THE TIMING COUNTER OF THE MEG EXPERIMENT: DESIGN AND COMMISSIONING

(OR "HOW TO BUILD YOUR OWN HIGH TIMING RESOLUTION DETECTOR")

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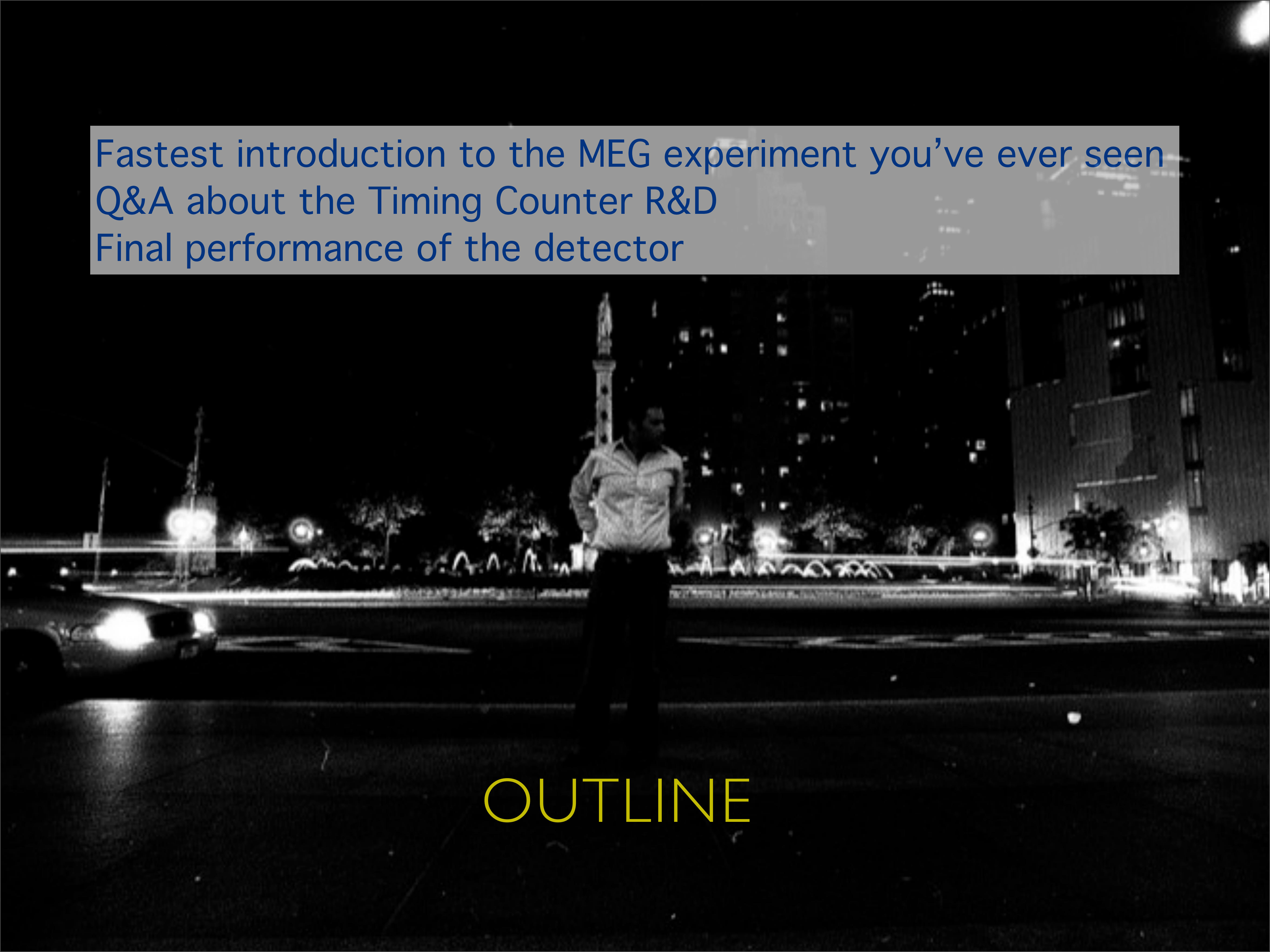
FRONTIER DETECTOR FOR FRONTIER PHYSICS - LA BIODOLA 2009


Fastest introduction to the MEG experiment you’ve ever seen
Q&A about the Timing Counter R&D
Final performance of the detector
OUTLINE

MEG?

The only thing of concern in this place is that in MEG we need to have a relative uncertainty in the photon-positron simultaneity as close as possible to zero.

Our goal was to obtain 150 ps FWHM for $\Delta t_{p-\gamma}$

This corresponds to 100 ps FWHM for the positron alone

So the Timing Counter main goal is to obtain this time resolution, and more....

TIMING COUNTER ISSUES - I

The TC has been studied to satisfy at least some minimum requirements:

© capability to deliver a fast signal with preliminary track information,

© high efficiency,

© <u>high timing resolution $\sigma_t \sim 40$ ps,</u>

© reliable operation.

Among these items, the first two are relevant for triggering purposes, the third is of paramount importance for our experiment while the latter is constrained by both the harsh environment in which the whole detector is working and the reduced redundancy allowed by the final setup.

TIMING COUNTER FINAL DESIGN

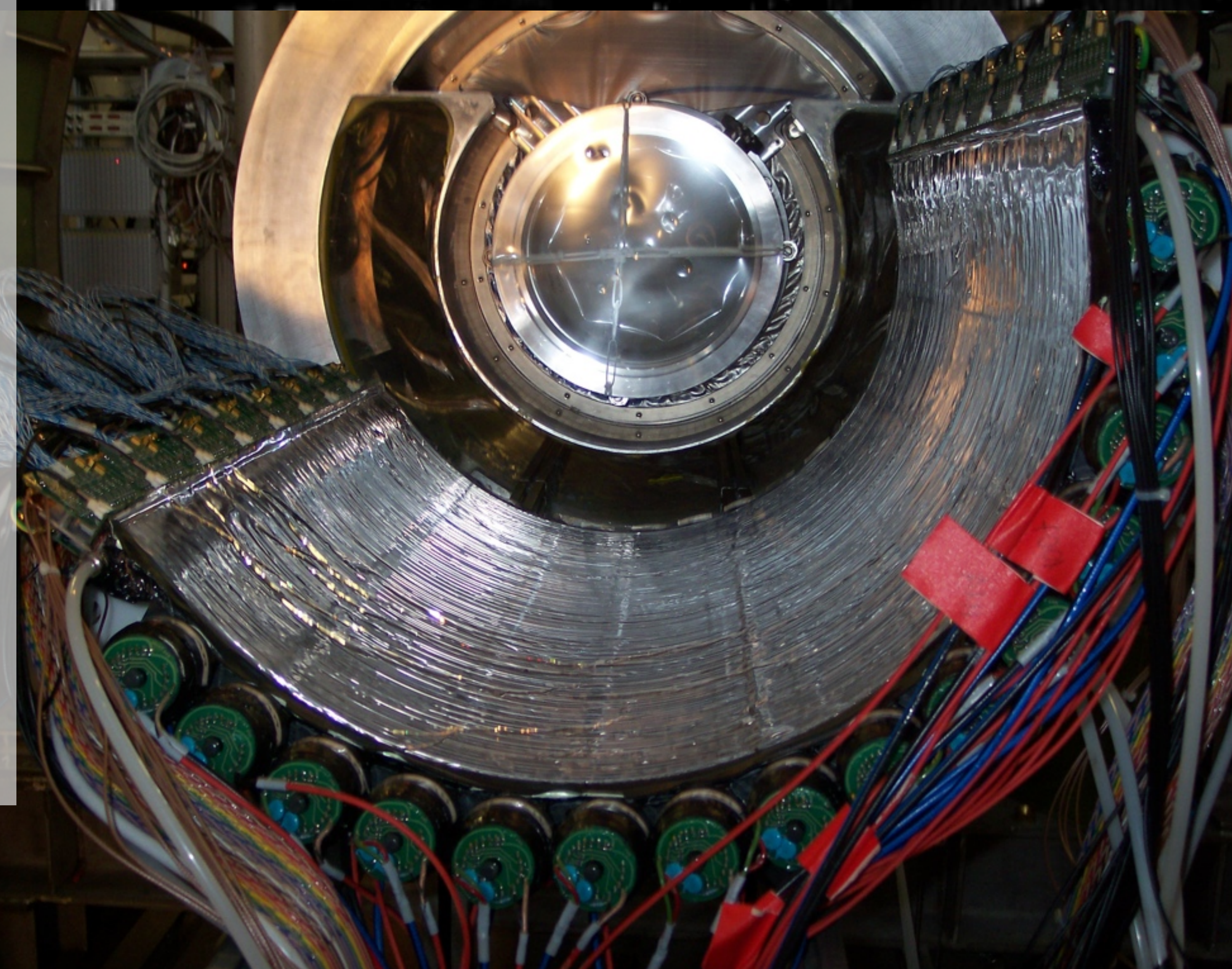
The TC in its final shape is represented here, then we will review the R&D steps leading to this shape: we have two identical modules lying UpStream and DownStream the target, inside the COBRA magnet

Each module has two layers: inner layer is built with scintillating fibers, 6 mm pitch, readout by APDs while outer layer is made by 15 scintillator bars with PMT transducing

APD readout has two complementary implementations:

- analog signals from 16 fibers (i.e. 9.6 cm) are summed and acquired by the trigger boards
- each APD channel is discriminated and this output is sampled by an FPGA

A similar architecture is envisaged for the PMT signals



TIMING COUNTER FINAL DESIGN

Choice of scintillator: fast, with a high output and a sufficient absorption length: two candidates, BC404 and BC408
Which device to read out the light?
-fast
-low jitter
-robust against magnetic field
ideal candidates: fine-mesh PMTs from Hamamatsu

parameter	BC404	BC408
light yield	0,68	0,64
rise time	700ps	900ps
decay time	1,8ns	2,1ns
attenuation length	140cm	210cm

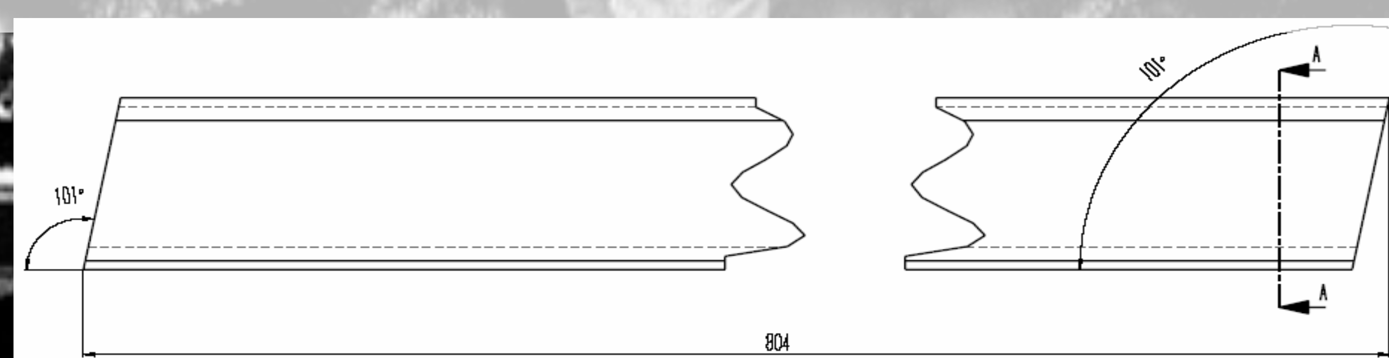
PM	TTS (FWHM) Typ.	TTS Measured
R7761-70(1.5”)	350 ps	470 ps
R5924 (2”)	440 ps	650 ps
XP2020 UR (2”)	350 ps	350 ps

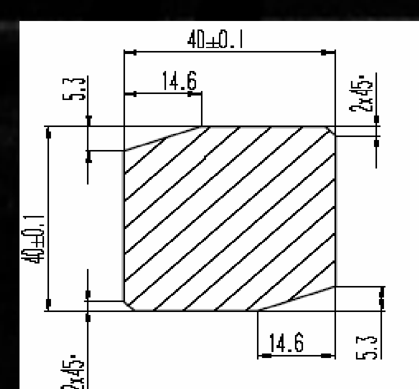
TIMING COUNTER FINAL DESIGN

Each bar has a slanted shape in order to minimize gain loss and timing worsening due to magnetic field: in our design the angle between the PMT axis and the field is around 20º which is optimum from this point of view

No light guides used nor reflecting wrapping of the bars: using only photons from surface reflection improves timing by selecting photons with low spread in path length from the particle impact point to the PMT

To obtain a sufficient amount of light and an optimum matching, bars have a squared 4x4 cm section (with some corner cut for mechanical constraints) and chosen PMTs are 2” fine-mesh R5924 from Hamamatsu equipped with custom-made voltage divider network.





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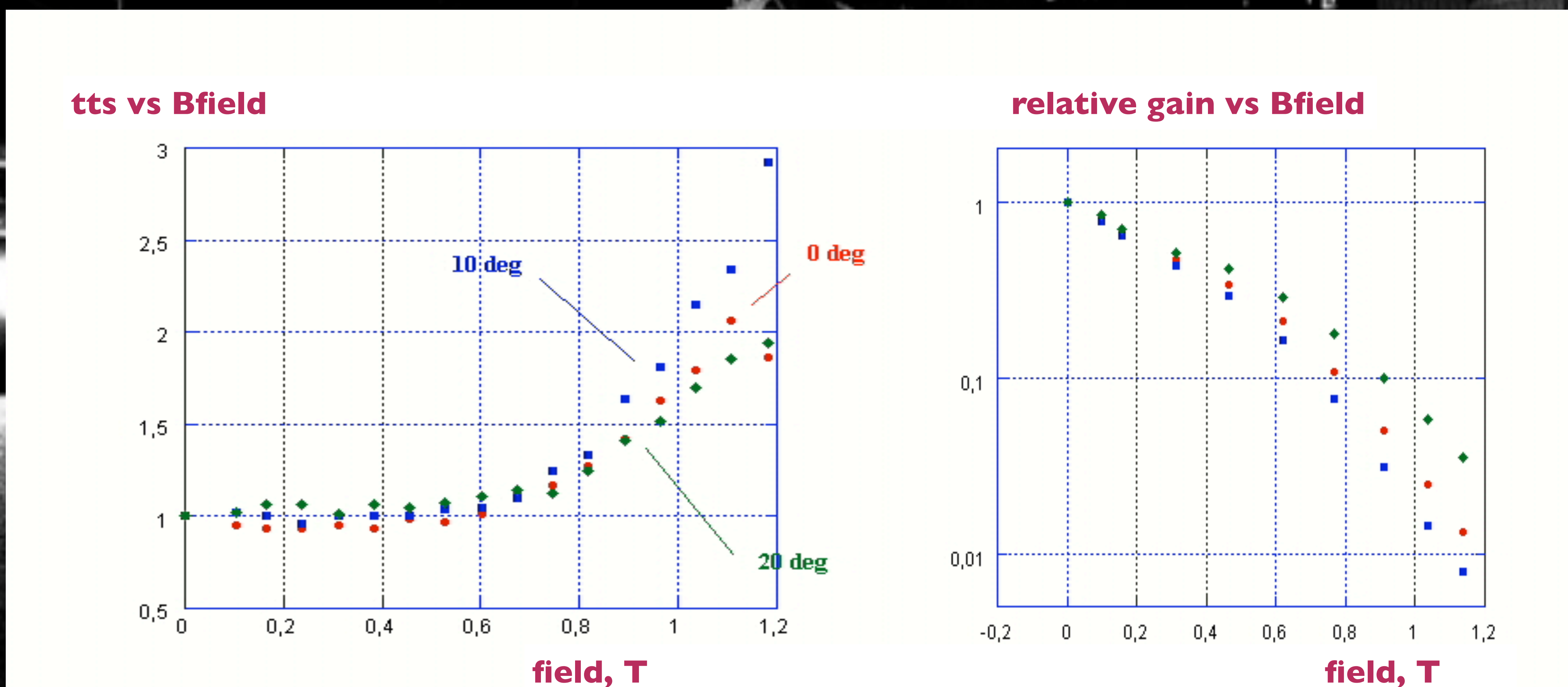

TC PERFORMANCES - I

most notable result for the Timing Counter is σ_t ~ 40 ps

Exp. application (*)	Counter size (cm) (T x W x L)	Scintillator	PMT	λ_{att} (cm)	σ_t(meas)	σ_t(exp)
G.D.Agostini	3x 15 x 100	NE114	XP2020	200	120	60
T. Tanimori	3 x 20 x 150	SCSN38	R1332	180	140	110
T. Sugitate	4 x 3.5 x 100	SCSN23	R1828	200	50	53
R.T. Gile	5 x 10 x 280	BC408	XP2020	270	110	137
TOPAZ	4.2 x 13 x 400	BC412	R1828	300	210	240
R. Stroynowski	2 x 3 x 300	SCSN38	XP2020	180	180	420
Belle	4 x 6 x 255	BC408	R6680	250	90	143

comparing it with other devices it turns out MEG TC is very good :)

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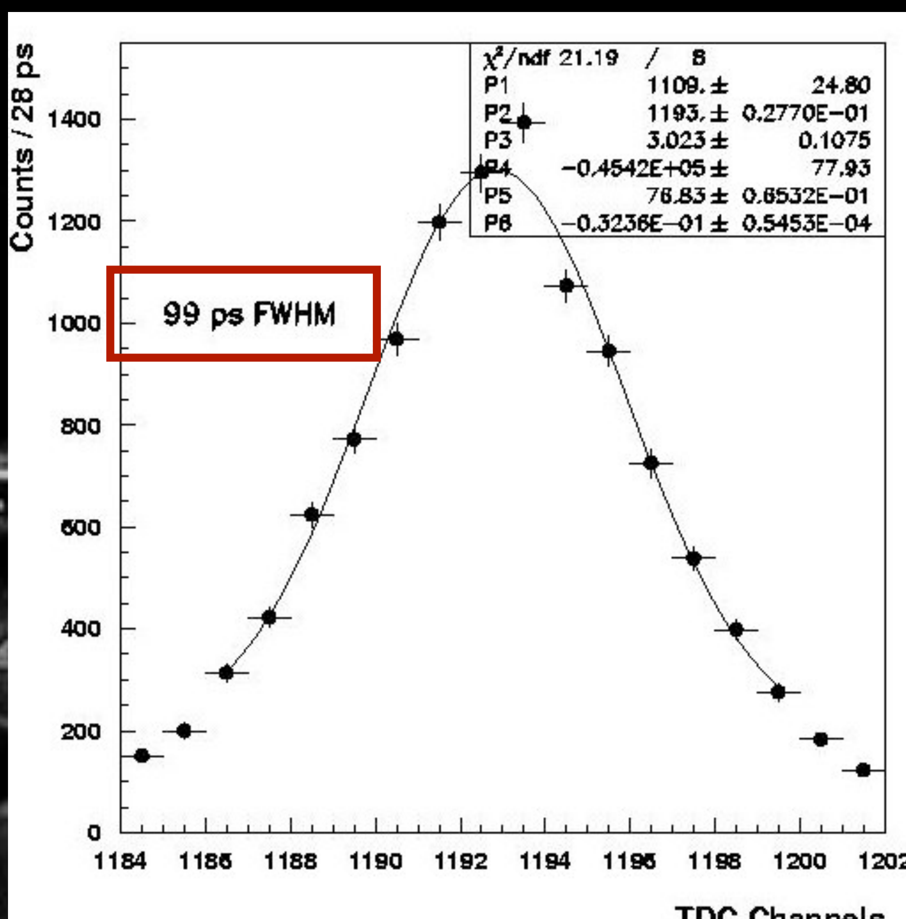

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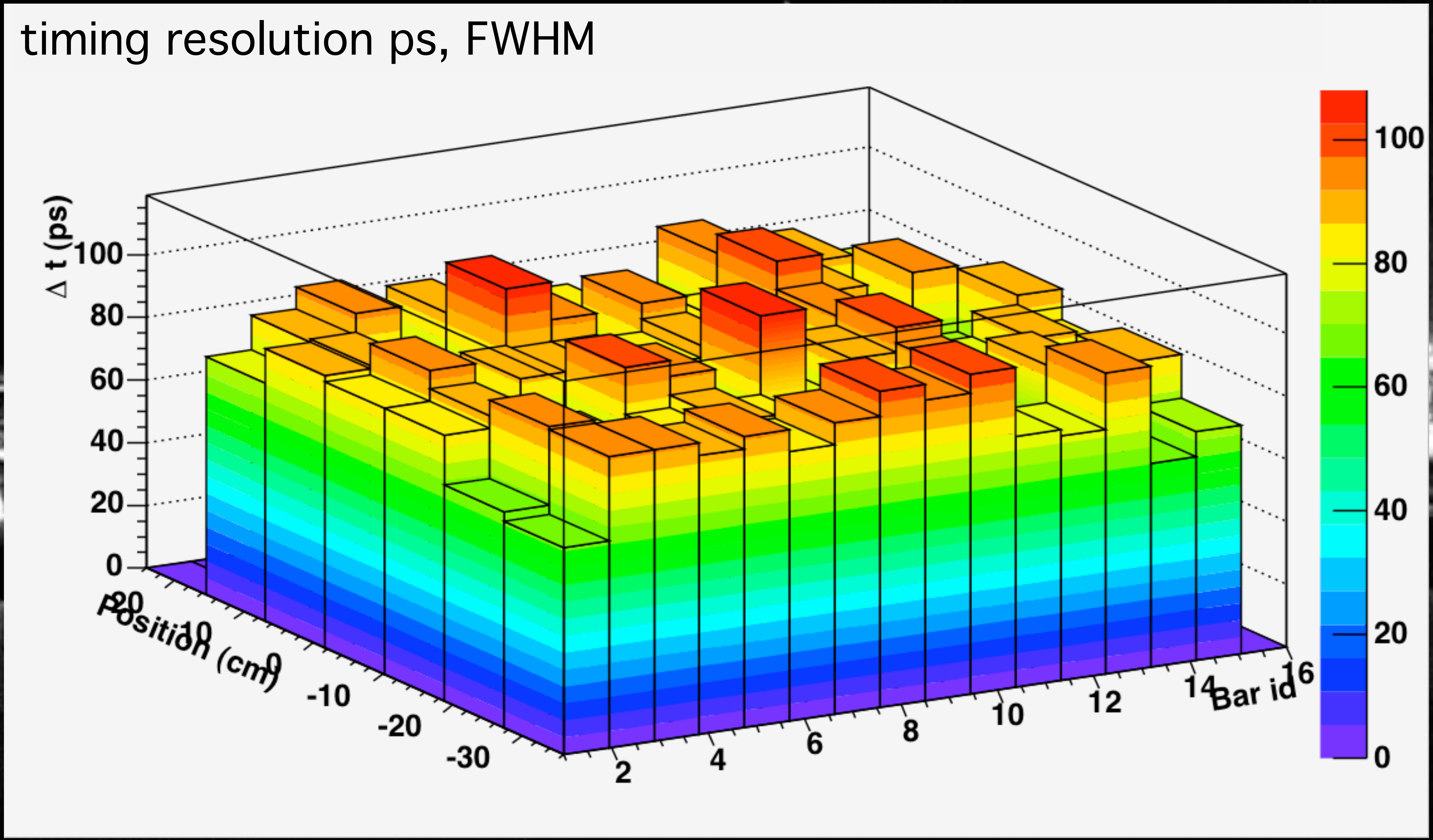
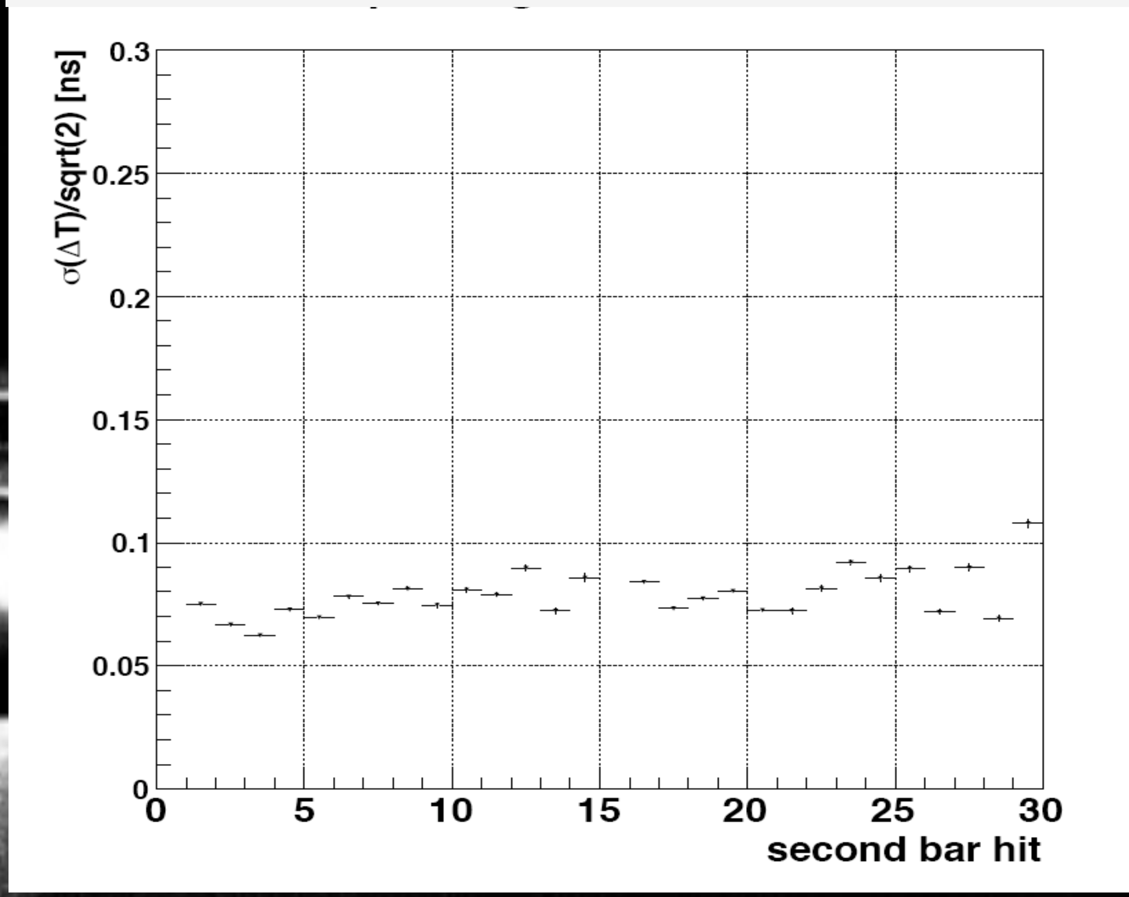
TC PERFORMANCES - I

BTF test beam results



TC PERFORMANCES - I

timing resolution ps, FWHM

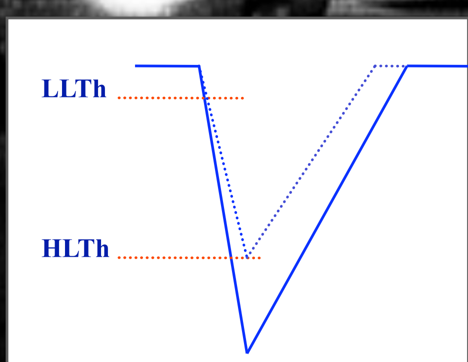


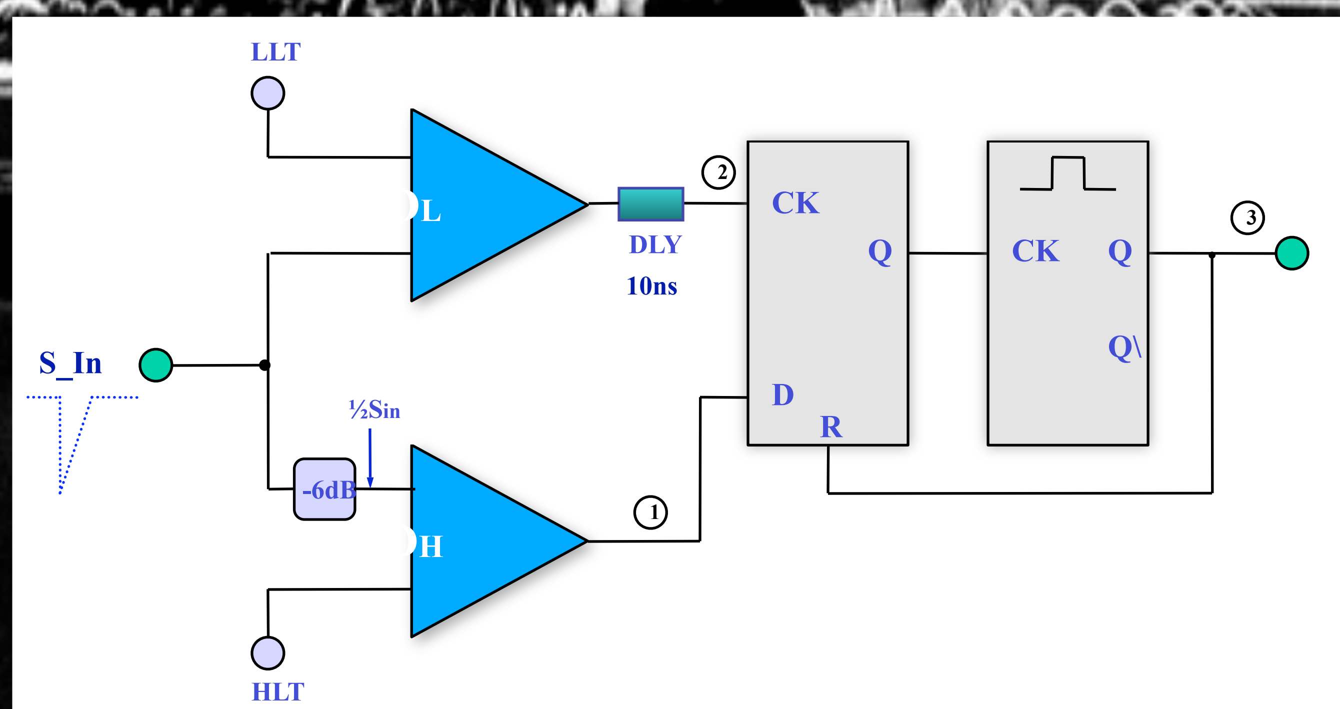
PSI final setup result, upper limit (measured with three bar telescope on Michel positrons)

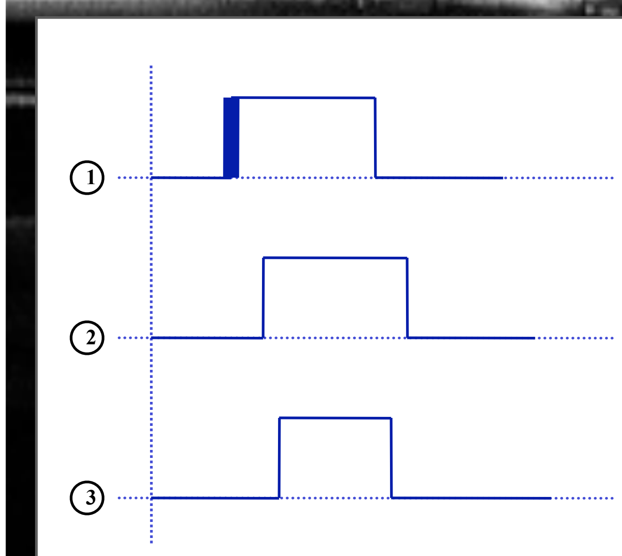
most bars have $60ps < \sigma_t < 80ps$ (<u>upper limit!</u>)

FRONTEND ELECTRONICS

The frontend electronics give a very important contribution to the final timing resolution.
We designed a double threshold fast discriminator
Low threshold give the signal timing with very low intrinsic jitter (dominated by photoelectron statistics)
High threshold applies an energy cut selecting signals from positrons with good tracks (low energy background rejection)
Contribution to total timing resolution <10ps (σ) from intrinsic jitter
Contribution from timing reconstruction algorithm is 7 ps (σ) @1.6 GS/s, ideal case (no noise, constant sampling speed)
Advantages of this approach is to have a reliable waveform to be digitized: even with a slower sampling speed timing resolution is not degraded significantly by the reconstruction algorithm :13 ps (σ) @1.2 GS/s, real case (noise and sampling speed jittering)







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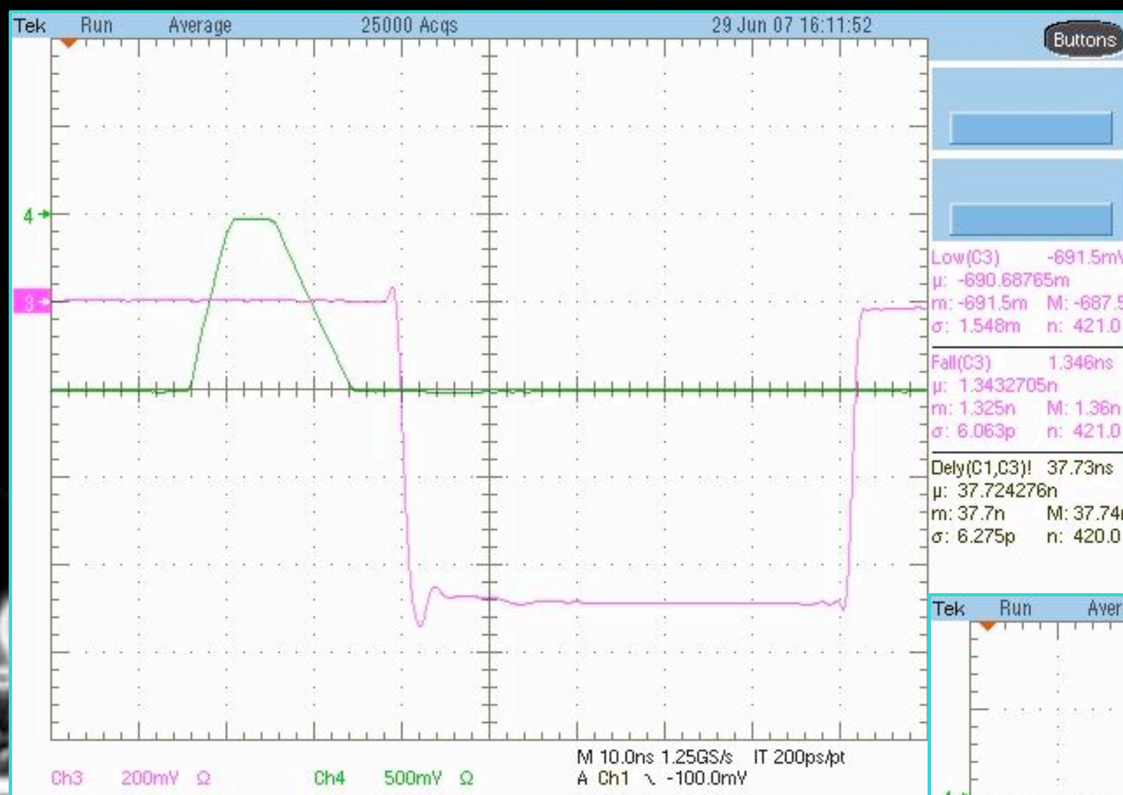
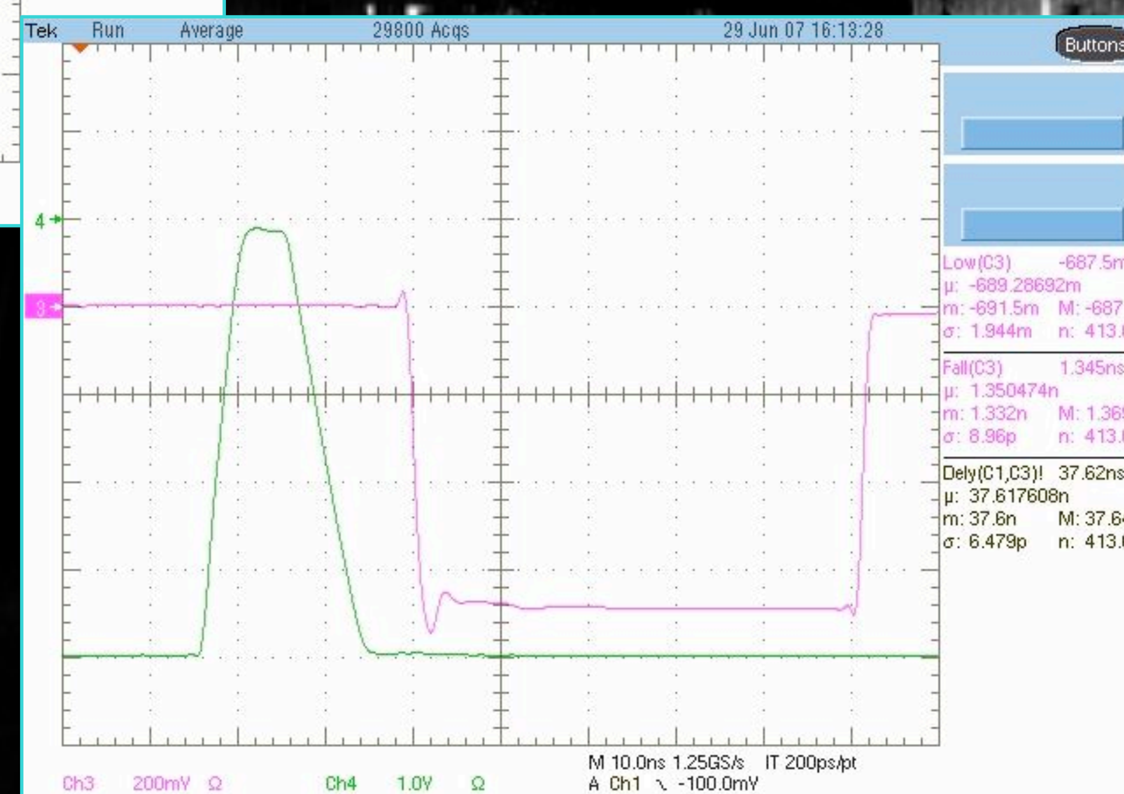
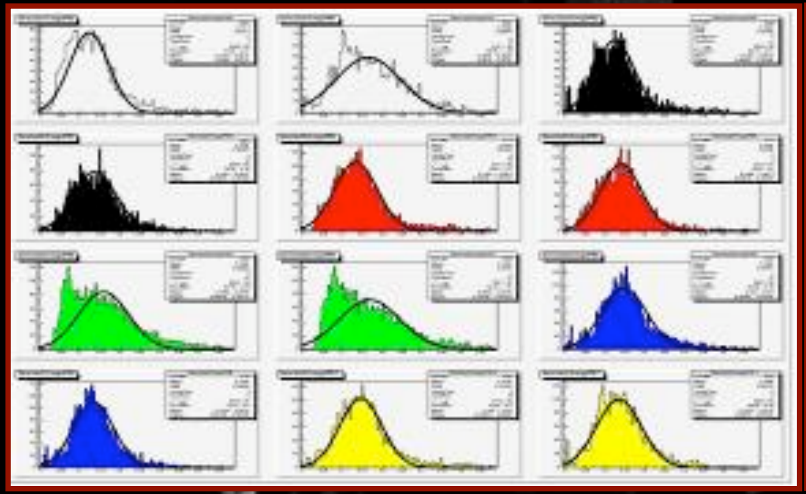


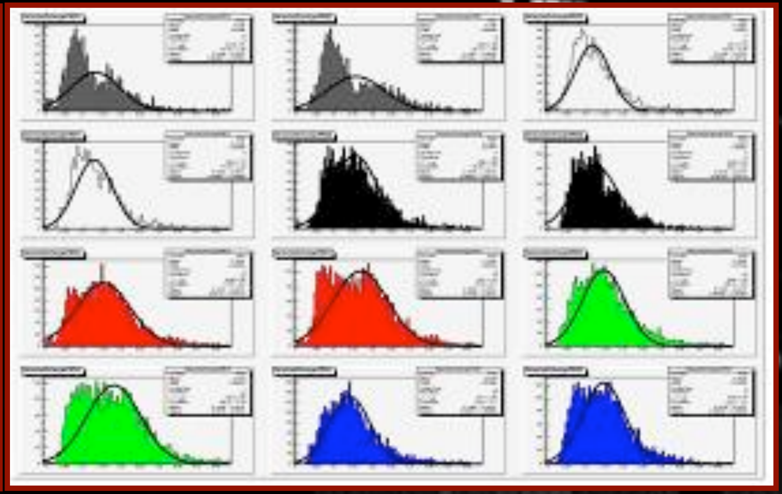
response of DTD with a PMT-like pulse at the input

nice signal with steep leading and trailing edges

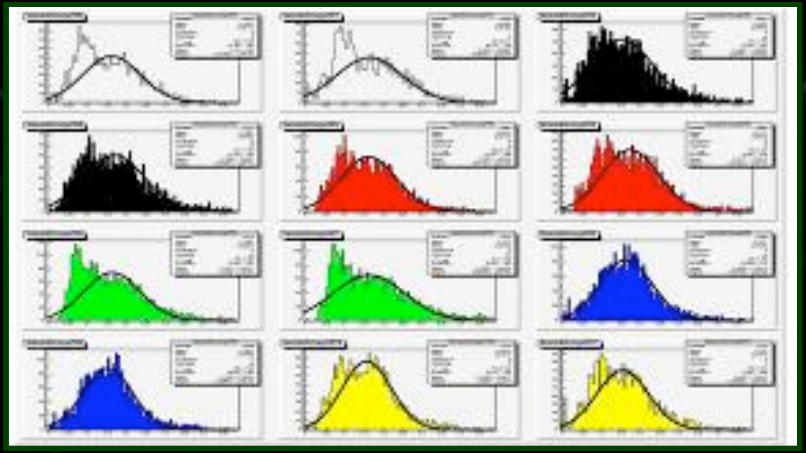


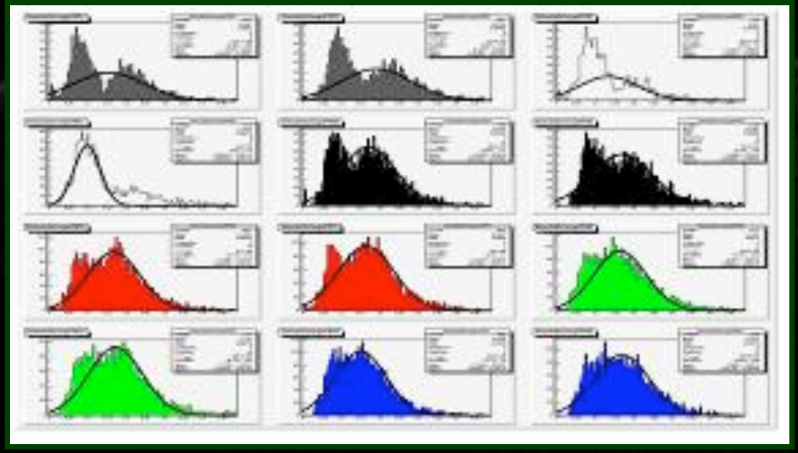
TIMING COUNTER ISSUES - CONT'D





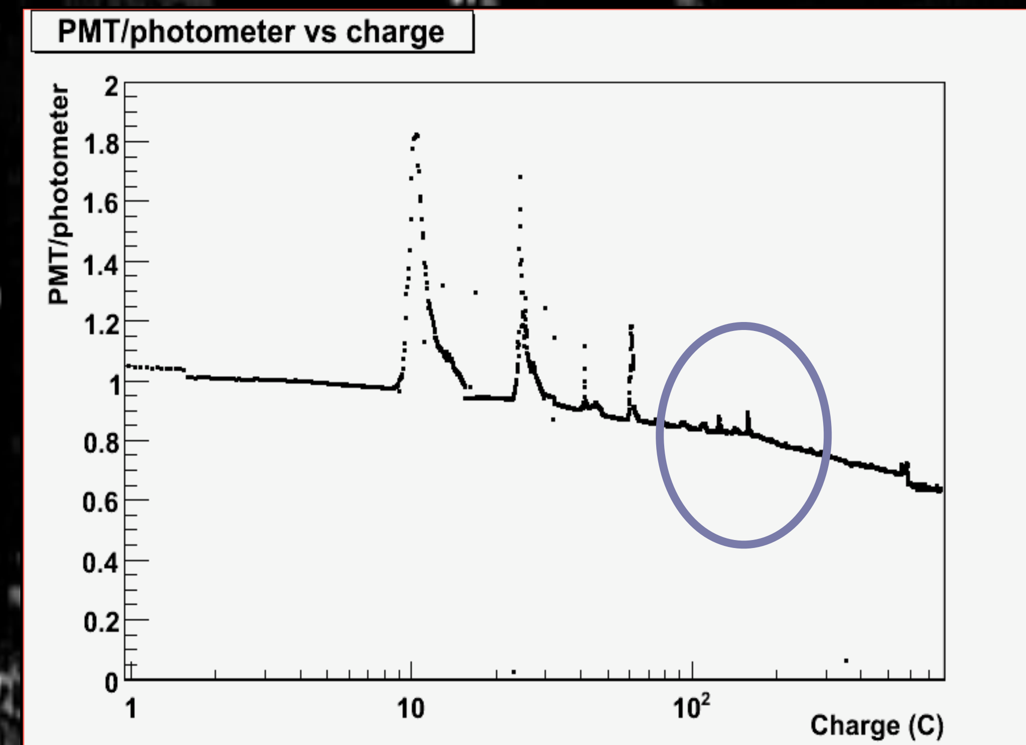
Final setup: needed inter-bar equalization for a uniform detector response (all thresholds are set together)
our choice was to use Michel and cosmics crossing the bar near the center, then find the landau peak and regulate HV for each PMT to obtain equal values for each couple

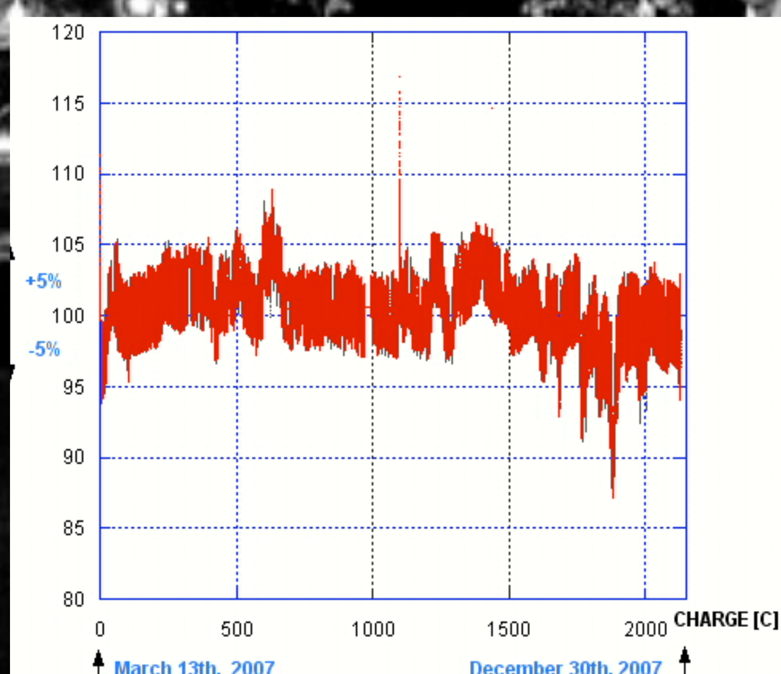




TIMING COUNTER ISSUES - CONT'D

A quite important issue is how much charge can be extracted from the PMTs,without degrading their performances.
We performed a long-term measurement with a continuous light source with a periodic check of PMT gain
right, we have an older 1.5” PMT tested: after ~300 C have been drained the PMT performance degrades faster but with an acceptable rate, at least for a collected charge 5 times (approximately) larger
left, the same measurement for a new 2” PMT like the ones used in the TC: degradation not yet observable after 2100 C of charge
Expected from our setup:





life	G/G(0)
0.2	90%
2.0	77%
3.3	70%
5.0	65%

TRANSVERSE DETECTOR

The reconstruction of the z-coordinate of the impact position, useful to determine the positron-photon collinearity already at the trigger level but also in the data analysis, is performed by a layer of scintillating fibers readout by APD.

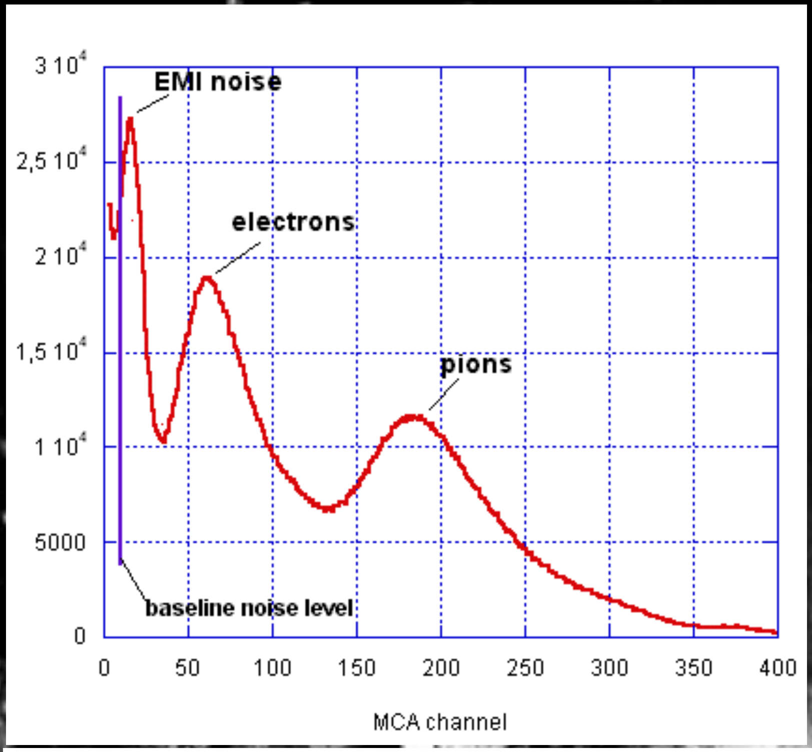
Due to the length of the fibers and the reduced particle path inside them, we need to use APDs just below the breakdown, to achieve a gain of ~500

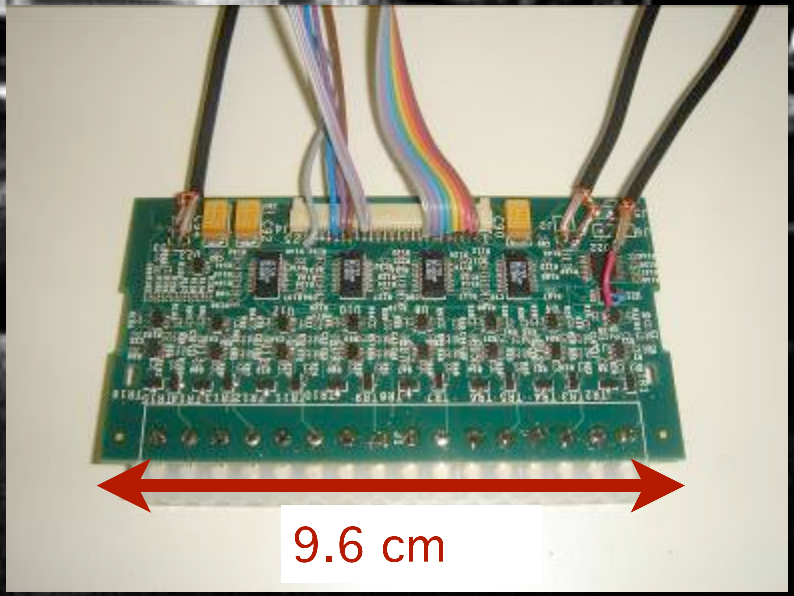
We obtained a nice separation between electrons and pions spectra at PSI

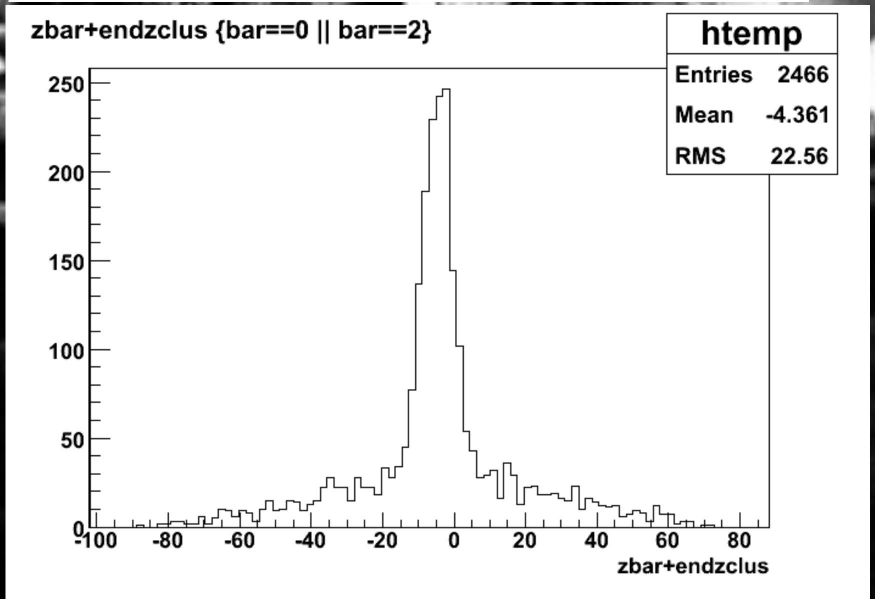
A 8-channel board is the basic module of this detector

Each channel is discriminated onboard, while the analog signal from each APD is summed: in this way we can effectively reduce data amount by only digitizing one bit for each channel.

Then the hit map is reconstructed by associating “on” bits to their z position







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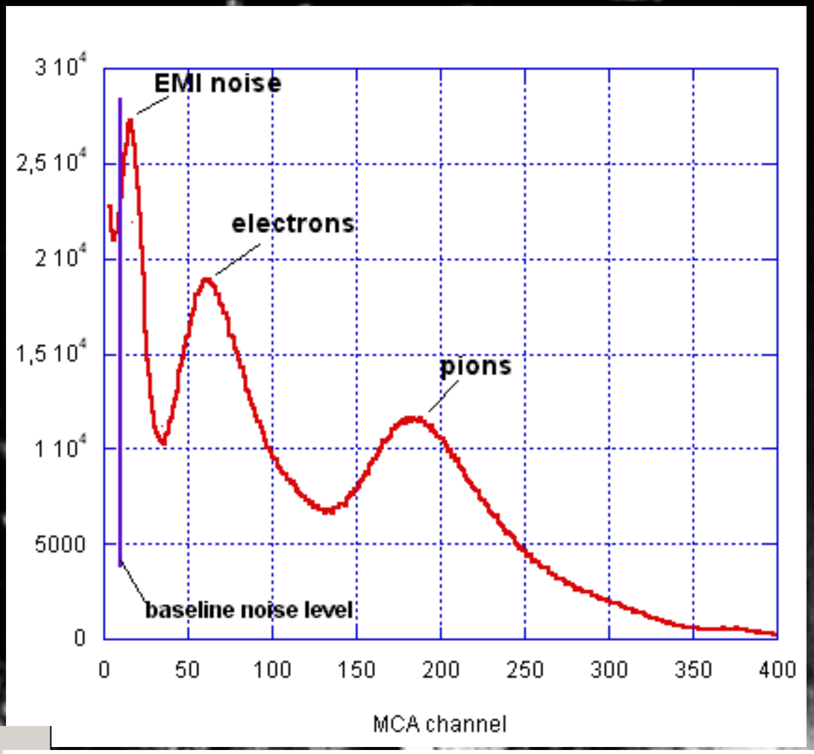

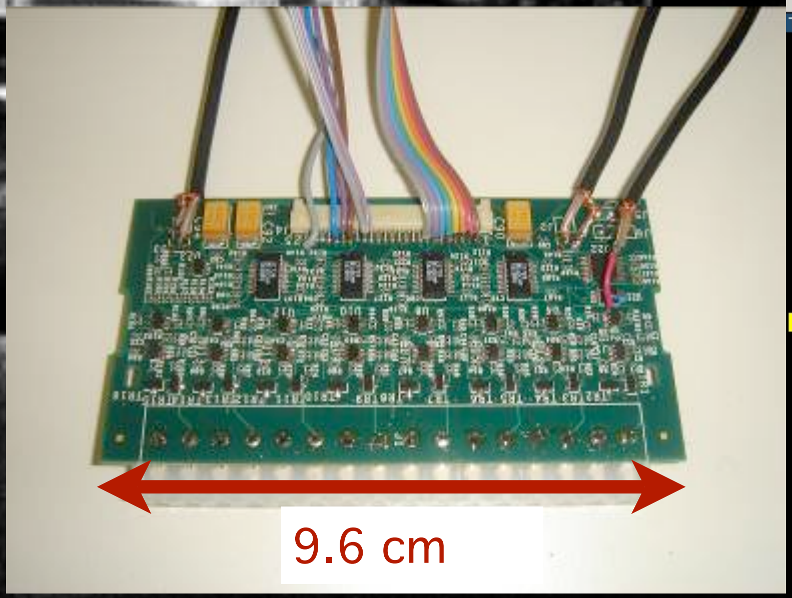

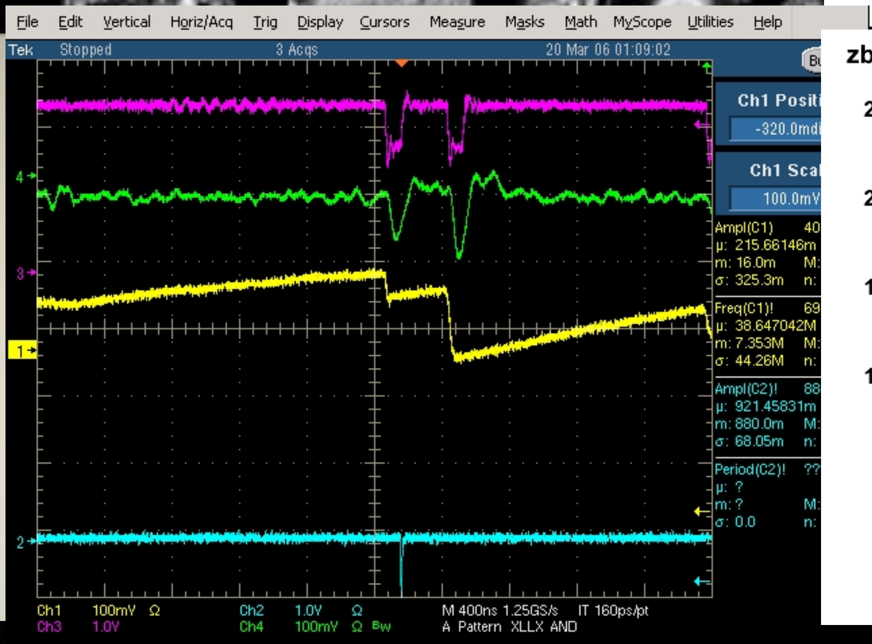

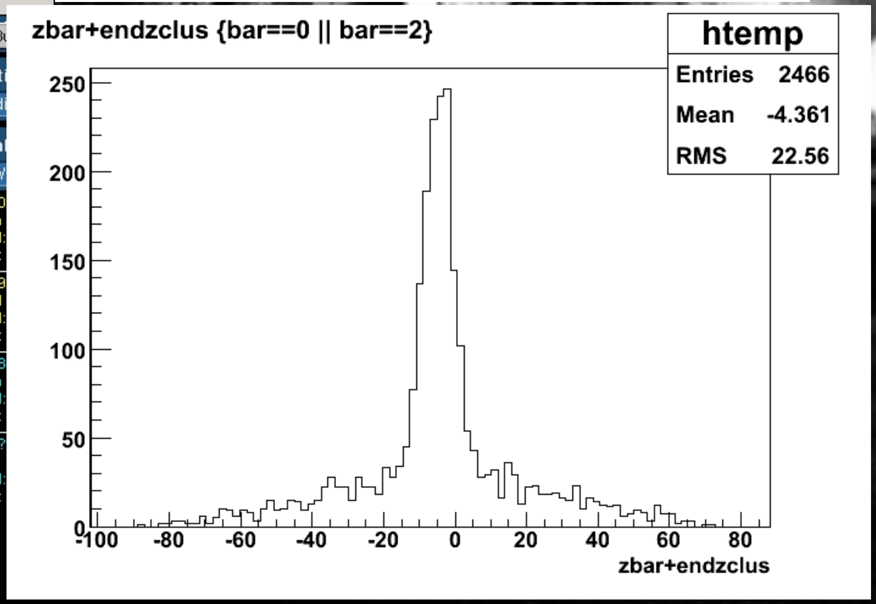

DAQ SCHEMATIC