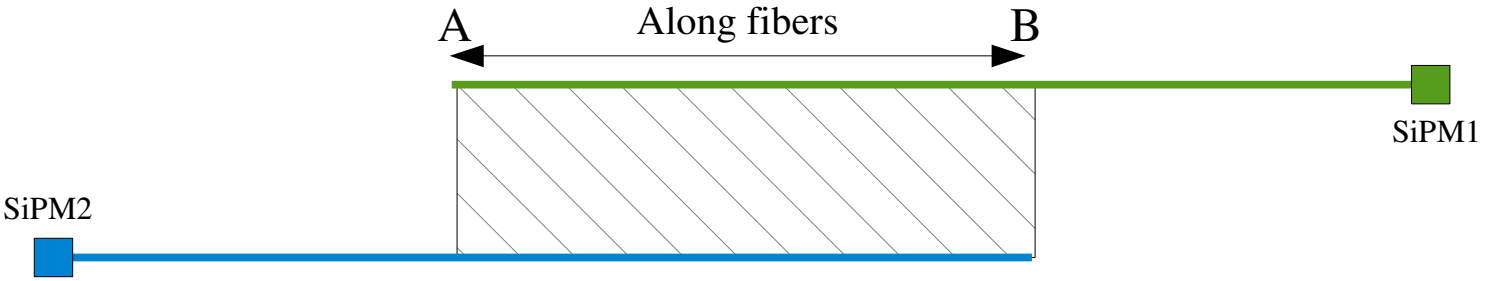
Time vs coordinate across fibers

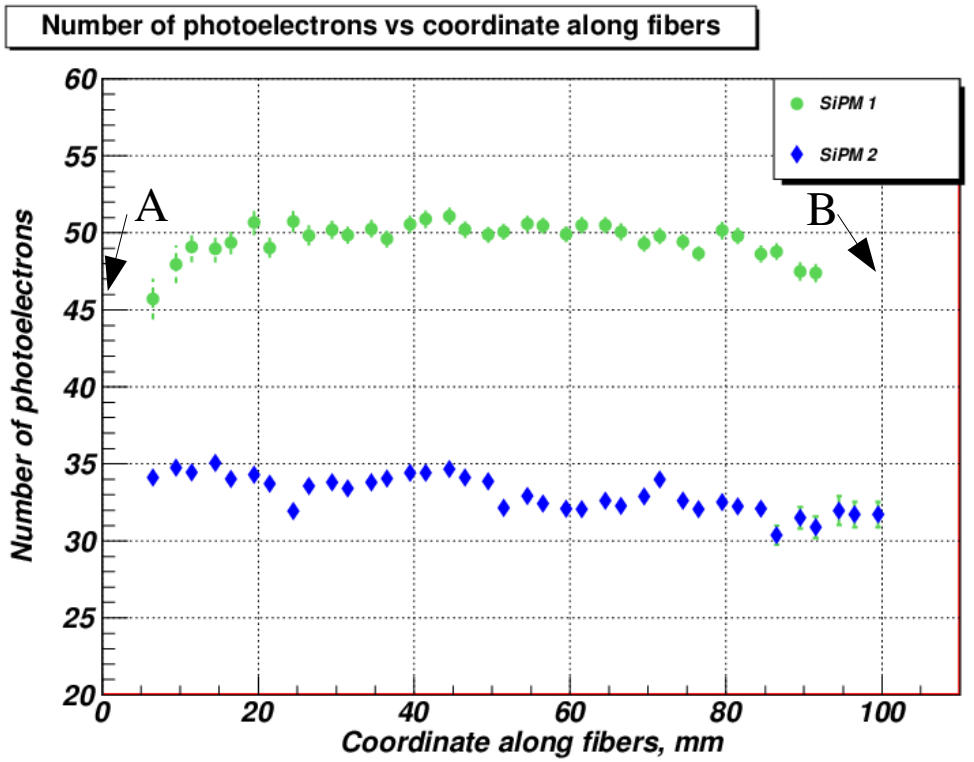


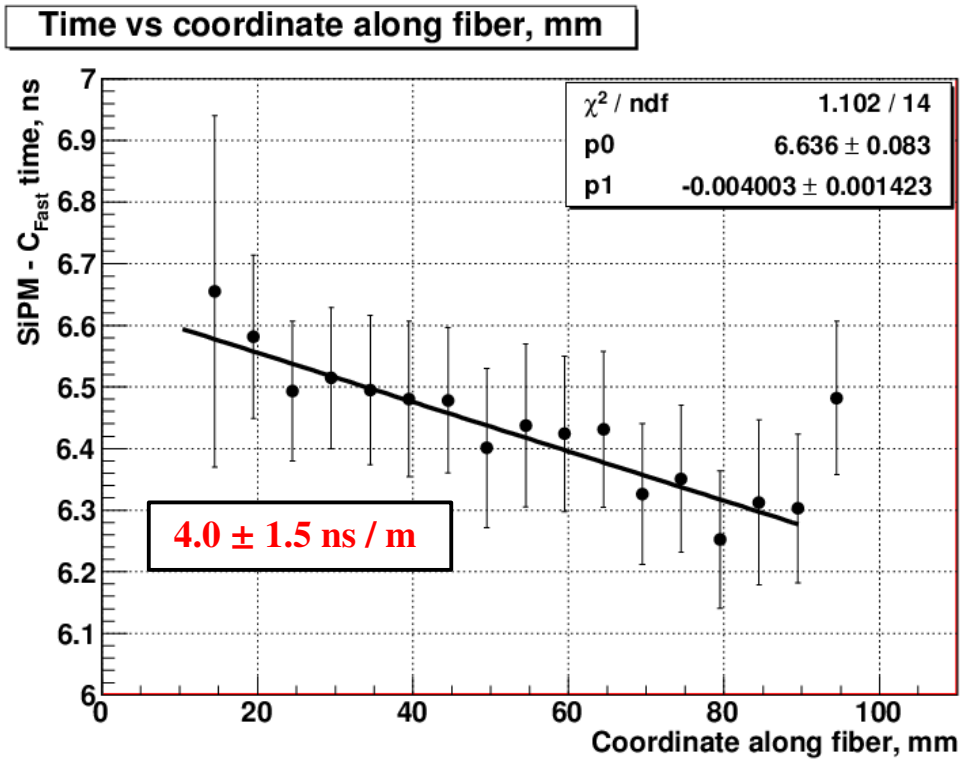
Dynamic range = $A^{max} / A^{min} \approx$ **1.10**

Signal arrival time variation vs coordinate across fibers is negligible

WLS Fibers readout – along fibers





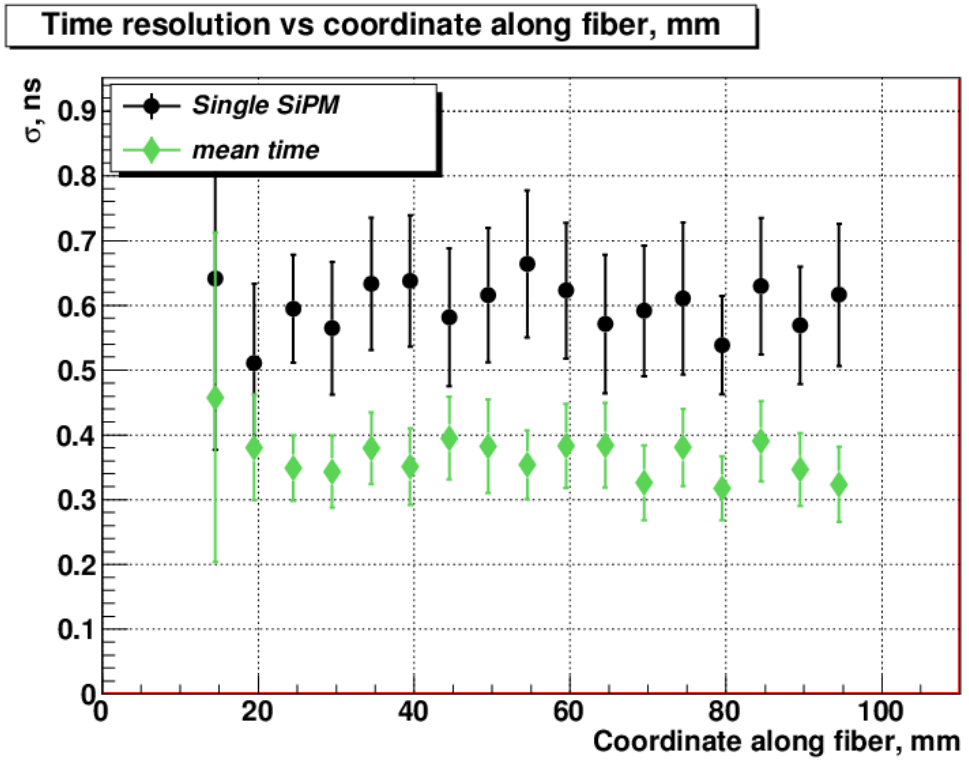


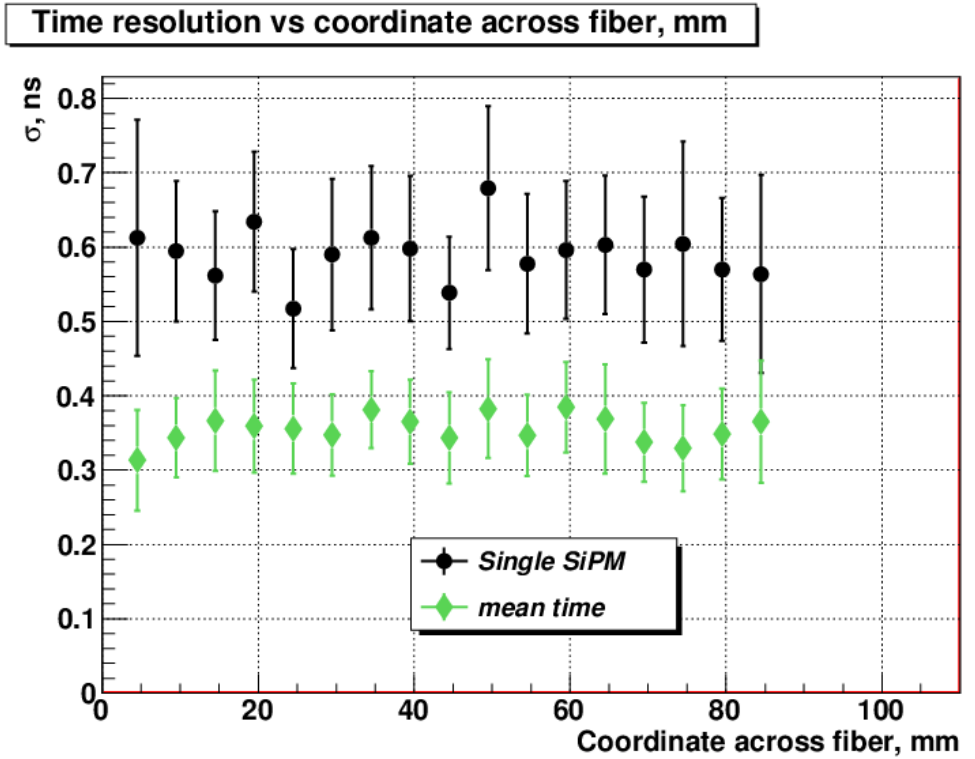
Time vs coordinate along fiber: max time spread ≈ 400 ps

107 mm x (4.0 ± 1.5) ns / m ≈ 430 ± 150 ps

WLS Fibers readout – time resolution

Good uniformity!!!

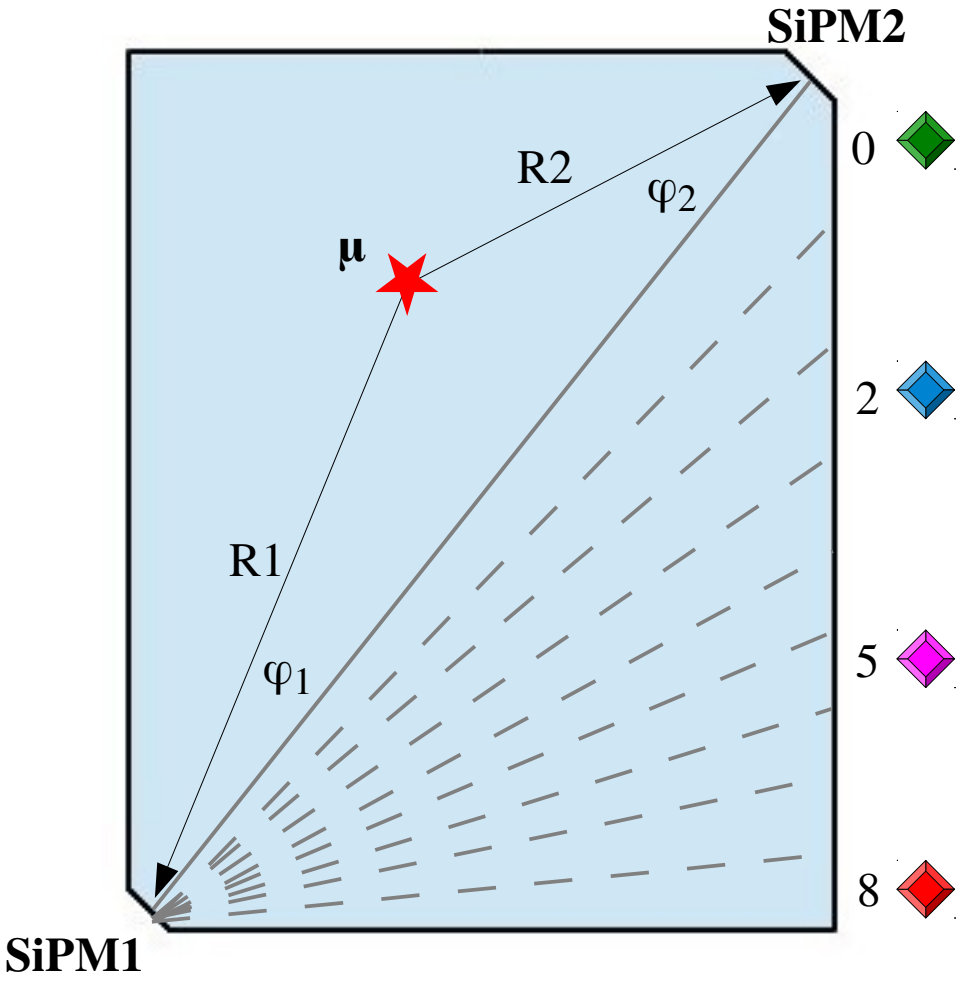




Time resolution:

Single SiPM	(worse one)	610 ± 10 ps
Mean (SiPM1, SiPM2)		370 ± 10 ps

Direct readout

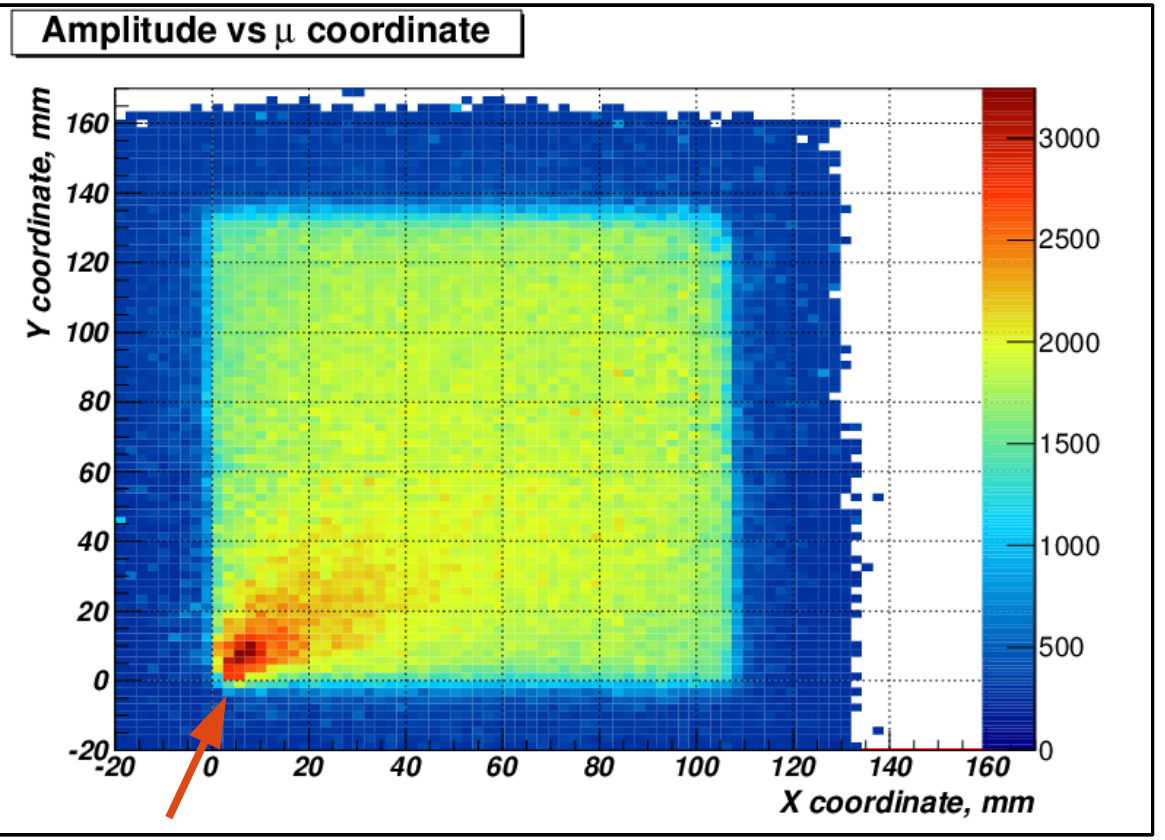


- Size: 132.5 x 107 x 20 mm^3
- SiPMs: 6x6 mm^2

  2 x SensL MicroFB-60035

  V_{br} + 3V
- CPTA amplifiers + shaper
- Covered by Tyvek

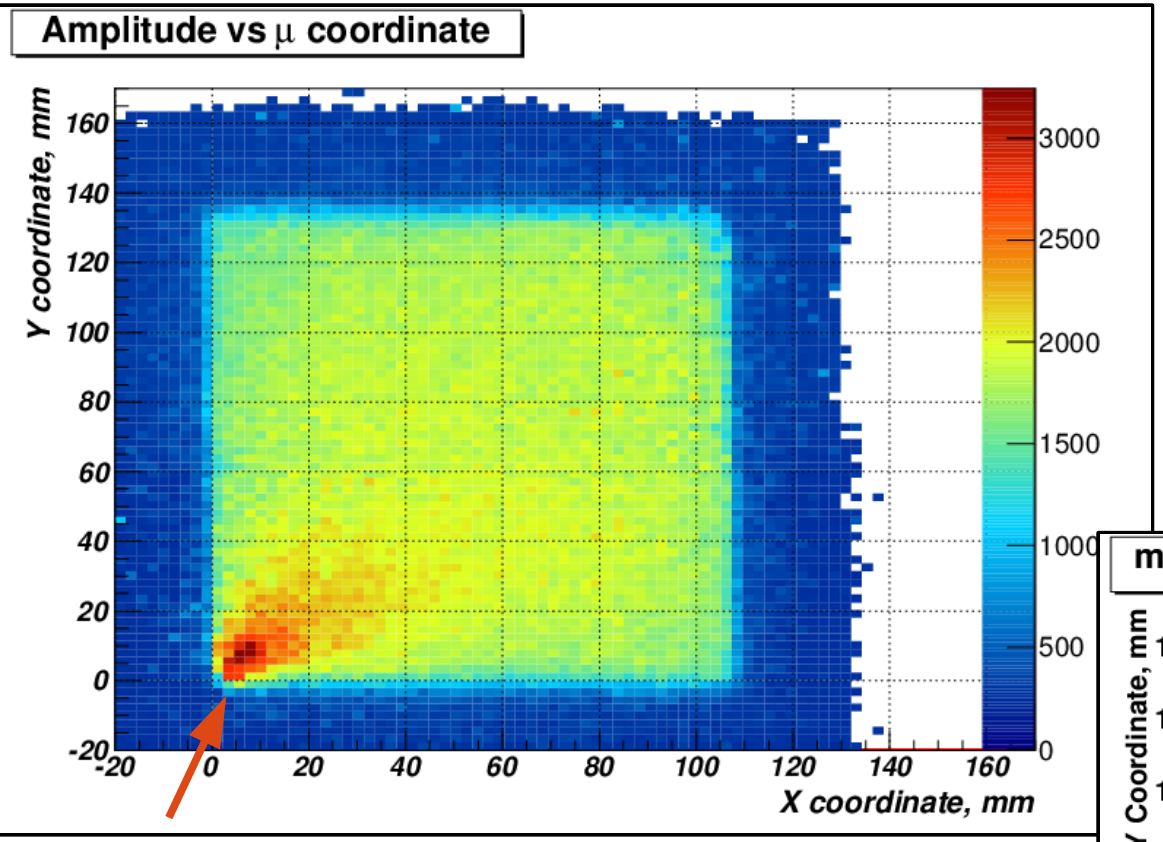
Direct readout (1)



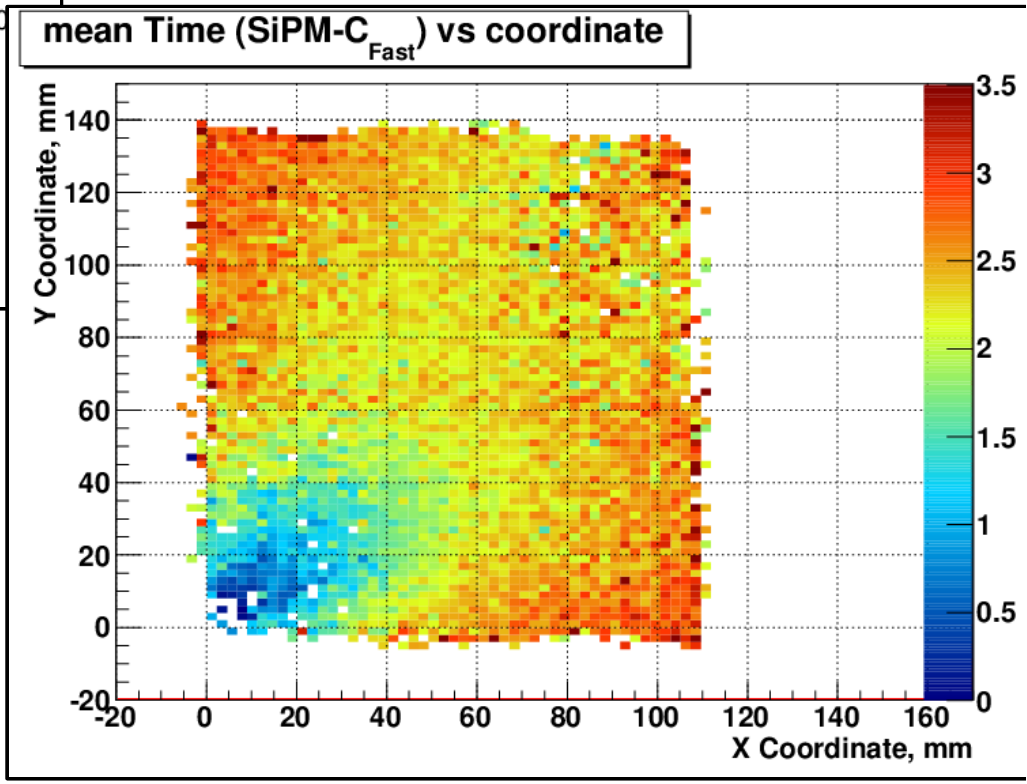
SiPM

Average amplitude vs XY coordinates we can easily see the edges of scintillator. Coordinate resolution ~ 2mm (1 bin).

Direct readout (2)

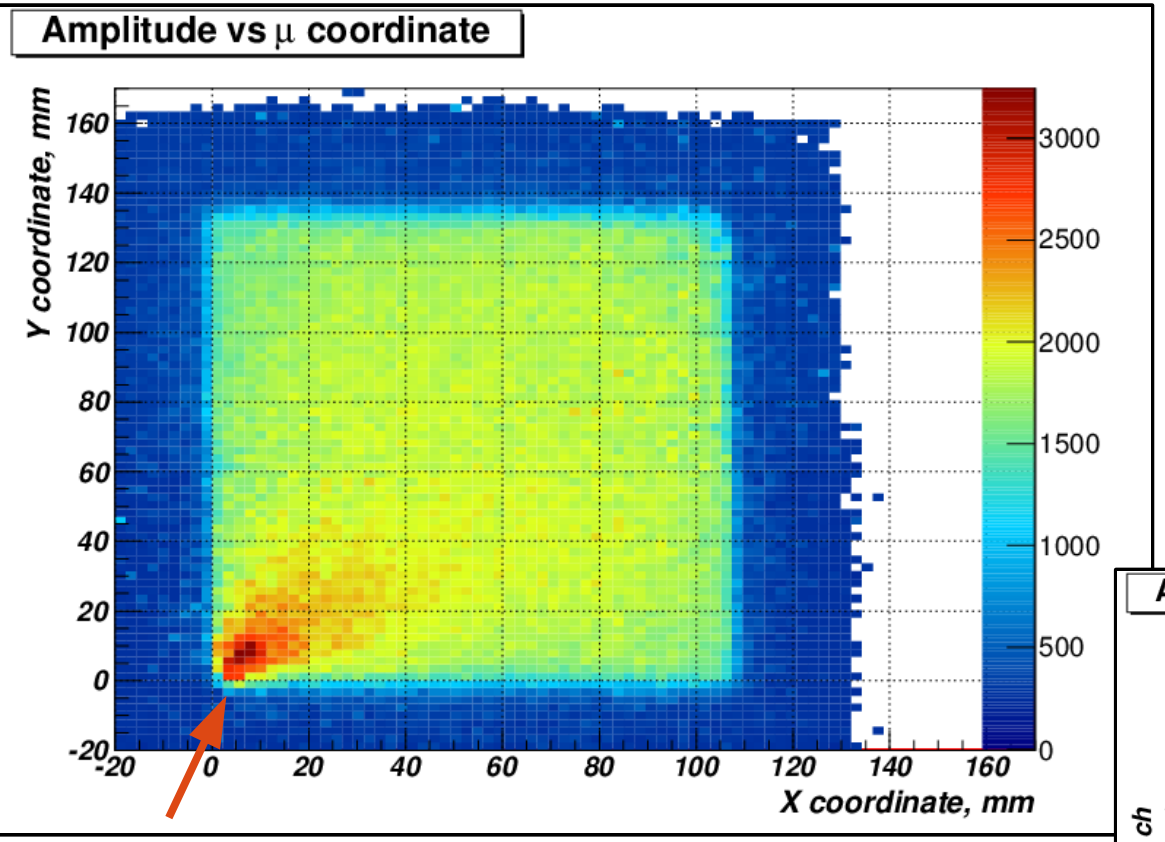


Average amplitude vs XY coordinates we can easily see the edges of scintillator. Coordinate resolution ~ 2mm (1 bin).

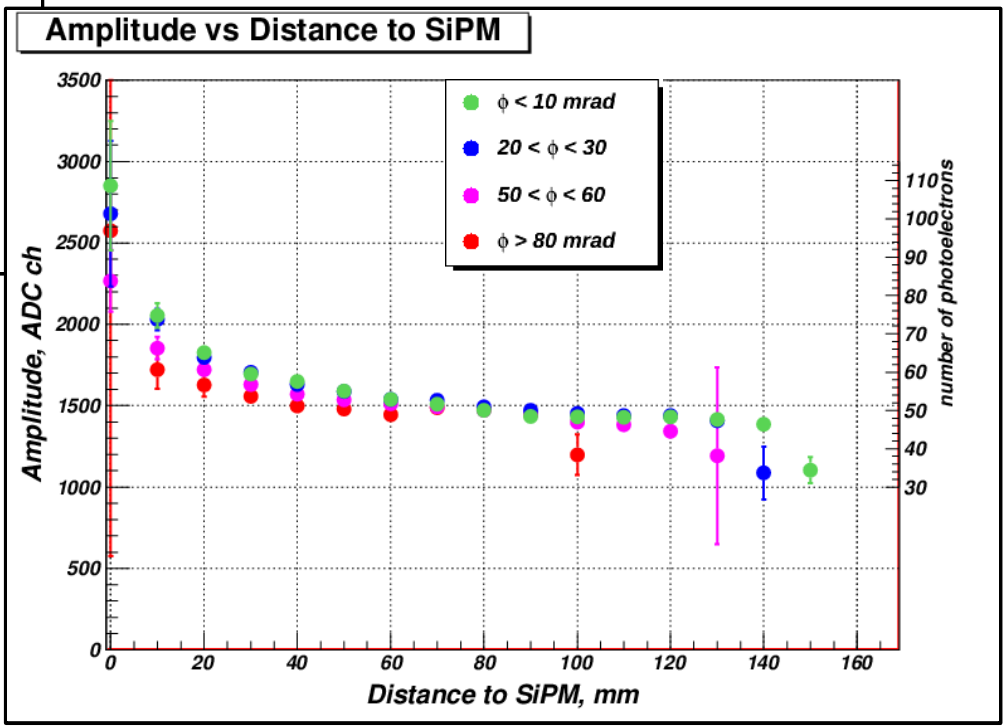


Arrival time vs coordinate dependency

Direct readout (3)

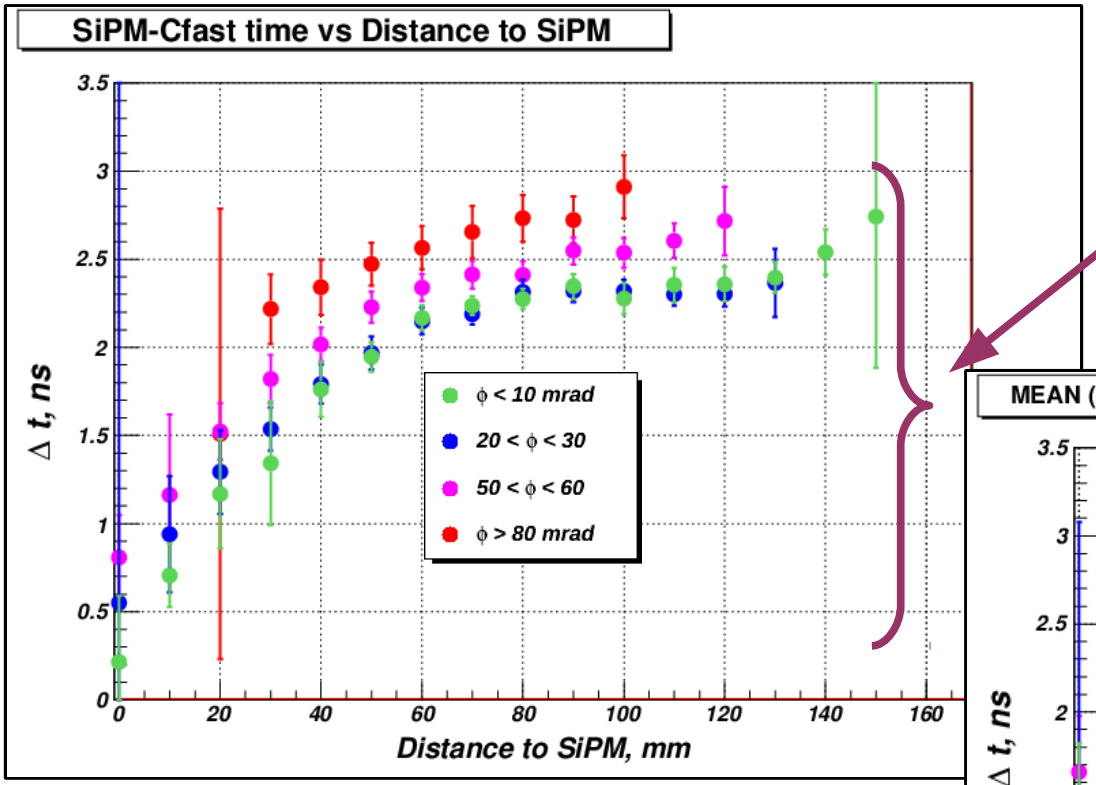


Average amplitude vs XY coordinates we can easily see the edges of scintillator. Coordinate resolution ~ 2mm (1 bin).



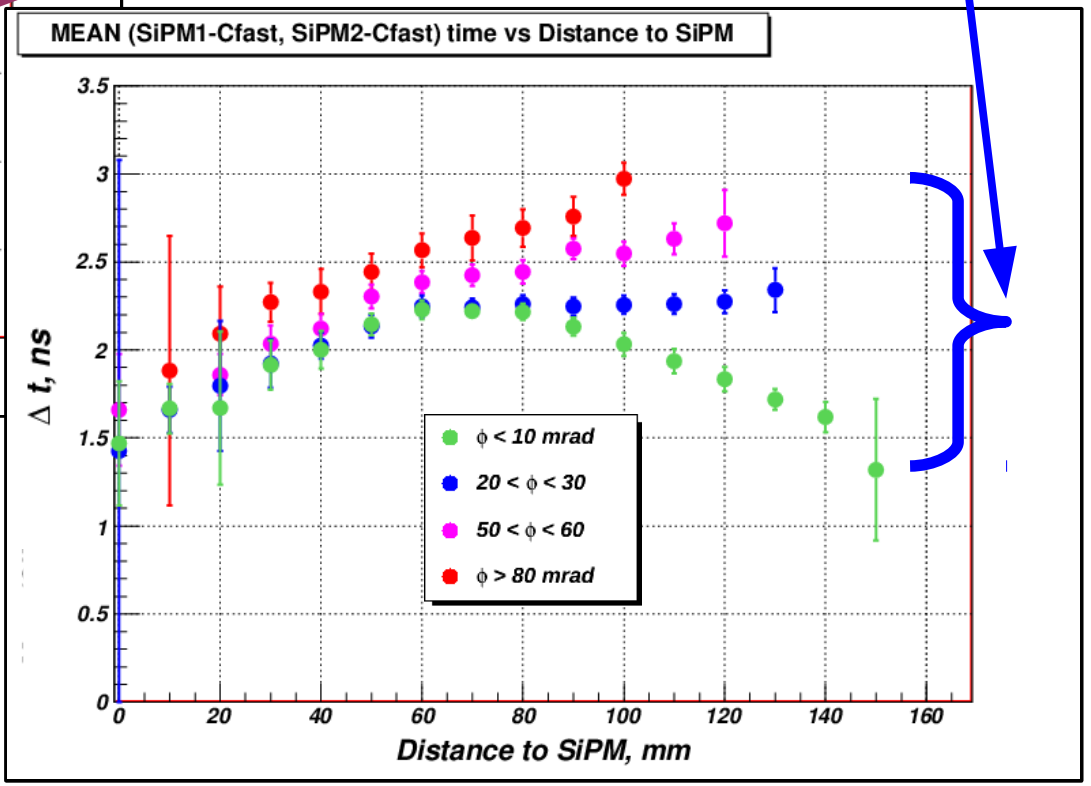
Dynamic range ≈ 3.2

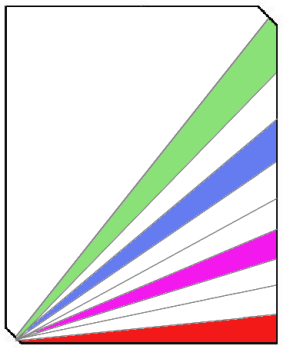
Direct readout (4)



Single SiPM:
Maximum spread = **2.7 ± 0.2 ns**

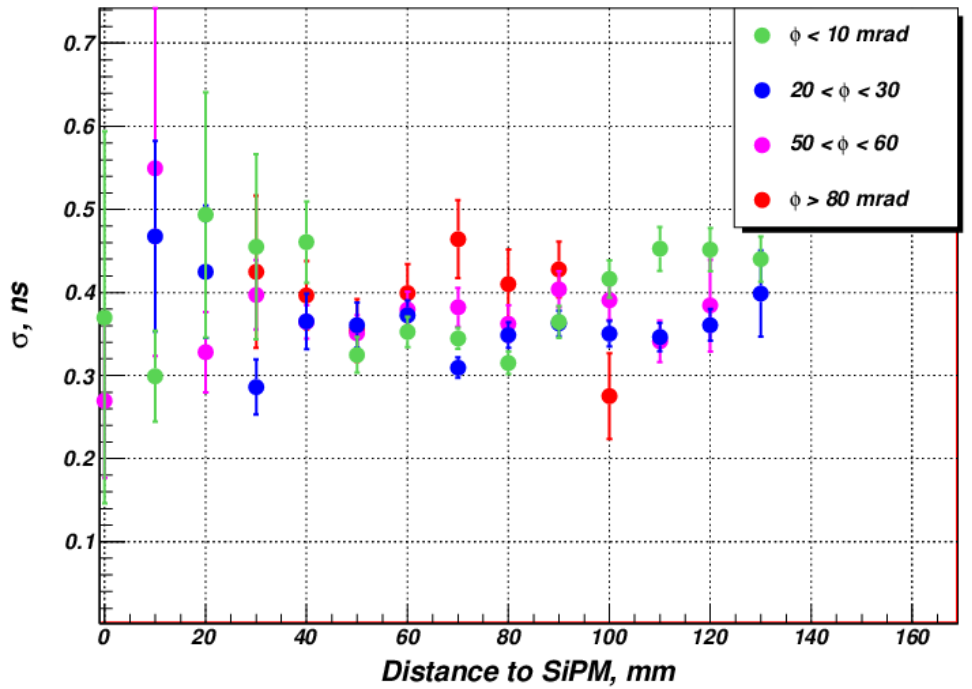
Mean timer:
Maximum spread ≈ **1.6 ± 0.2 ns**



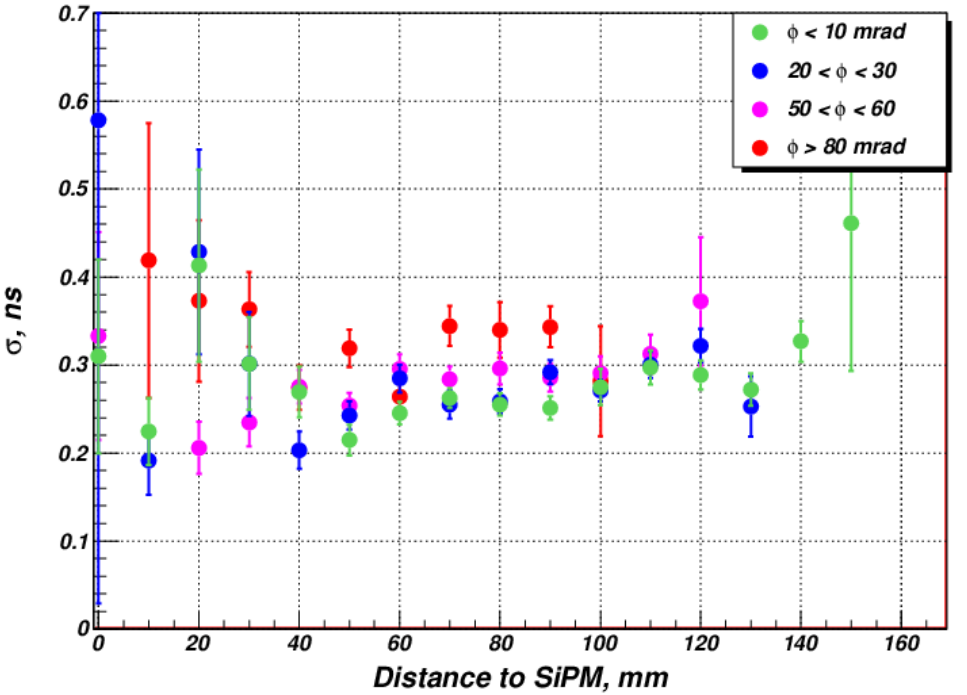


Direct readout: time resolution

Time resolution(single SiPM readout) vs distance to SiPM



Time resolution (mean-timer) vs distance to SiPM

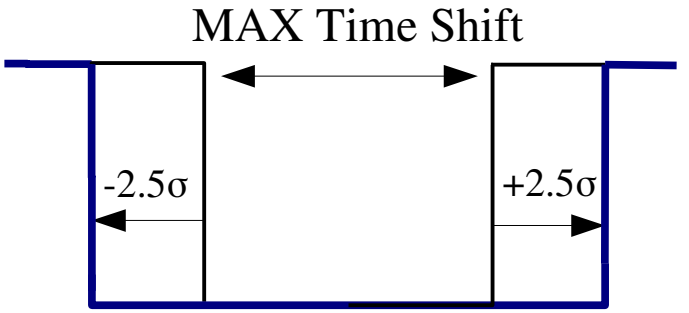


Time resolution:

Single SiPM	400 ± 10 ps
Mean (SiPM1, SiPM2)	300 ± 10 ps

Trigger gate length

Gate length



Long Gate: required to make coincidence between SiPMs.

Short Gate: trigger signal from hodoscope.

	Direct				**WLS-Fiber**	
	Single SiPM	First signal	Last Signal	Mean Time	Single SiPM	Mean Time
MAX Time shift	2.7 ± 0.2 ns	2.7 ± 0.2 ns	0.8 ± 0.1 ns	1.6 ± 0.2 ns	400 ± 150 ps	150 ps
Sigma	400 ± 10 ps	370 ± 10 ps	450 ± 10 ps	300 ± 10 ps	610 ± 10 ps	370 ± 10 ps
GATE	4.7 ± 0.2 ns	4.5 ± 0.2 ns	**3.0 ± 0.2 ns**	**3.1 ± 0.2 ns**	3.5 ± 0.2 ns	**2.0 ± 0.2 ns**

2.5 ± 0.2 ns

Increasing due to WLS fibers length: 40 cm → 110 cm

Conclusion

News from last NA62 collaboration week (10-15 Feb 2014):

- WLS Fibers readout selected as main option
- Starting to build a prototype (10-20% of detector) and planing to test it during next run (October - 2014)

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- WLS Fibers readout selected as main option
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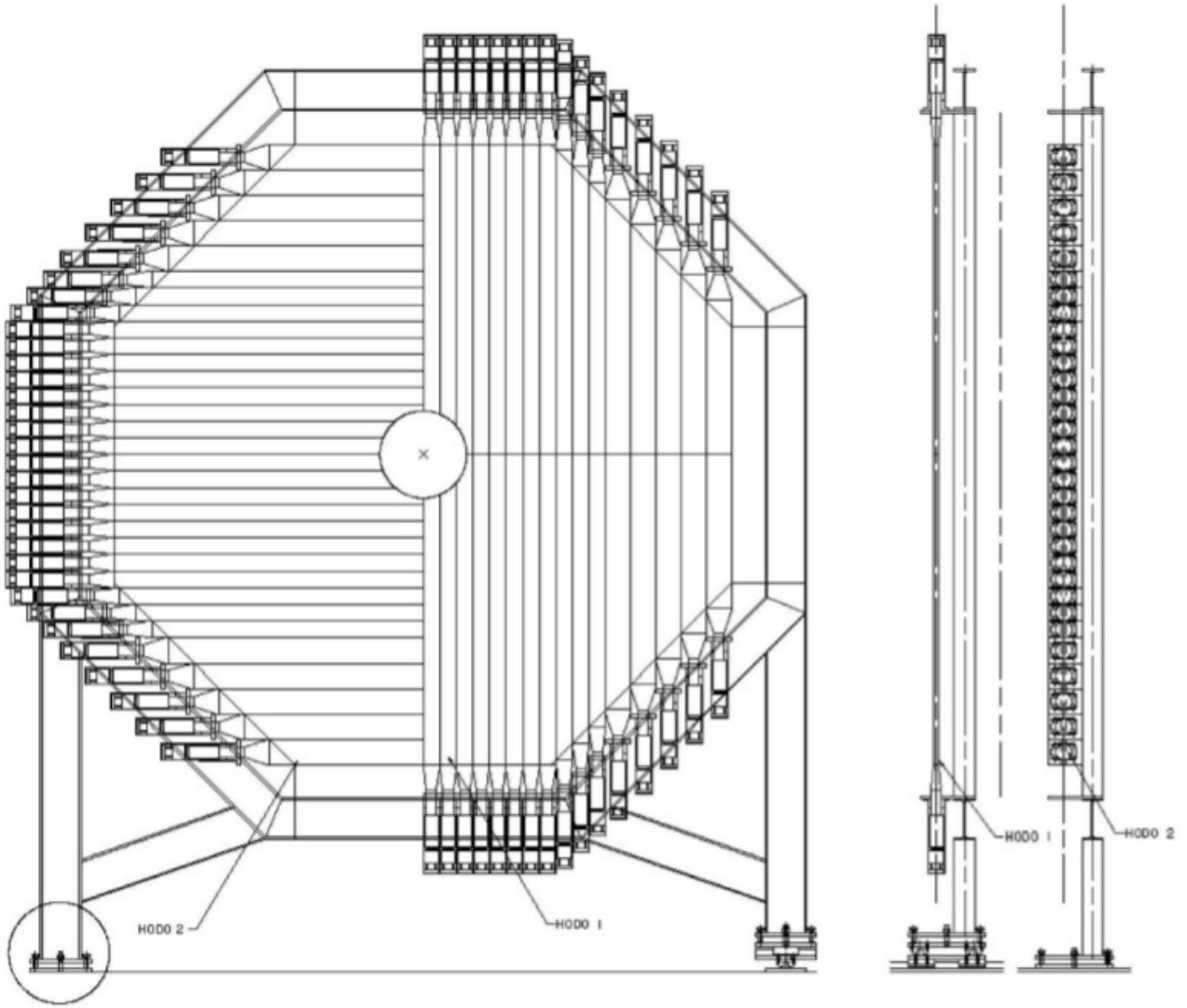
backup slides

NA48 Charged Hodoscope

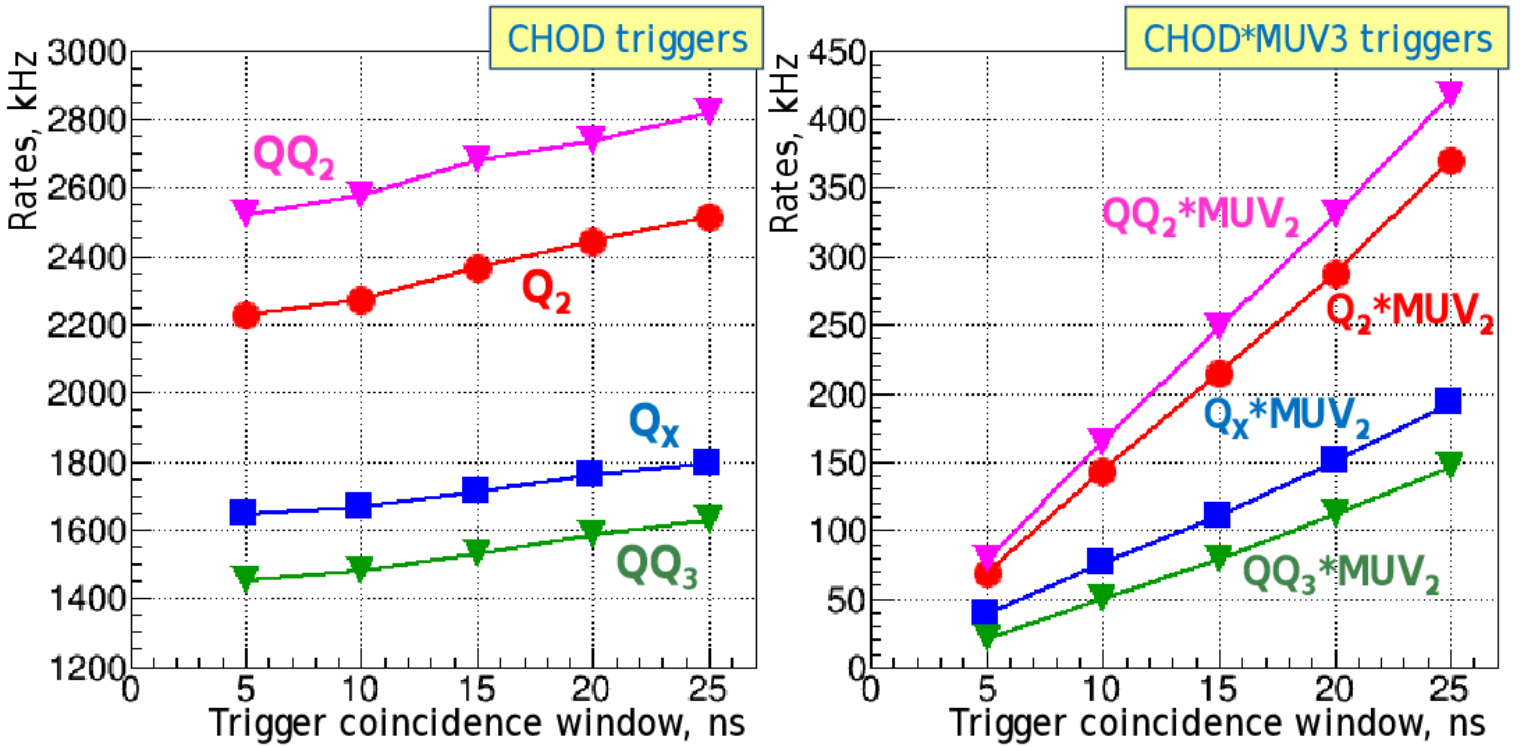


Long bars of BC-408 scintillator and single PM readout

CHOD rate vs gate length

Rates vs coincidence window

(plots from October 2013 meeting)



- *(Q_N, QQ_N) rates are dominated by single decays;*
- *(Q_N, QQ_N)*MUV_2 rates are dominated by coincidences for ΔT>5ns.*

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CHOD trigger rates

Track multiplicity

Trigger condition: $RICH_4$ × ...

kHz	$K_{2\pi}$	$K_{3\pi}$	$K_{3\pi0}$	$K_{\mu2}$	$K_{\mu3}$	K_{e3}	Total
Rate [104-300m]	2,730	739	233	8,396	443	670	13,211
Q_1	1,435	412	137	3,848	235	333	6,400
Q_2	809	394	99	75	118	200	1,695
QQ_2	854	397	105	138	126	221	1,841
Q_X	645	364	76	15	84	148	1,332
QQ_3	525	301	73	20	70	149	1,138

Trigger condition: $RICH_4$ × $!E_{LAV}(4)$ × $!E_{SAV}(4)$ × ...

kHz	$K_{2\pi}$	$K_{3\pi}$	$K_{3\pi0}$	$K_{\mu2}$	$K_{\mu3}$	K_{e3}	Total
Rate [104-300m]	2,730	739	233	8,396	443	670	13,211
Q_1	854	355	63	3,843	156	170	5,441
Q_2	447	343	44	73	74	92	1,073
QQ_2	468	345	46	135	79	102	1,175
Q_X	343	320	31	14	49	63	820
QQ_3	228	262	27	19	35	55	626

- Including beam pions and halo, the $F(Q_1) \approx 10MHz$. [Giuseppe]
- In general, $F(QQ_3 \times ...) < F(Q_X \times ...) < F(Q_2 \times ...) < F(QQ_2 \times ...)$.

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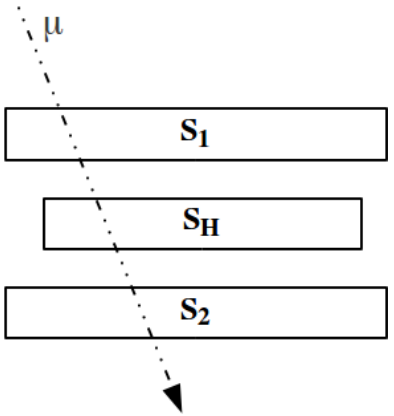
Intrinsic time resolution



Time spectrum of two counters where S2 was used as a Start and S1 – as a stop signal could be described by Gaussian with sigma:

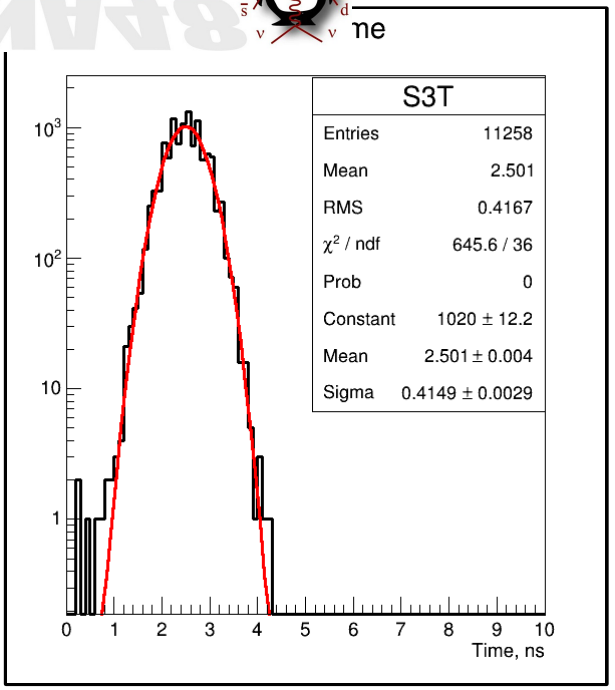
$$\sigma_{tr}^2 = \sigma_{S_1}^2 + \sigma_{S_2}^2$$

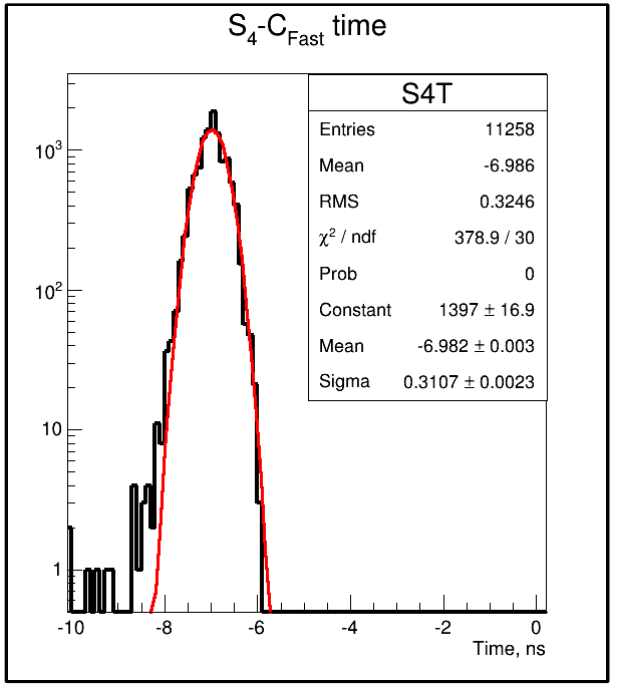
Where σ_{S1}, σ_{S2} – intrinsic time resolution of counters S_1 and S_2

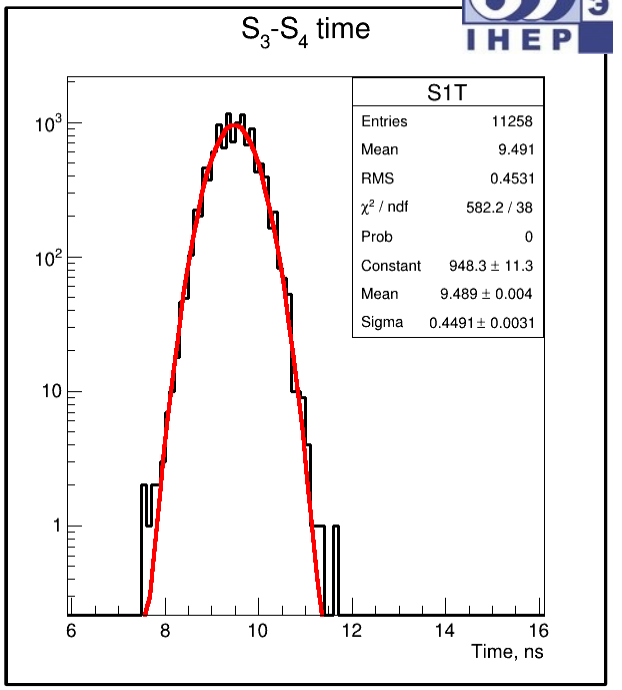
Writing the same equations for pairs trigger – studying counters (S_1, S_H) and (S_2, S_H) we can get intrinsic time resolution of all counters:

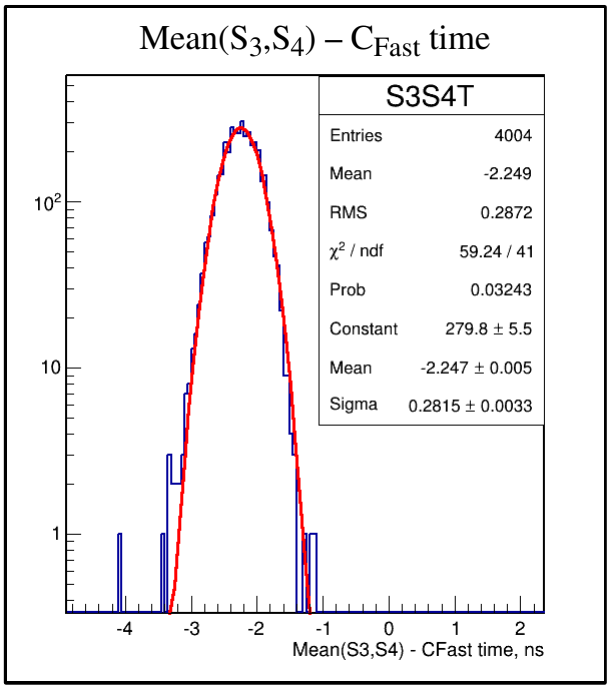
$$\sigma_{S_H} = \sqrt{\frac{(\sigma_{S_H S_1}^2 + \sigma_{S_H S_2}^2 - \sigma_{tr}^2)}{2}}$$

Trigger counters time resolution





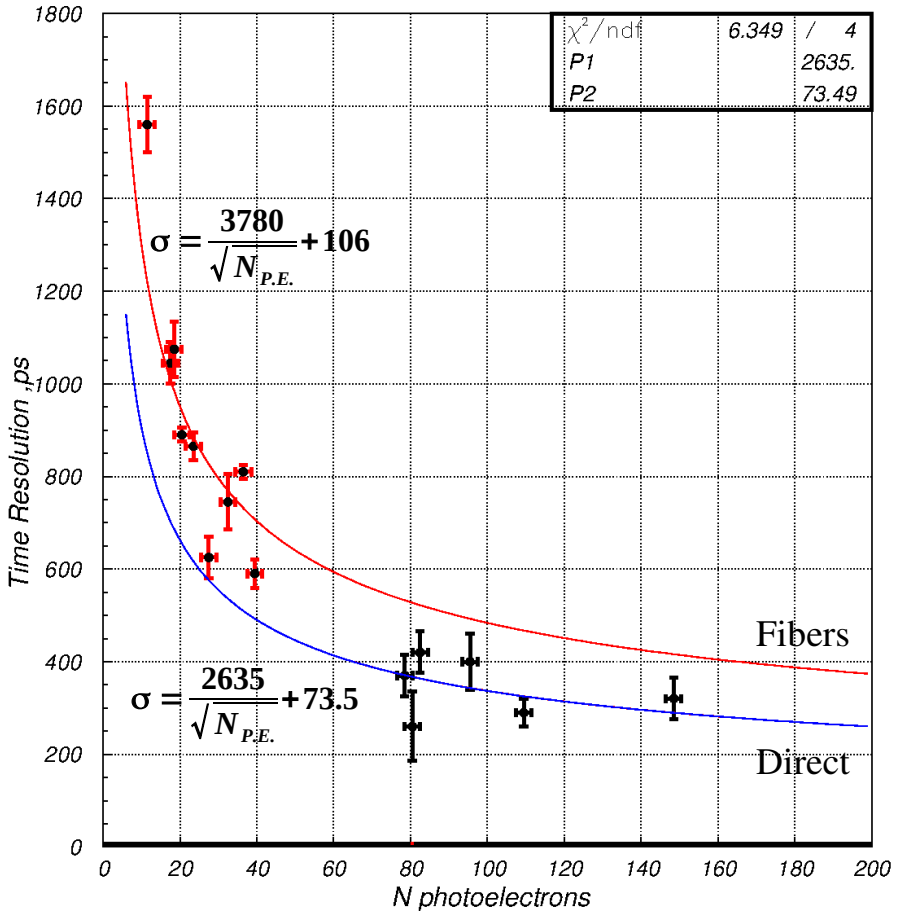


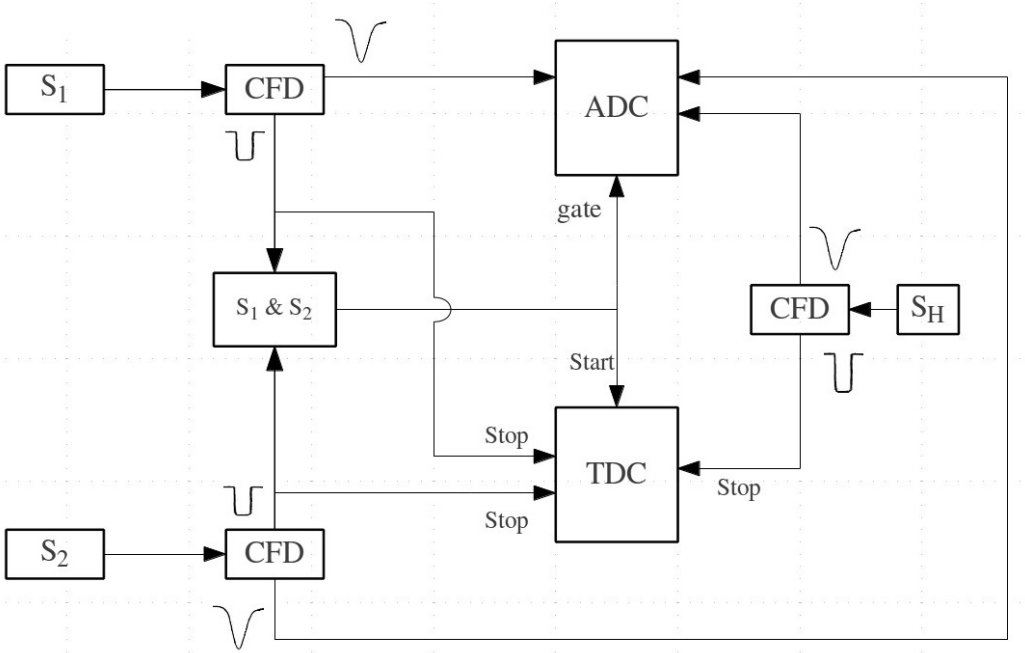


To get intrinsic time resolution:

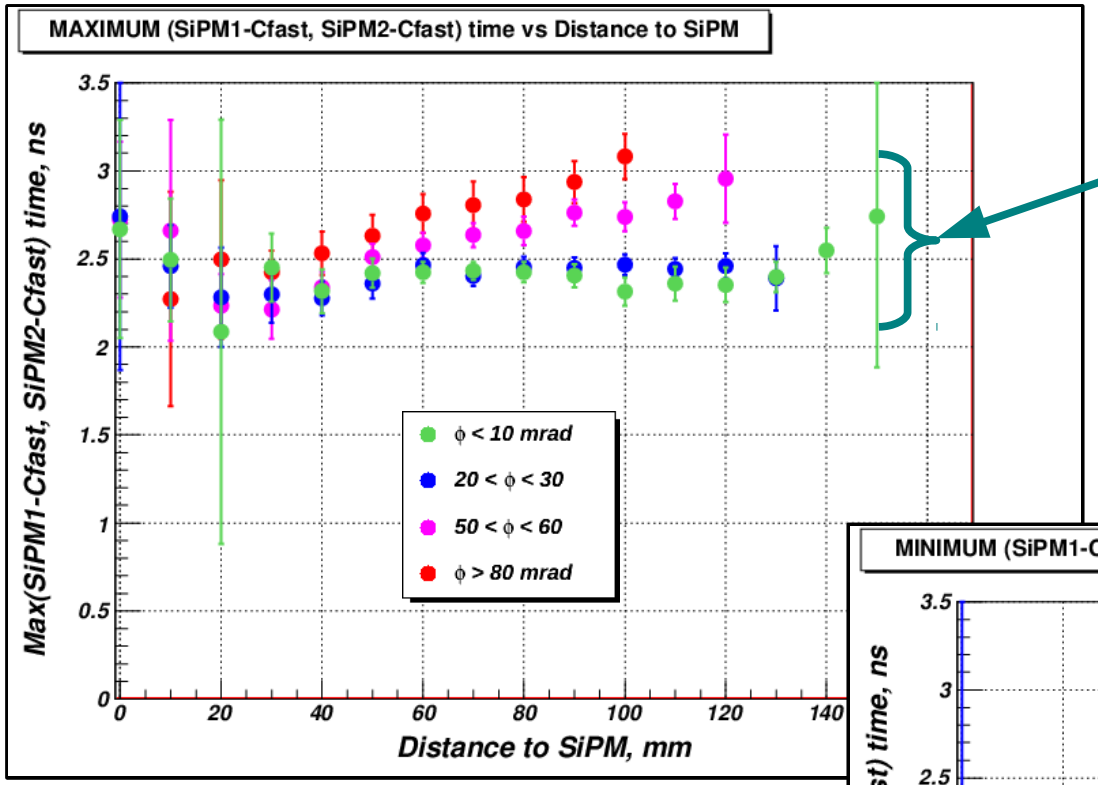
$$\sigma_{Fast} = \sqrt{\frac{\sigma^2_{S3-Fast} + \sigma^2_{S4-Fast} - \sigma^2_{S3-S4}}{2}}$$

$\sigma(\check{C}_{Fast})$	$\approx$ 175 ps
$\sigma(S_3)$	$\approx$ 370 ps
$\sigma(S_4)$	$\approx$ 250 ps
$\sigma(\text{mean}[S_3,S_4])$	$\approx$ 225 ps



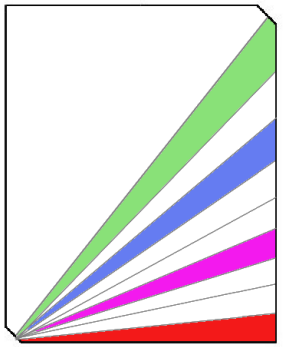


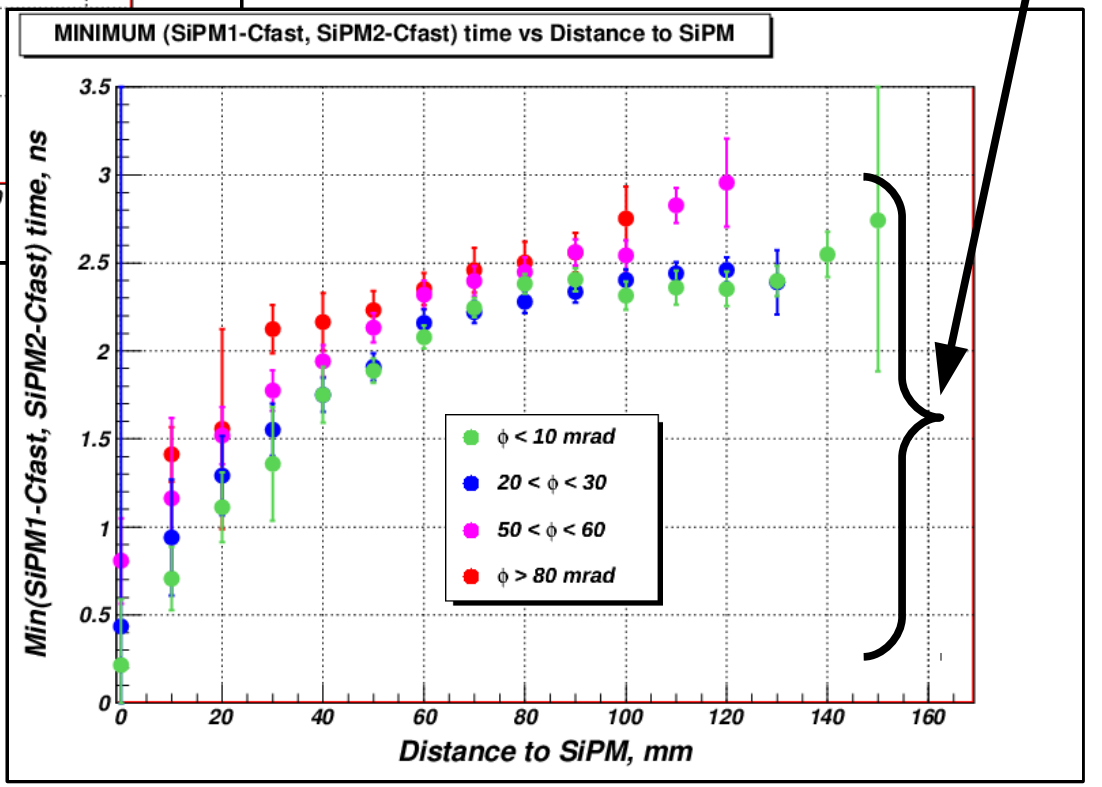
Фит функцией: $\sigma = P_1 \cdot \frac{1}{\sqrt{N_{p.e.}}} + P_2$



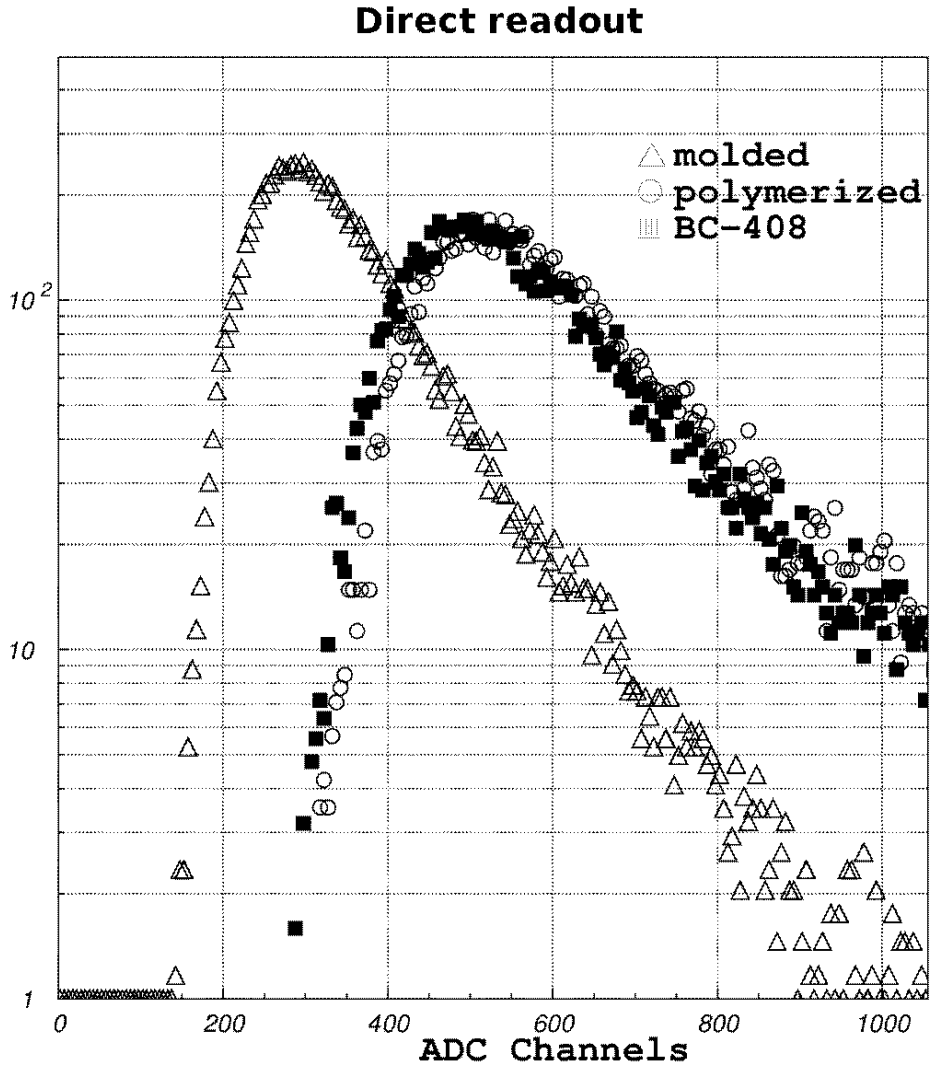
Last signal:
Maximum spread ≈ **0.8 ± 0.1 ns**

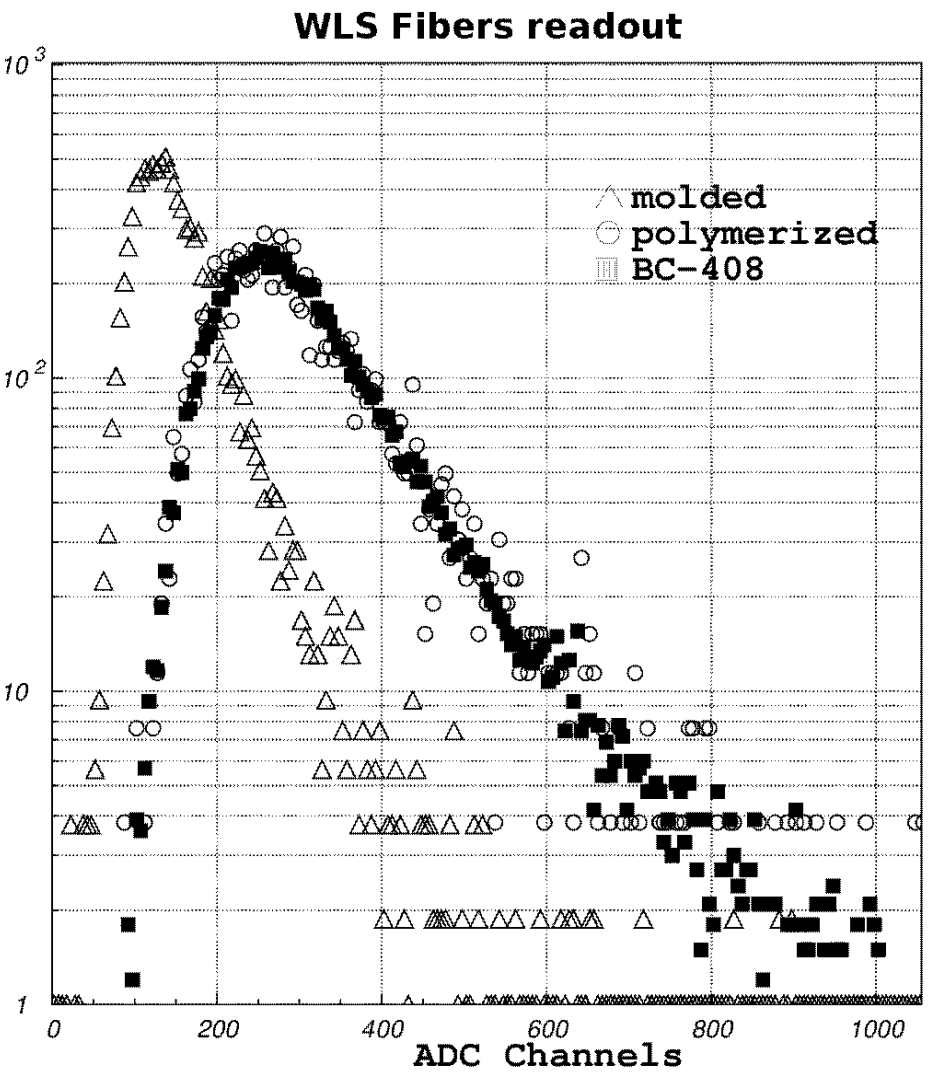
First signal:
Maximum spread ≈ **2.7 ± 0.2 ns**





Scintillators





SensL 3x3 SiPM noise

SensL 3x3 SiPM noise
(25.5 + 2.0 V)