Un detecteur pour l'identification des particules chargées dans la region avant de SuperB

A detector for charged particle identification in the forward region of SuperB

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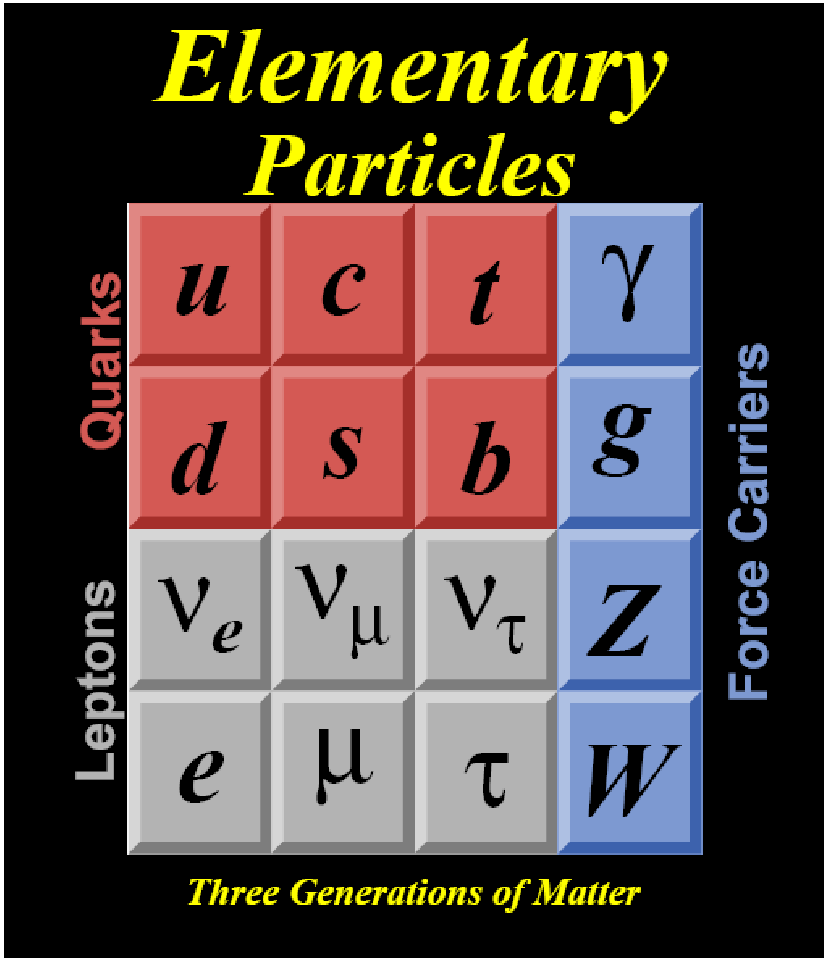
Outline

- Introduction
- The FTOF: a particle identification detector in the forward region of the SuperB experiment
- Test at SLAC of a FTOF prototype
- Background studies
- Test of photon detectors
- Conclusions

Introduction

The Standard Model of strong, weak and electromagnetic interactions



- Matter consists of 6 quarks and 6 leptons (3 generations) and antiparticles
- The interactions are mediated by vector gauge bosons (force carriers)
- The particle masses appear through the Higgs mechanism (which still needs to be confirmed experimentally)
- Quark flavour mixing and CP-violation are described by the Cabibbo-Kobayashi-Maskawa (CKM) unitary (3 x 3)-matrix

CKM unitary matrix and Wolfenstein parametrization

Weak eigenstates (*d', s', b'*) are linear combinations of the mass eigenstates (*d, s, b*)

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} = V_{\mathrm{CKM}} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

The non – diagonal elements of the CKM matrix allow for the transitions between quarks of different families

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Wolfenstein parametrization of the CKM matrix is shown below:

$$V_{\mathrm{CKM}} = \begin{pmatrix} 1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

3 real parameters (λ, ρ, A) and 1 <u>CP – violating complex phase</u> (η)

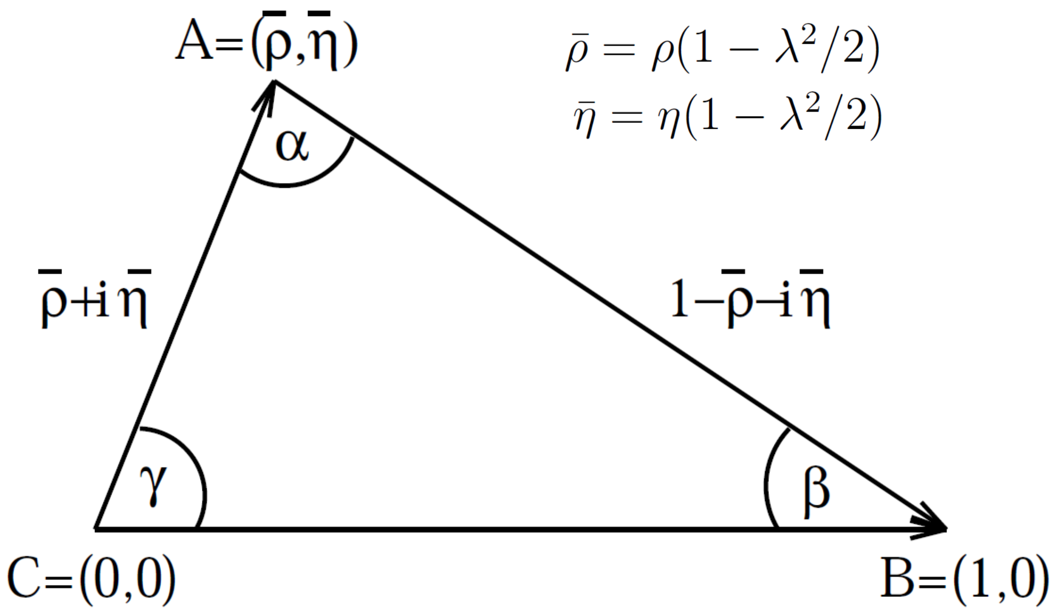
Unitarity Triangle

The CKM matrix is unitary → $V_{\mathrm{CKM}} V_{\mathrm{CKM}}^{\dagger} = 1$

One of the six triangular equations:

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 \qquad \frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} + 1 + \frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*} = 0$$

This equation represents a triangle in the complex plane:

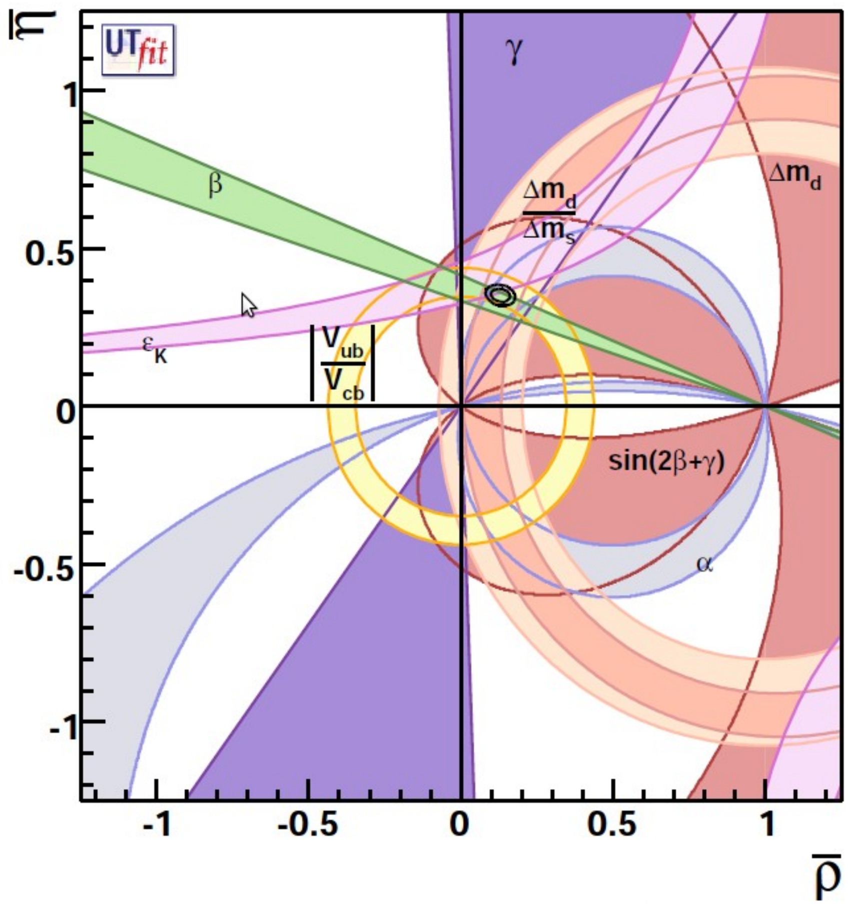


$$\bar{\rho} = \rho(1 - \lambda^2/2)$$
$$\bar{\eta} = \eta(1 - \lambda^2/2)$$

B physics plays an important role in constraining the angles and the sides of the Unitary Triangle

Current status of the Unitarity Triangle

In the last decade, the main role in B physics has been played by the PEP – II and KEK – B B-factories, which produced ~10^9 B-mesons



Constraints in the $(\bar{\rho} - \bar{\eta})$ plane.
colors represent 2 σ contours

Coherent picture of Standard Model (SM) describing CP and flavour mixing phenomena

But:
SM is not the final theory

The goal of the new generation of high energy experiments is to find scale of the New Physics

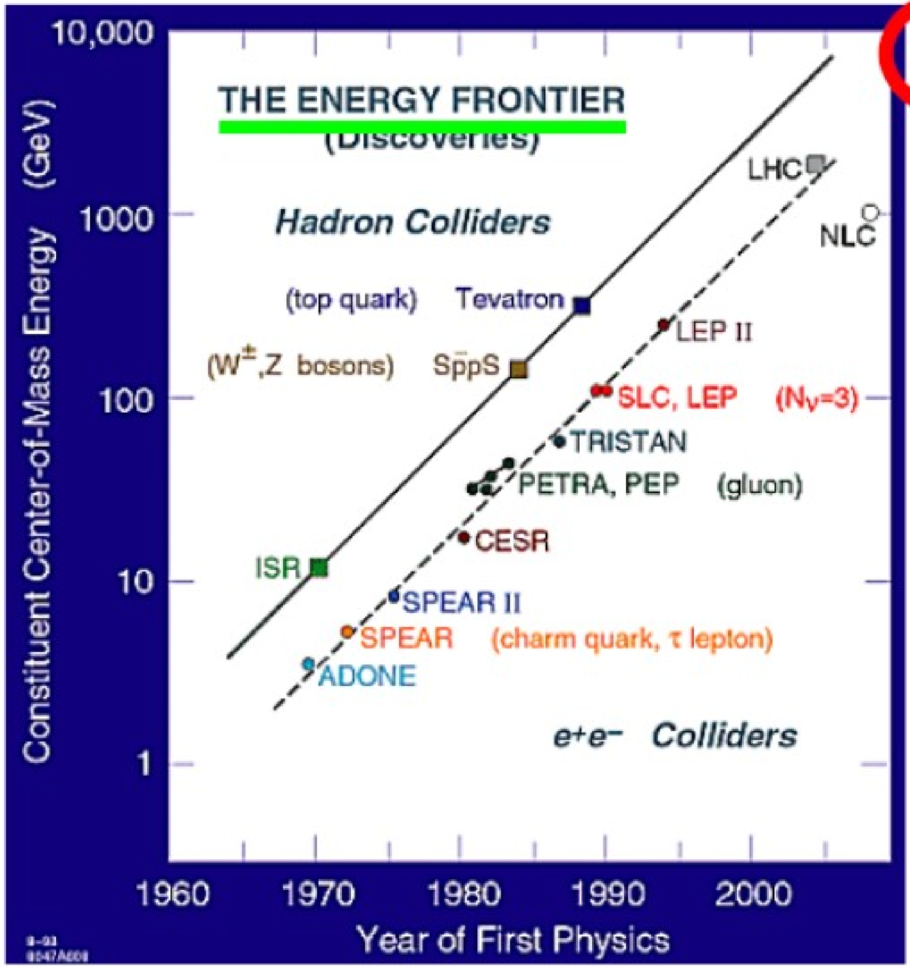
Ways to explore the properties of matter

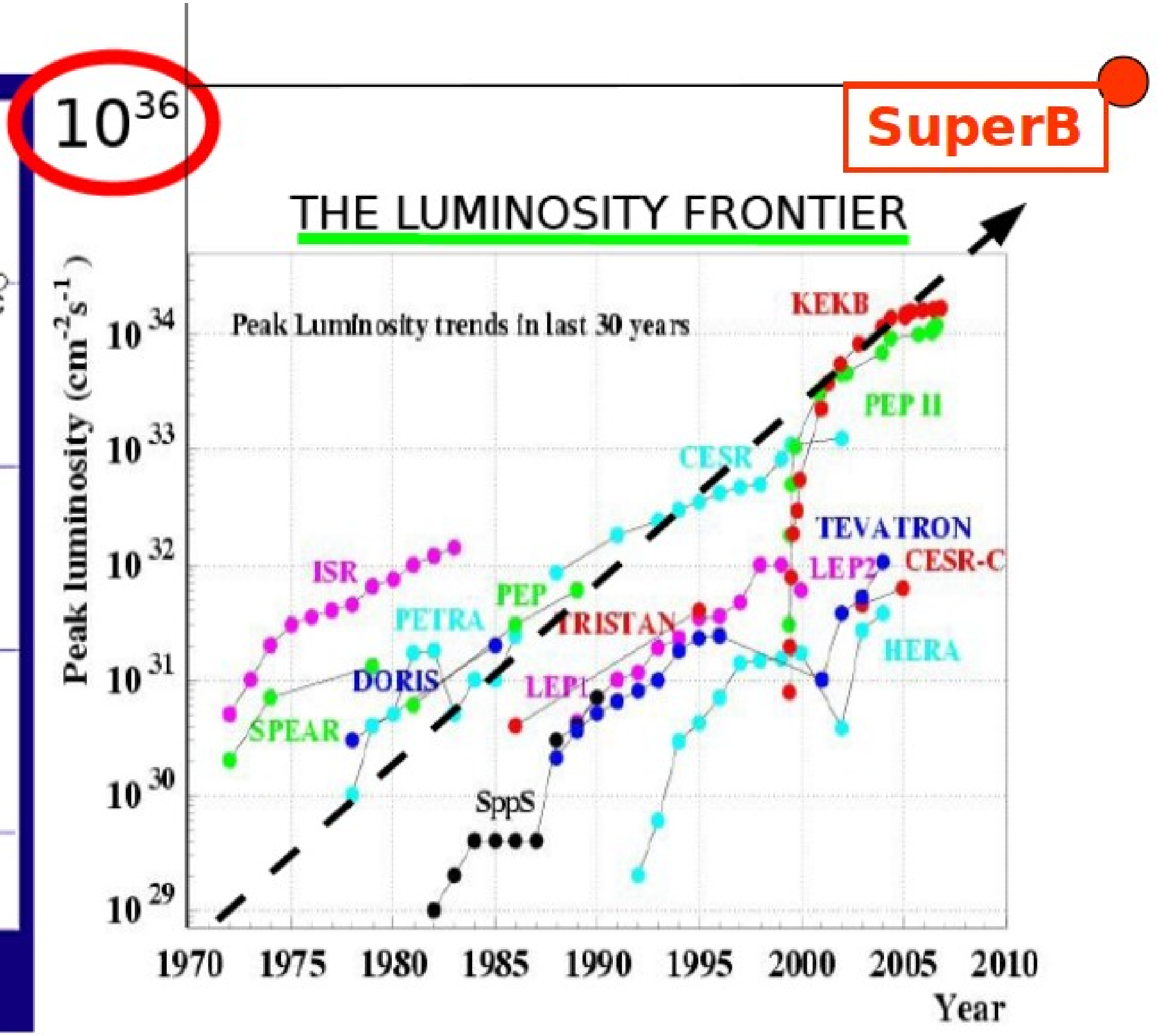
Direct way:
observation of new particles

Indirect way:
very precise measurements of observables
and comparison with SM predictions

Crucial: Center-of-mass energy

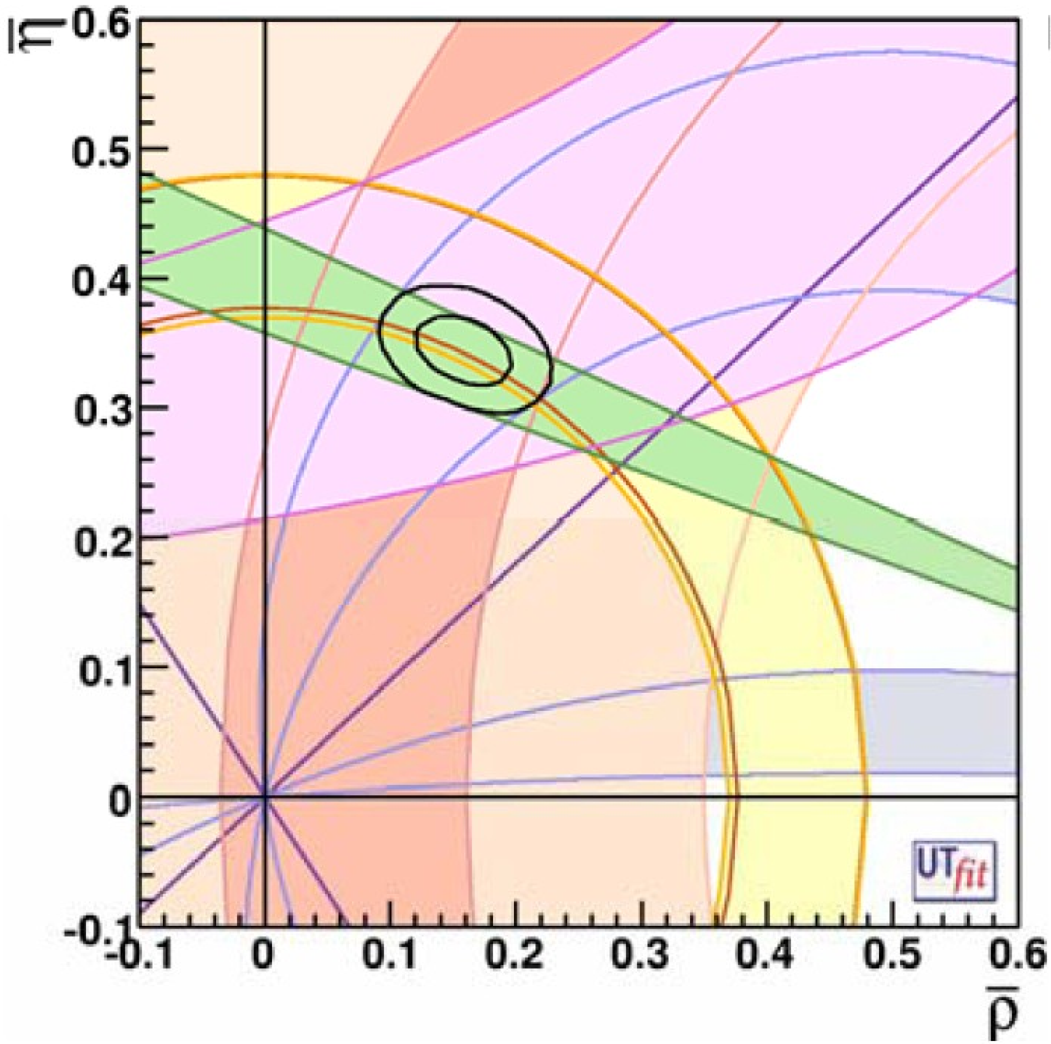
Crucial: Luminosity



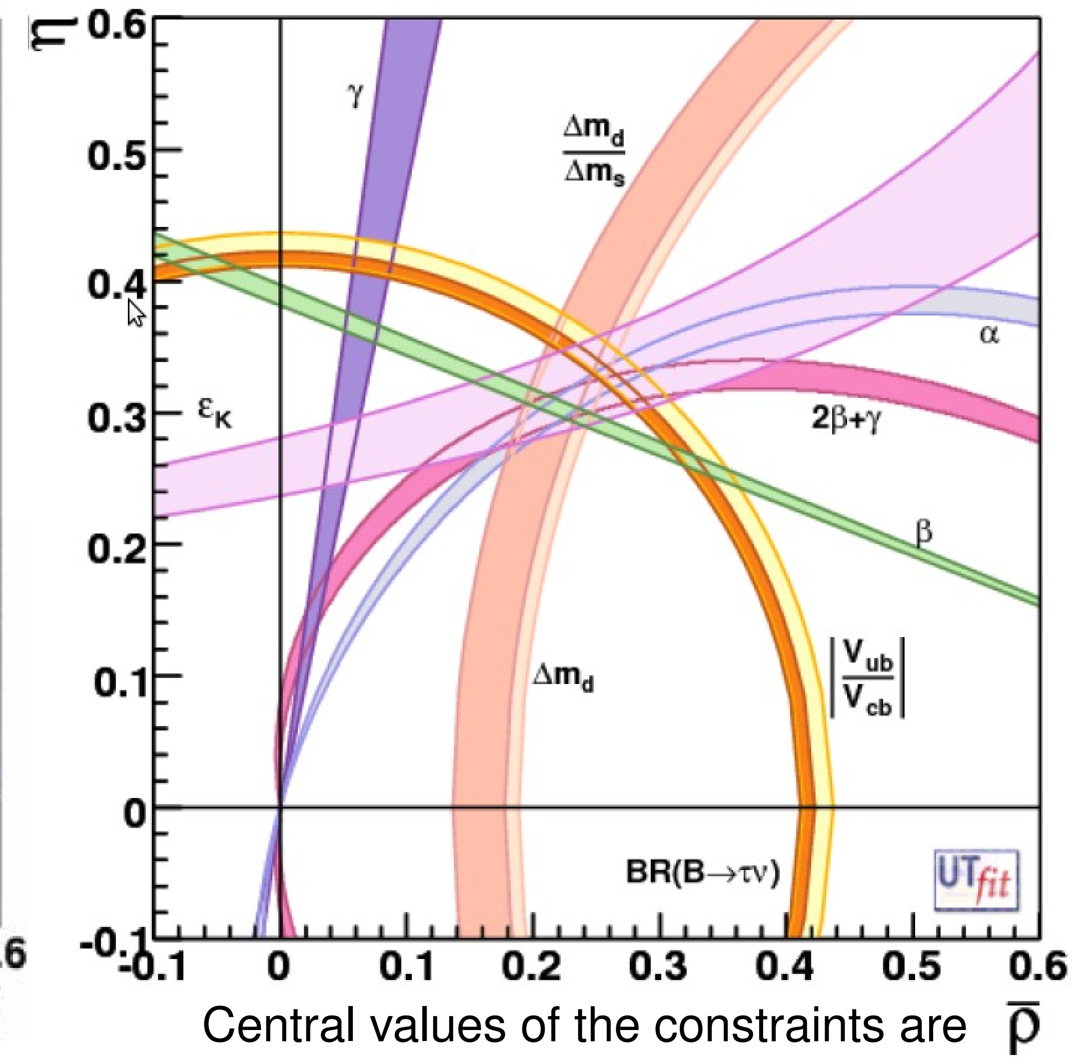


SuperB: The luminosity frontier

Apex of the Unitary Triangle
(present knowledge)



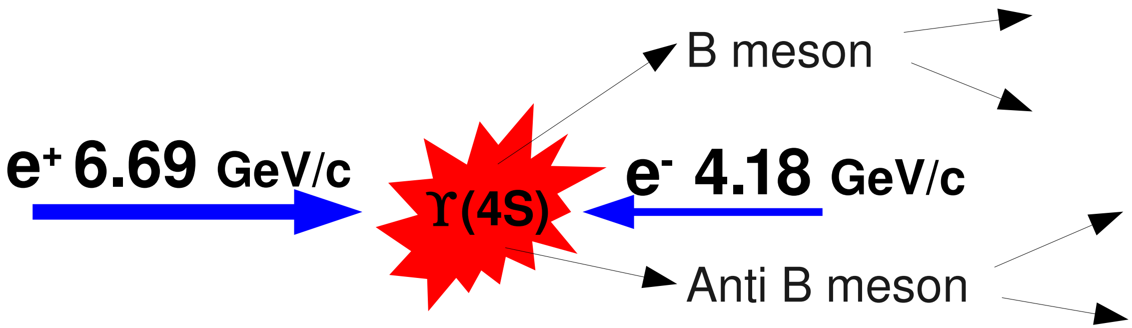
SuperB would allow us to look more
precisely into the flavour sector



Central values of the constraints are from the present data. While errors are those expected at SuperB.

The SuperB project in a nutshell

• Electron positron asymmetric collider



• Energy in the center of mass is 10.58 GeV, corresponding to the mass of the Υ(4S) resonance.

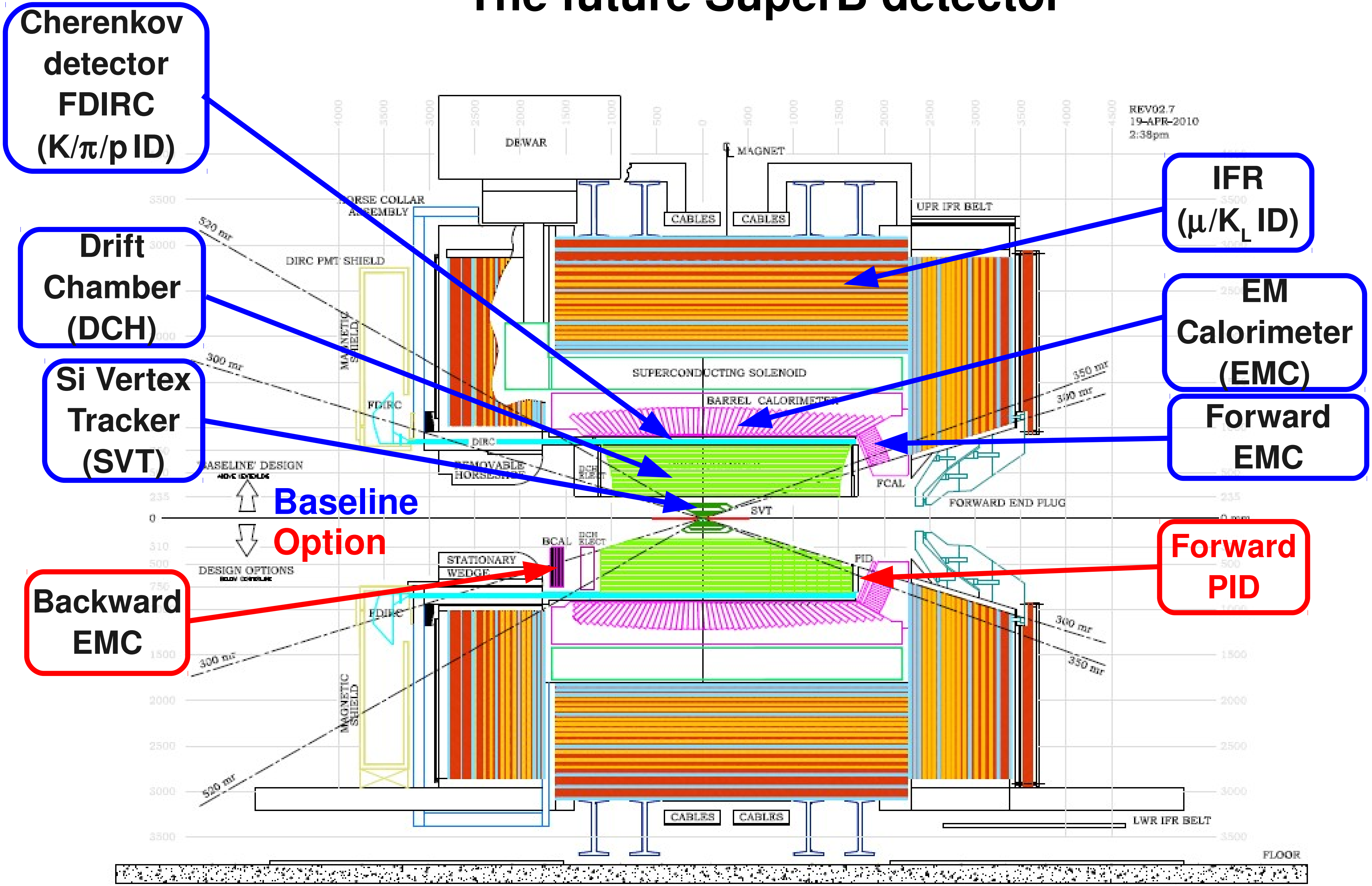
• Boost $\beta\gamma$=0.24 (reduced w.r.t. BaBar which was 0.56)

• Peak Luminosity goal: 10^{36} $cm^{-2}s^{-1}$ (15 ab^{-1} per year and 75 ab^{-1} in total). 100 times more than PEP II (BaBar) and KEK-B (Belle).

• Use large Piwinski angle and new crab waist bunch crossing scheme, tested at DAΦNE (2008-2009) [I took part in this experiment] (M. Boscolo et al. , Nucl. Instrum. Methods A621 , 121 (2010))
(M. Boscolo et al. , Nucl. Instrum. Methods A617 , 453 (2010))

• SuperB detector based on BaBar but substantially improved.

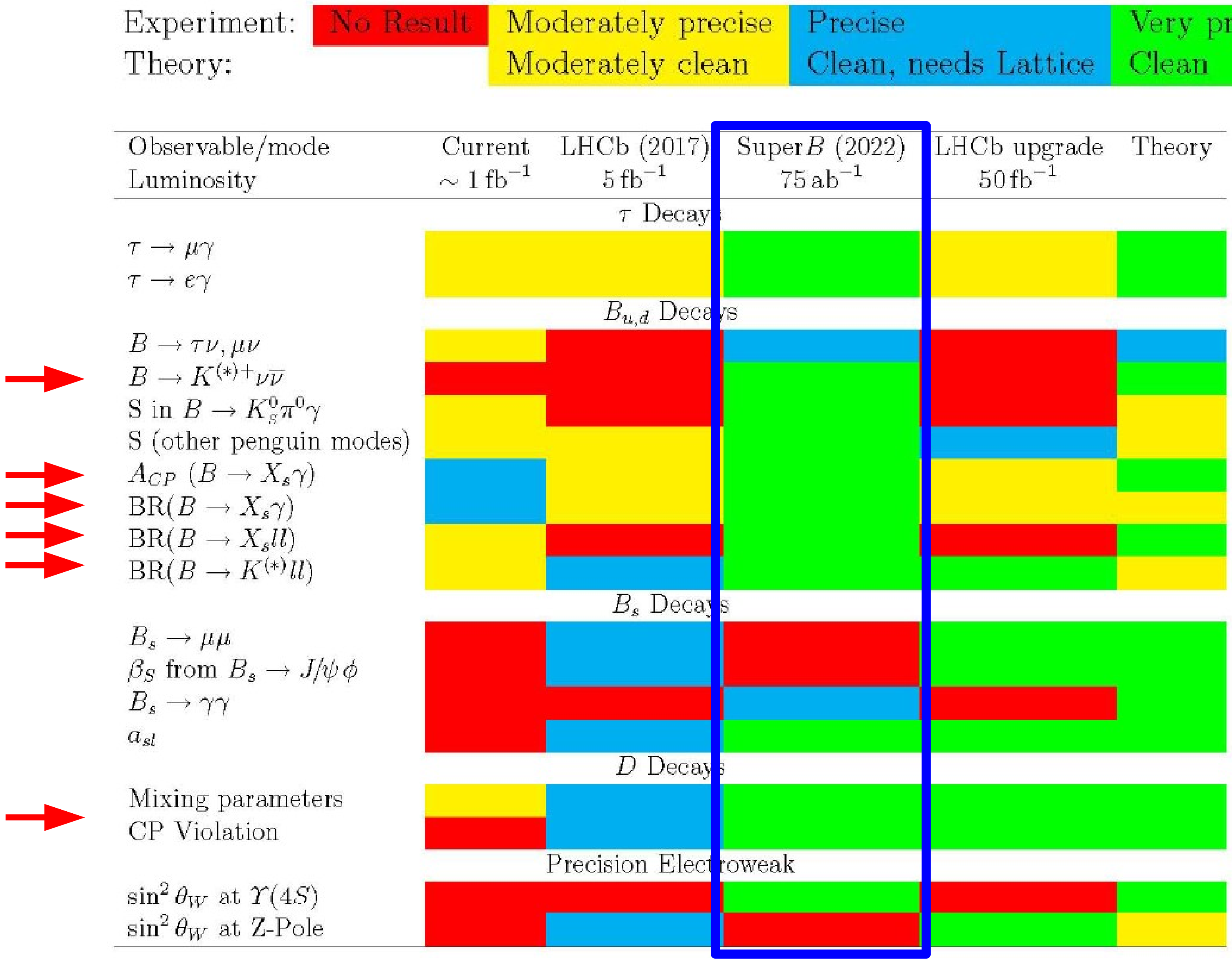
The future SuperB detector



The Detector Geometry Working group has been studying the possible options

FTOF: a particle identification detector in the forward region of the SuperB experiment

Golden measurements which require good PID



"B reco technique"

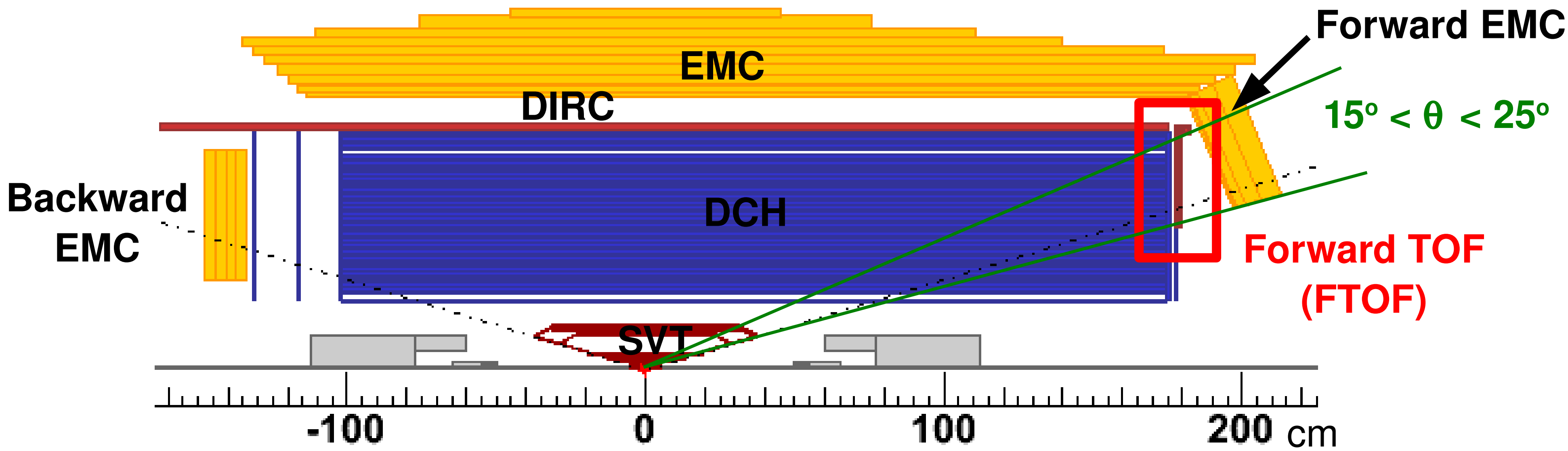
One of the B needs to be reconstructed

B → D X
→ K ....

arXiv:1109.5028

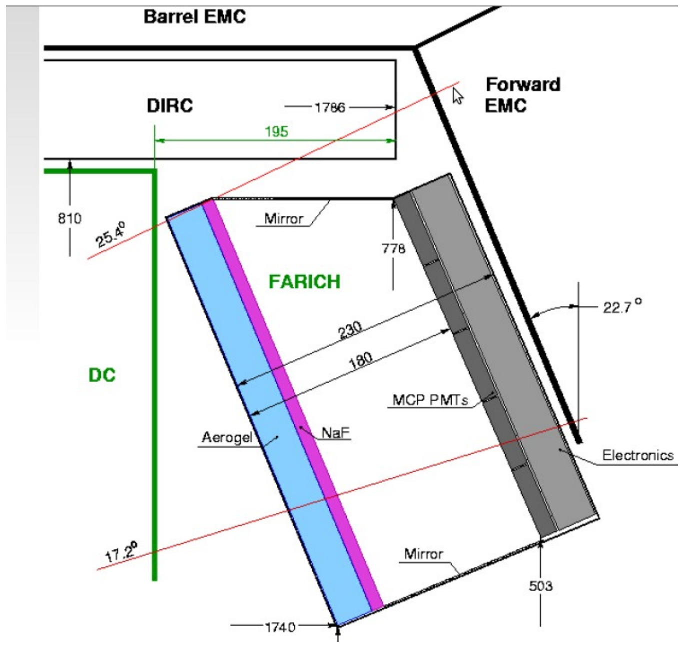
Barrel region covered by a good PID detector (FDIRC)

Requirements for particle identification in the forward region



- Good K/π separation in (0.7-3.0) GeV/c momentum range
- Compact device (limited space between DCH and forward EMC)
- Small amount of material in front of the EMC
- Radiation hard (close to IP)

Possible choices for forward PID detectors



Focusing Aerogel RICH

M.Yu.Barnyakov, S.A.Kononov, E.A.Kravchenko, et al.

Very good PID performances

- ➔ X/X_0 = 26 %
- ➔ 23 cm thick
- ➔ 20,000 readout channels

Time-Of-Flight (TOF)

Proposed by Jerry Va' vra

"Pixelated" TOF

- ➔ X/X_0 ~ 30 %
- ➔ ~5 - 7 cm thick
- ➔ ~7200 readout channels

DIRC-like TOF

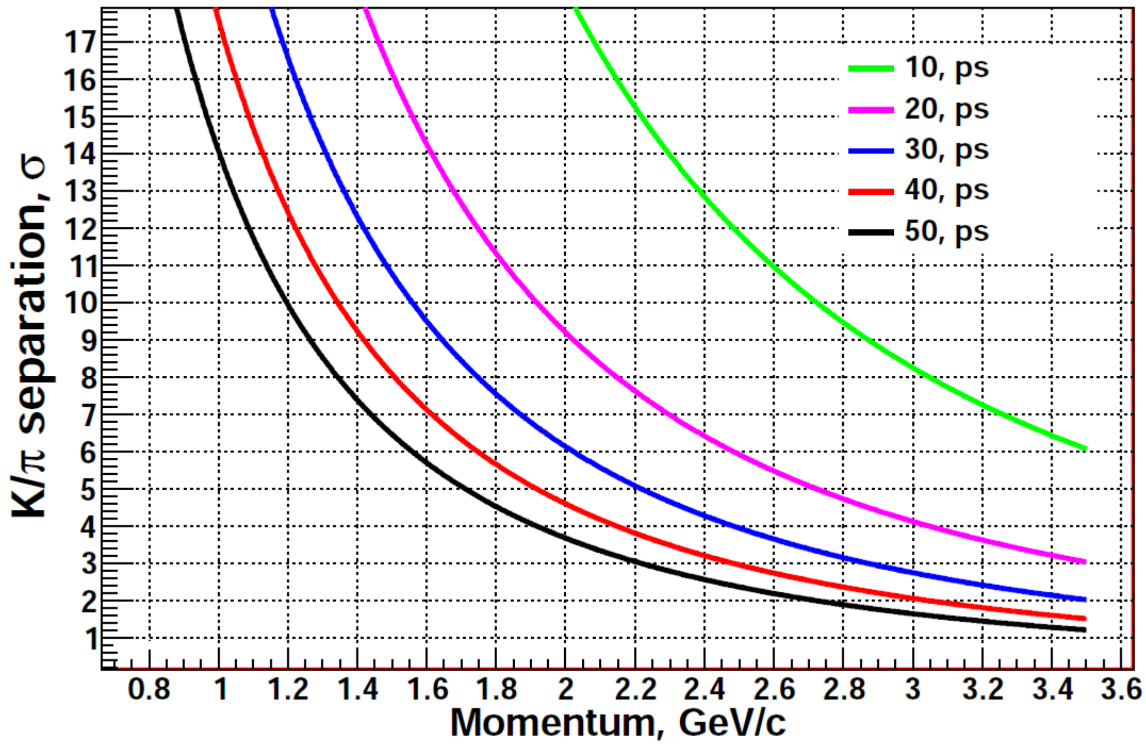
- ➔ X/X_0 = 12 %
- ➔ ~5 cm thick
- ➔ ~700 readout channels

SLAC + LAL

Time-Of-Flight concept

Two particles with masses m_1, m_2, with same momentum p flying over a distance L, have a Δt time flight difference given by:

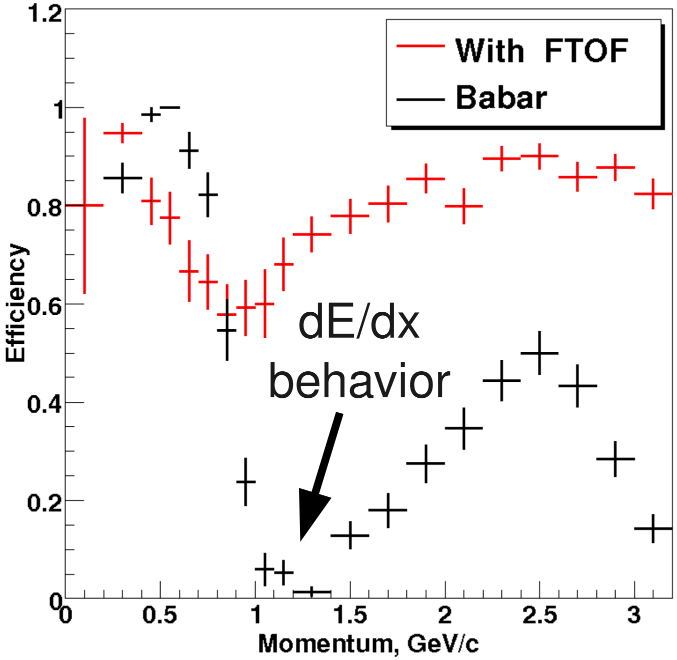
$$\Delta t = \frac{Lc}{2p^2}\left(m_1^2 - m_2^2\right)$$



A TOF detector with 30 ps resolution and 2 m flight length has 3 σ K/π separation at 3 GeV/c.

Physical gain with FTOF

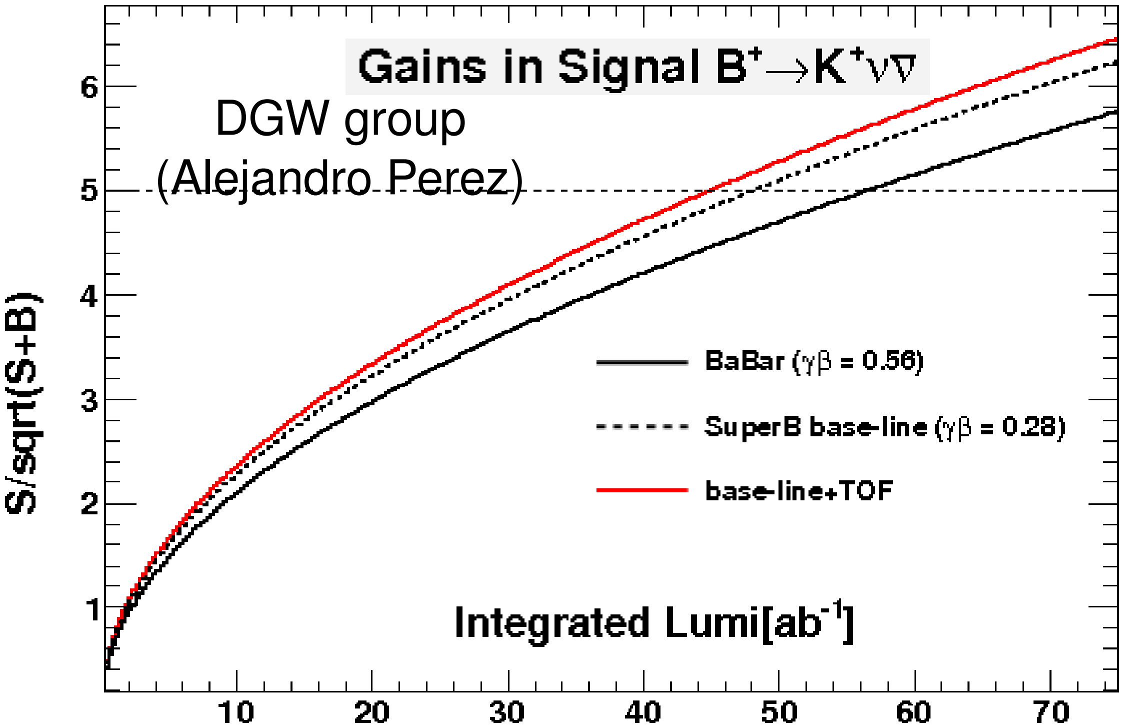
Kaon identification



Many rare B modes required PID

→ FastSim: a parametric fast simulation for detector optimization.
(R. Andreassen, N. Arnaud, DN Brown, L. Burmistrov, J Carlson, C. Cheng, A. Di Simone, I. Gaponenko, E. Manoni, A. Perez, "Nuclear Science Symposium Conference Record (NSS/MIC), 2010 IEEE")

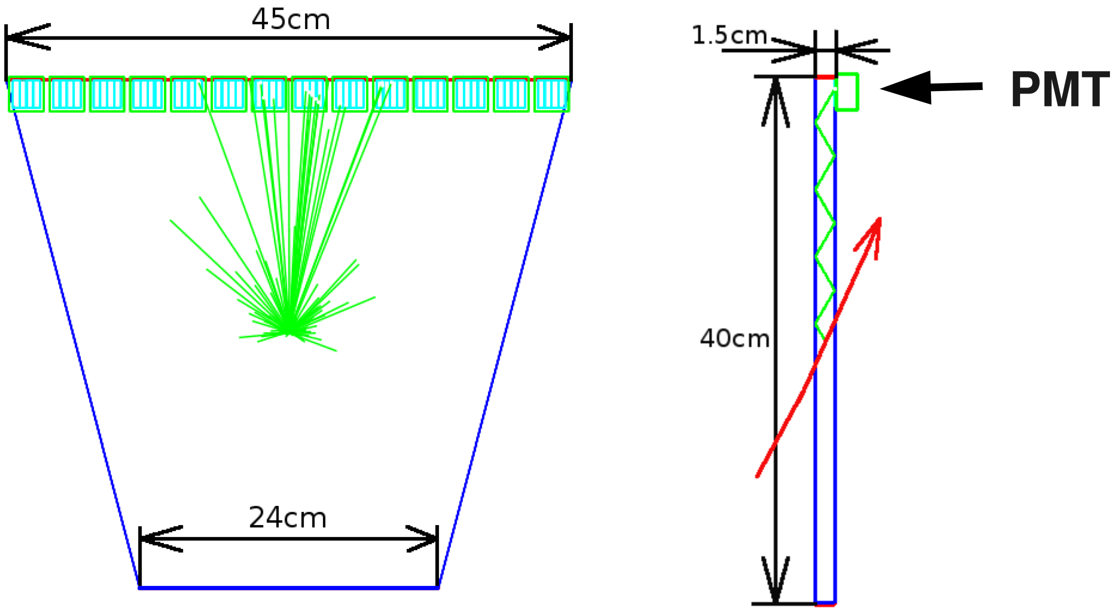
→ The 30 ps FTOF improves kaon identification probability, while keeping high pion rejection efficiency (~99 %)



Reach 5 σ significants with (5 – 10) % less integrated luminosity

FTOF: a DIRC-like TOF detector

Detection of Internally Reflected Cherenkov light (DIRC)



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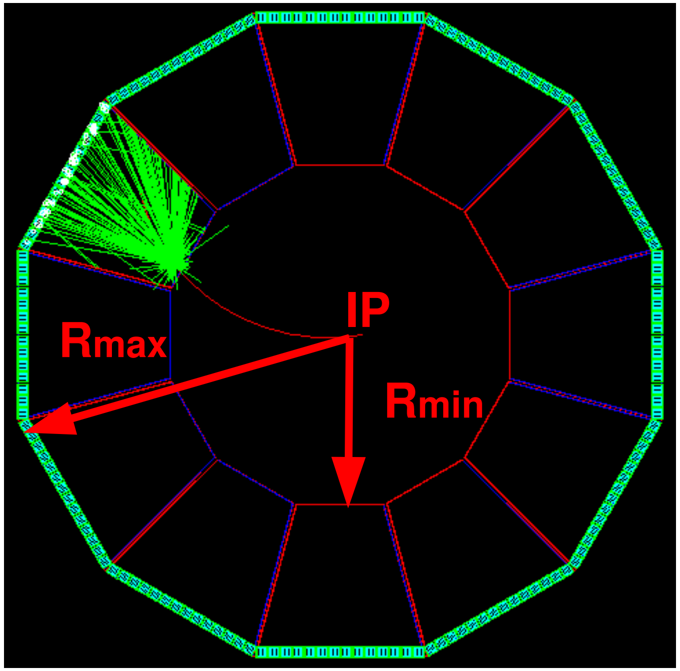
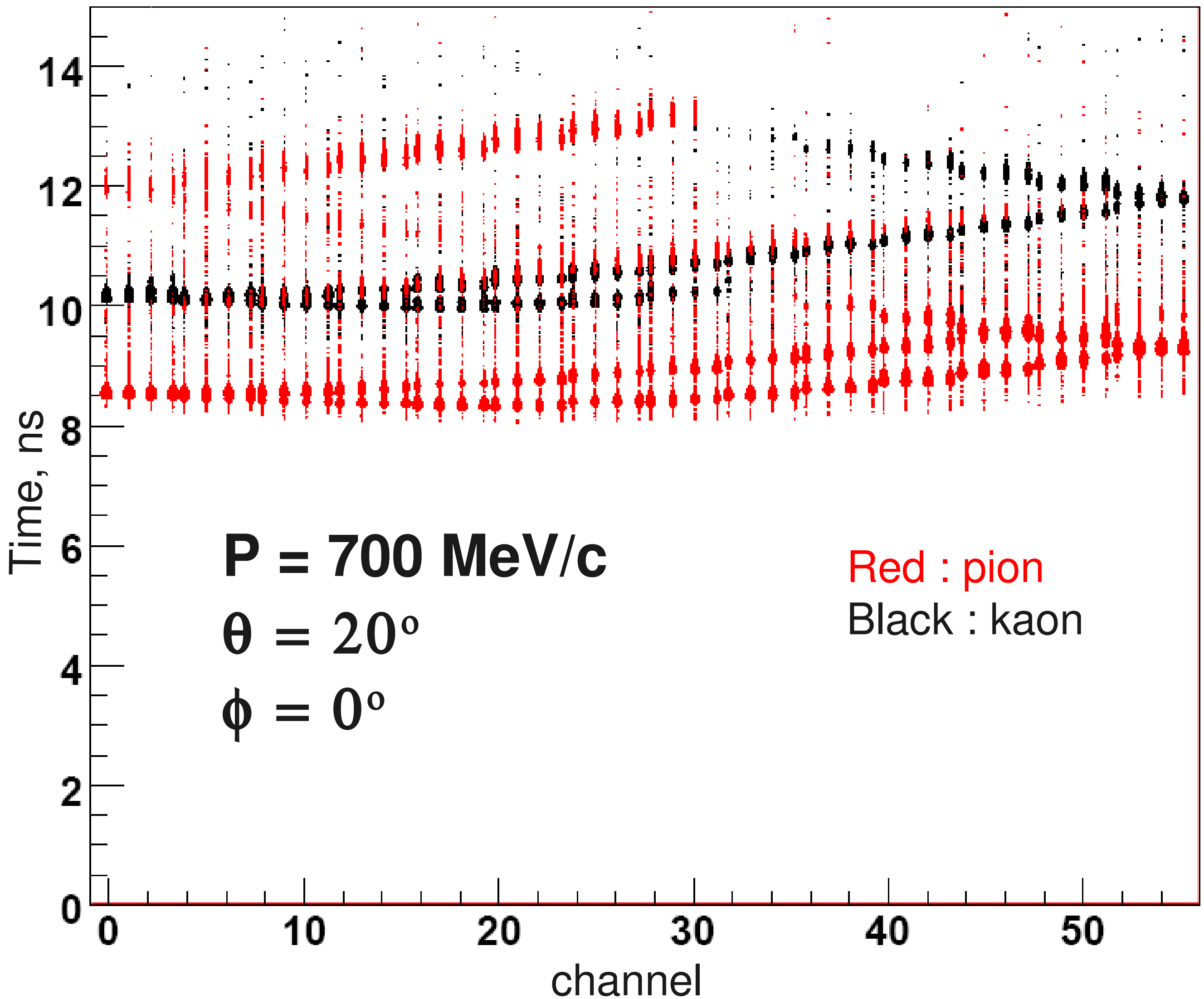


- Detector made of 12 well-polished quartz sectors, covering 2π in azimuth
- The quartz used as radiator of Cherenkov photons and as light guide (DIRC technique)
- Thickness of the detector is 1.5 cm (12 % of X_0)
- R_{min} ~ 50 cm, R_{max} ~ 90 cm

- Each sector is readout by 14 very fast photon detectors – micro channel plate photomultipliers (MCP-PMT).
- **This is a 2D device which measures the time and the position of the photon hits.**

FTOF detector is a 2D device

Use both time and channel information to separate kaon from pion



14 PMTs x 4 channels /PMT = 56 channels

Time resolution of the FTOF detector

The total time resolution of this detector is the quadratic sum of different contributions:

$$\sigma_{\text{tot}}^2 \sim \left(\frac{\sigma_{\text{electronics}}}{\sqrt{N_{\text{p.e.}}}}\right)^2 + \left(\frac{\sigma_{\text{detector}}}{\sqrt{N_{\text{p.e.}}}}\right)^2 + \left(\frac{\sigma_{\text{TTS}}}{\sqrt{N_{\text{p.e.}}}}\right)^2 + \sigma_{\text{trk}}^2 + \sigma_{t0}^2$$

The contribution from:

- Electronics : 10 ps (D. Breton, E. Delagnes, J. Maalmi, TWEPP, 2009, http://hal.in2p3.fr/in2p3-00421366/en/)
- t_0 : 20 ps, $\sigma_t=\sigma_z/c$, σ_z – longitudinal size of the bunch

In this thesis I studied:

- The Transit Time Spread (TTS) for MCP-PMT, measured at LAL test bench.
- The track term (σ_{trk}) estimated with the FastSim simulation tool.
- **Detector term (timing properties) and number of photoelectrons** (N_{pe}) estimated with full Geant4-based simulation.

Study of the σ_{trk}

σ_p

Time uncertainties coming from the precision of the track momentum reconstruction

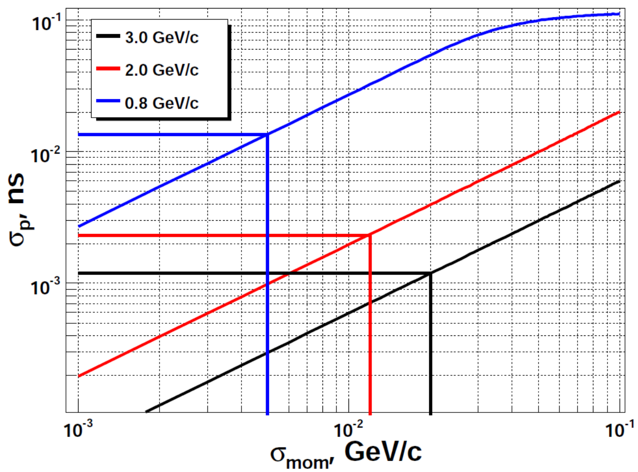
σ_L

Time uncertainties coming from the precision of the track flight length reconstruction

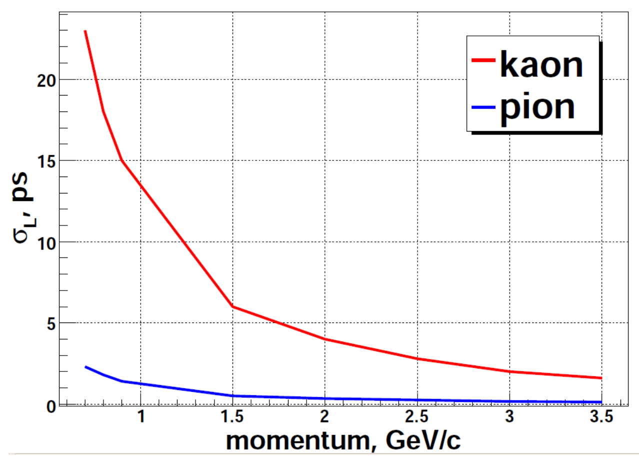
$\sigma_{\text{coupling to bar}}$

Time uncertainties coming from the precision of the track parameters at the FTOF entrance

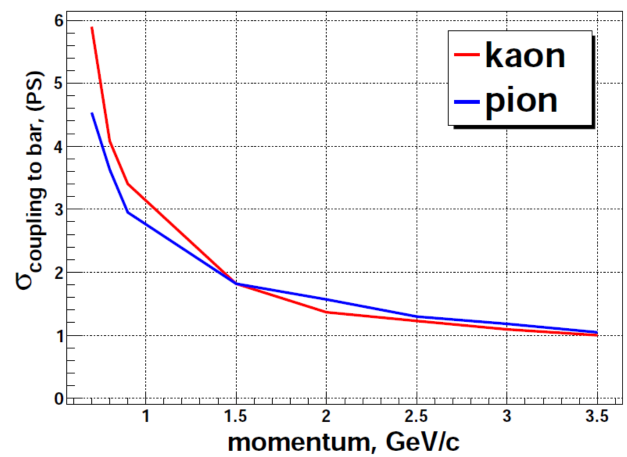
Toy Monte Carlo



FastSim



FastSim

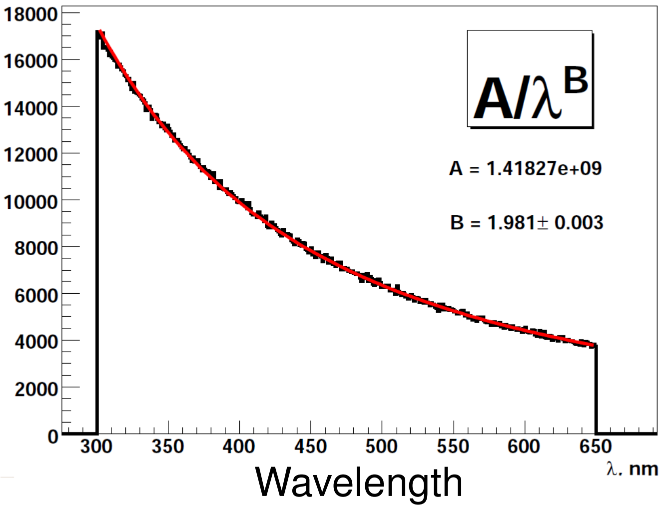


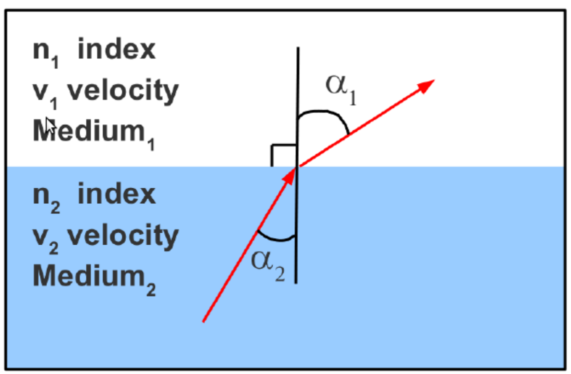
σ_{trk} for kaon with momentum larger than 2 GeV/c is below 10 ps.

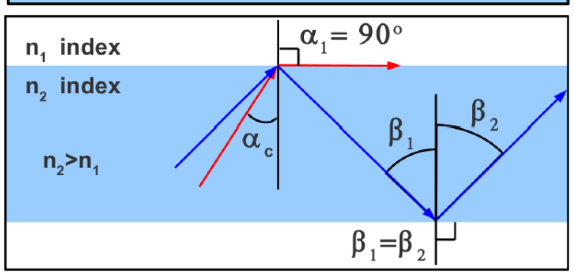
Full simulation of the FTOF detector: general

Optical physics: Cherenkov effect and Snell's laws

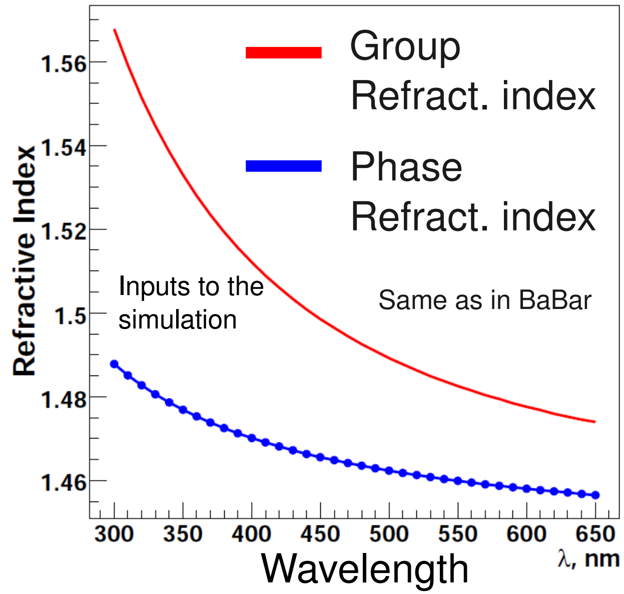
$$\cos\theta_c = \frac{1}{n\beta}$$

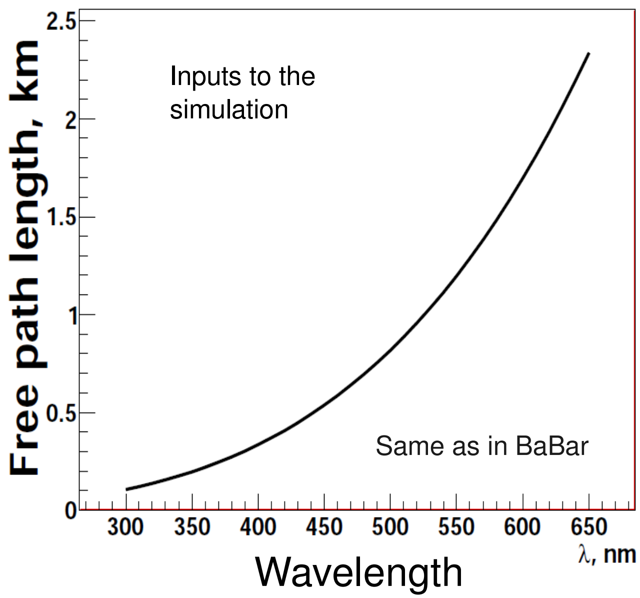




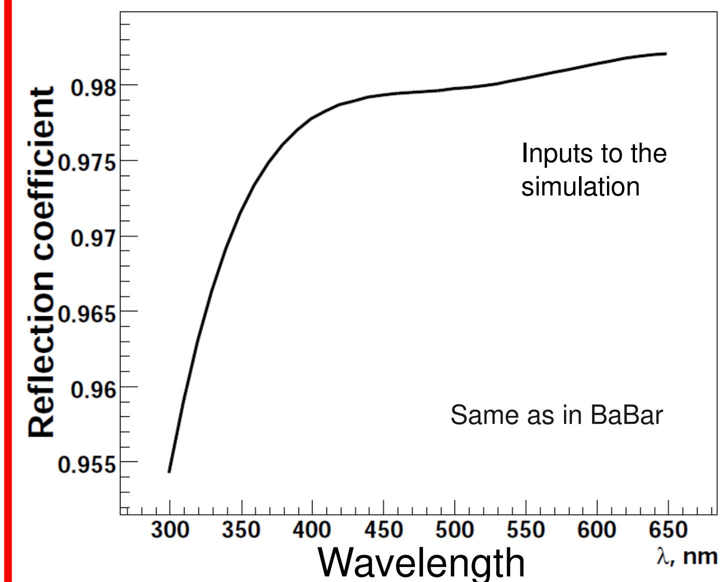


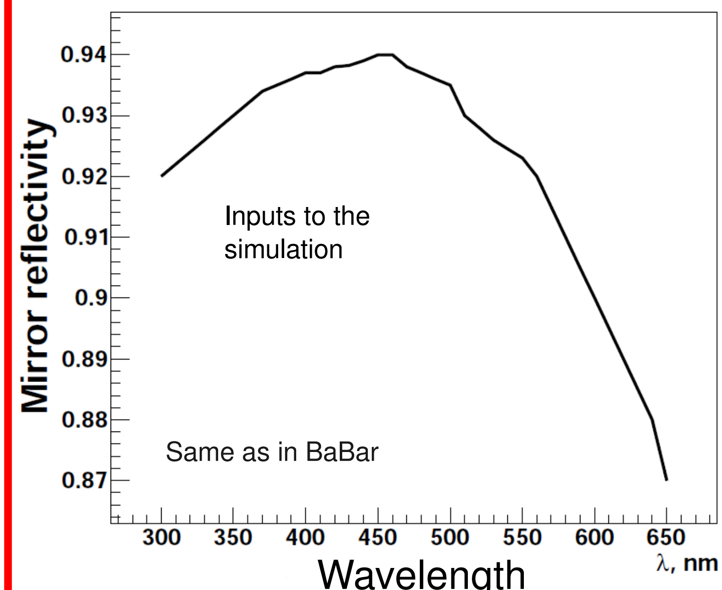
Optical properties of the quartz radiator:





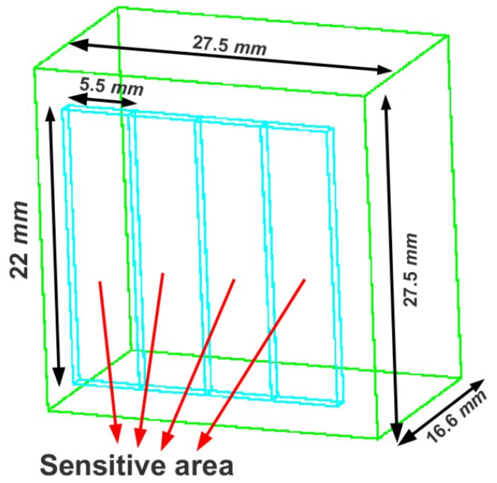
Properties of the quartz and mirror surfaces:

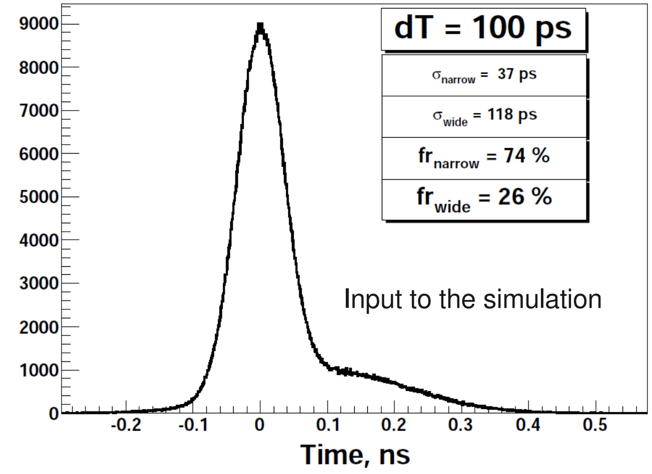




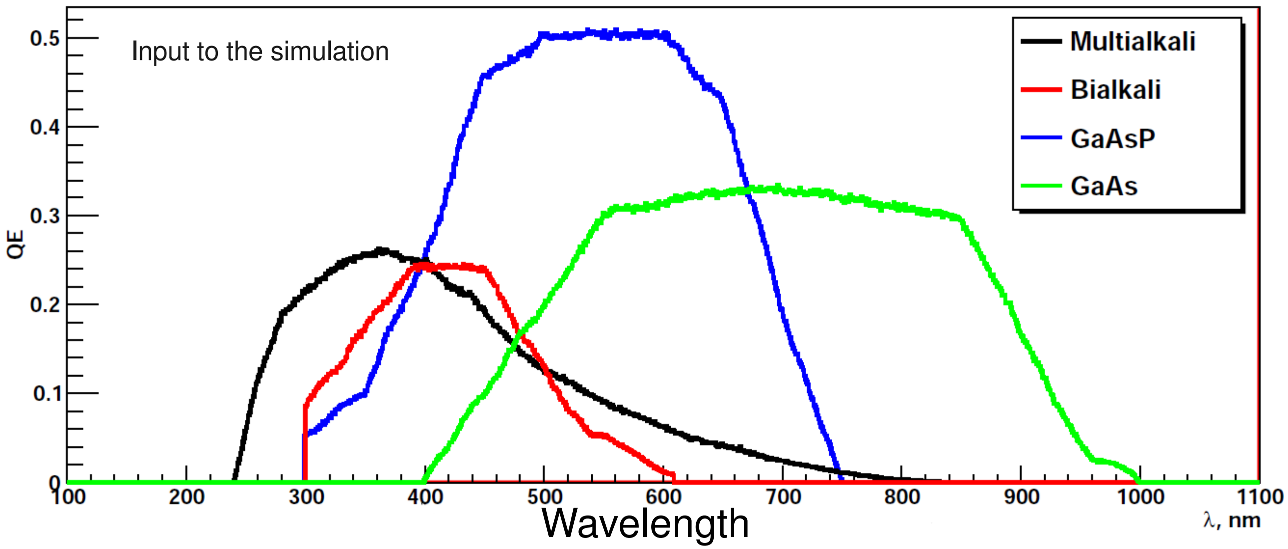
Full simulation of the FTOF detector: PMT

A simple parametric model of MCP-PMT is implemented independently from Geant4





→ Transit time spread (TTS)



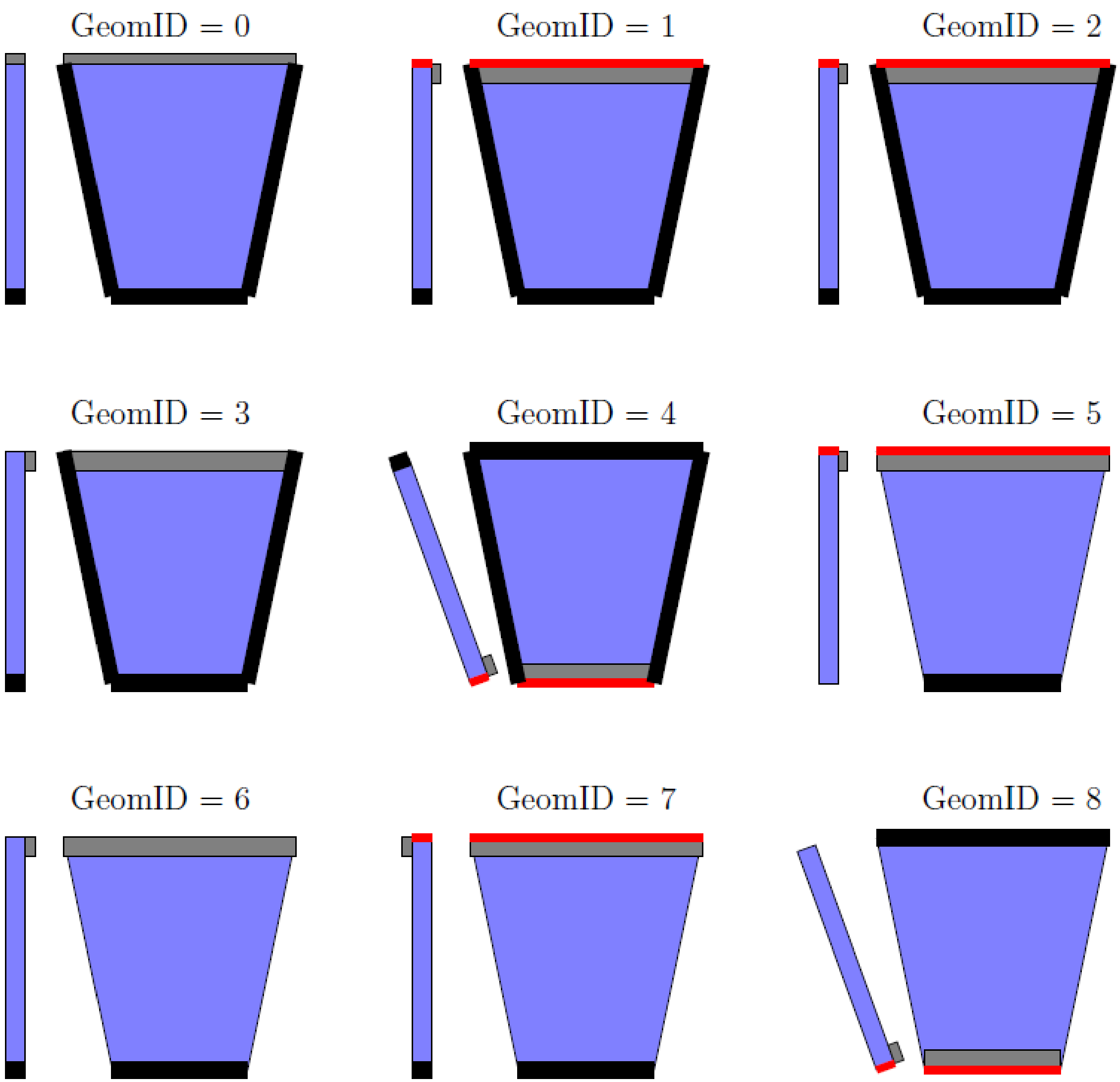
→ Quantum efficiency of the photocathodes

→ Collection efficiency

60% For SL-10 MCP-PMT.

FTOF geometry optimization

9 different geometries have been studied



gray box – PMT
black box – absorber
red box – mirror

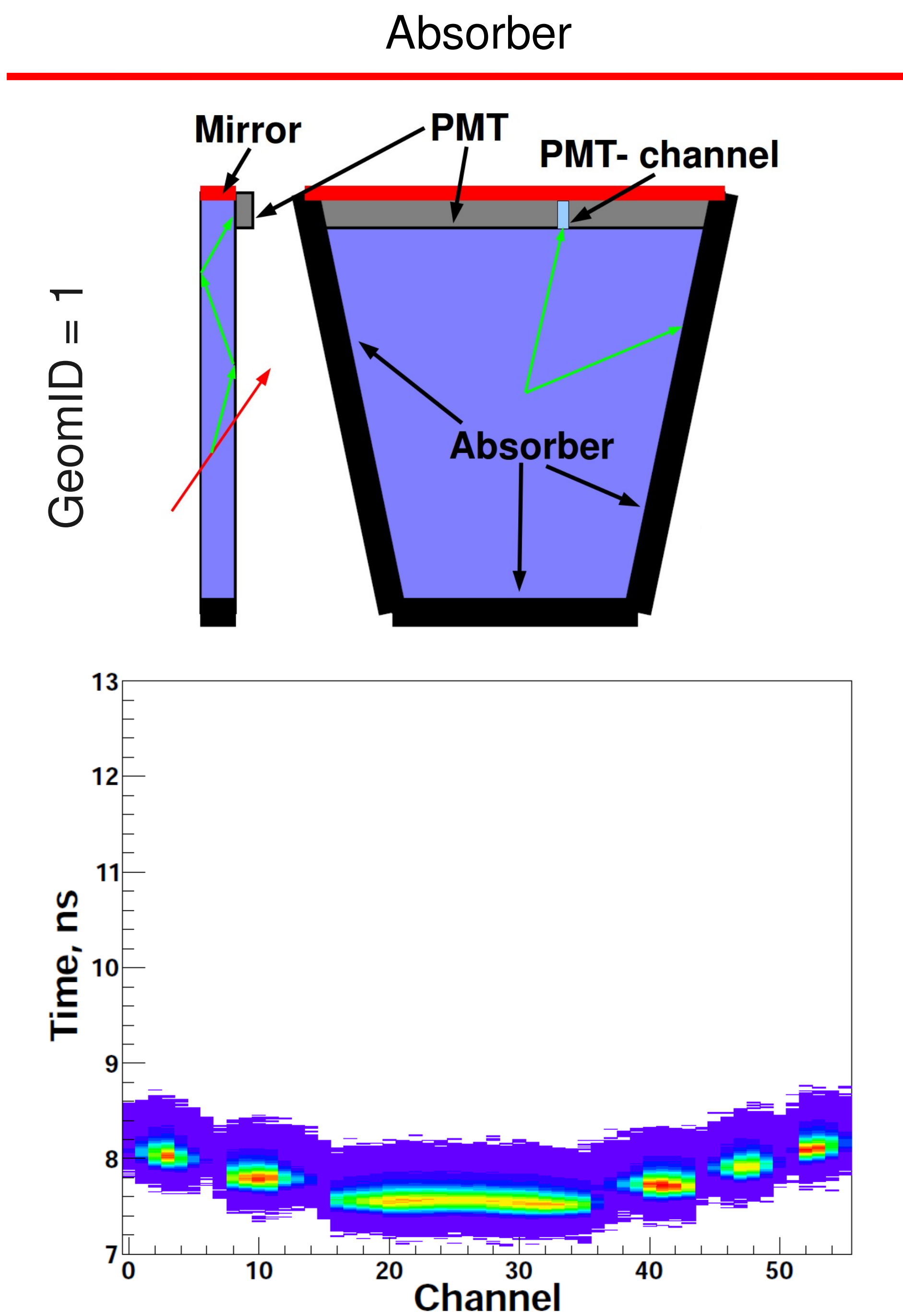
- Effect coming from the photon absorber on the sides
- Position of the FTOF: (close to the DCH) or (close to the EMC)
- Effect coming from mirror
- Position of the photon detectors with respect to the SuperB magnetic field
- Orientation of the MCP-PMT channels

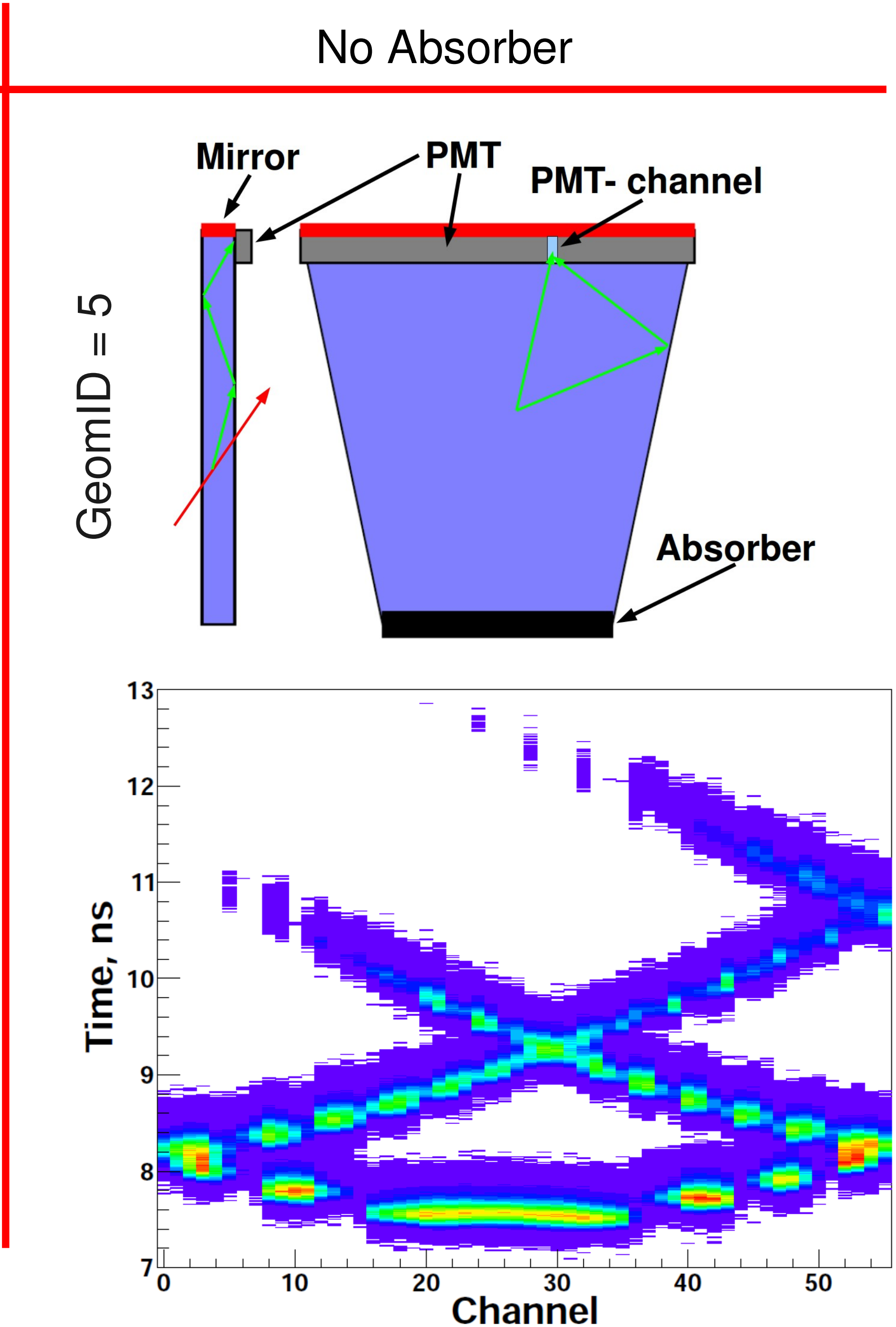
Two main parameters to be optimized:

Number of detected p.e. $N_{p.e.}$

Timing err. of arrival of p.e. $\sigma_{detector}$

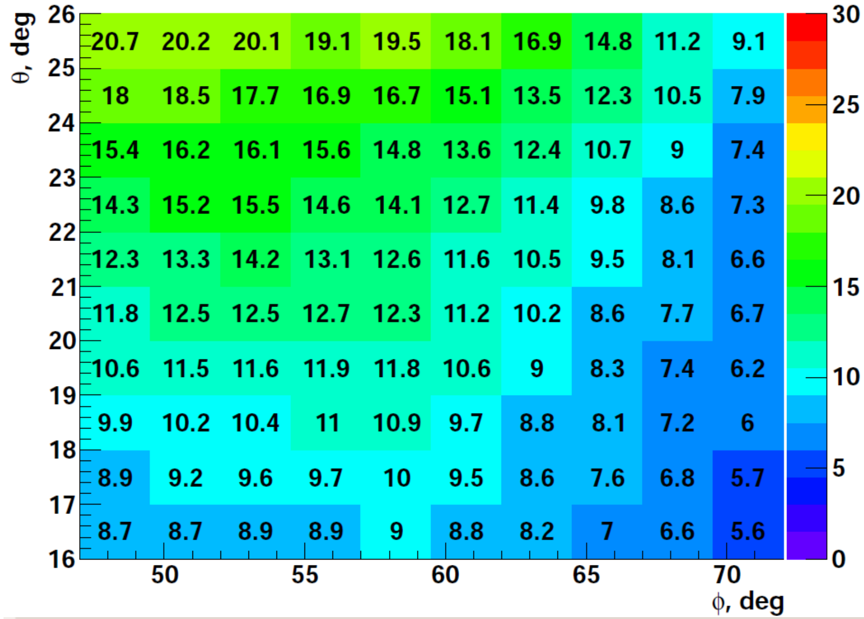
Effect coming from the photon absorber

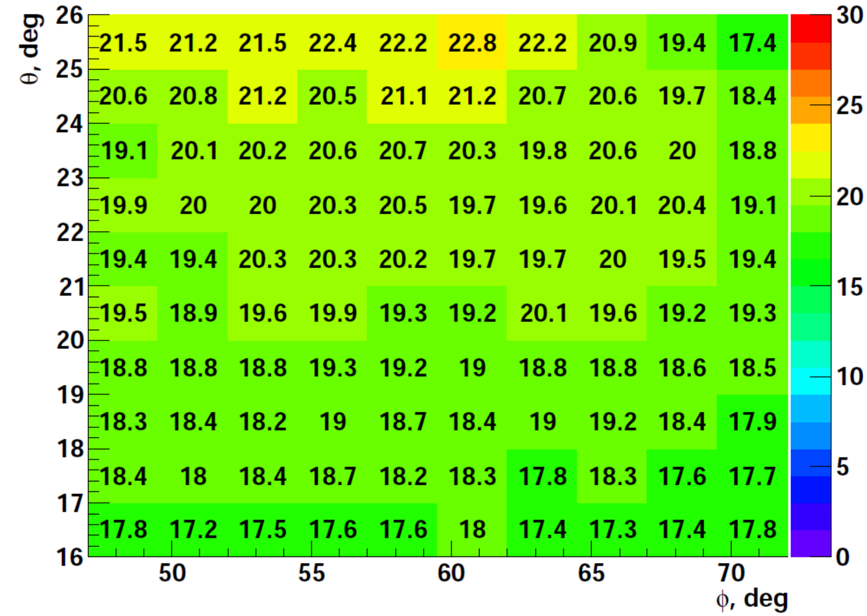


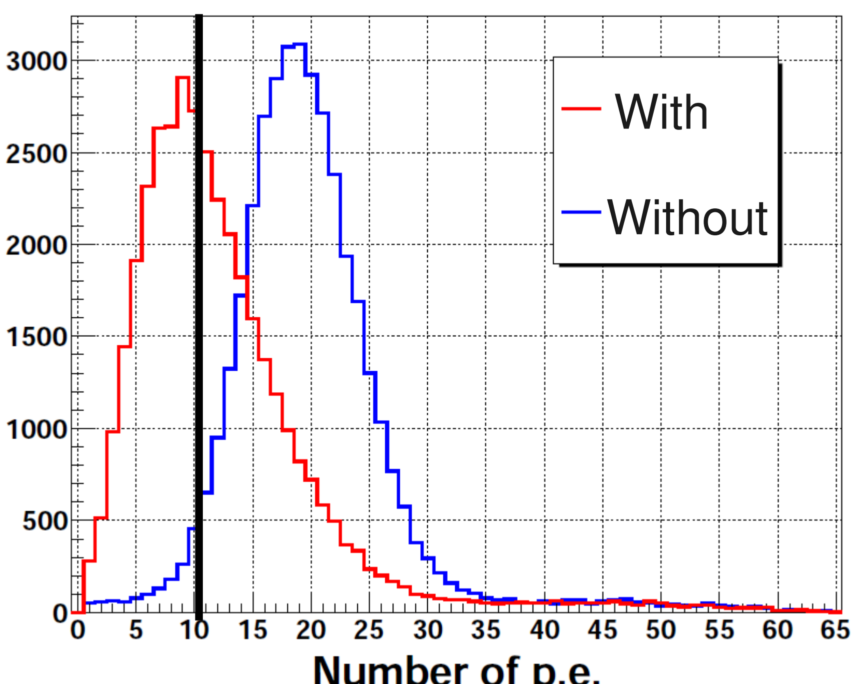


Effect coming from the photon absorber

Absorber	No Absorber







- Maps computed using: 0.8 GeV/c momentum K^+ in a 1.5 T magnetic field

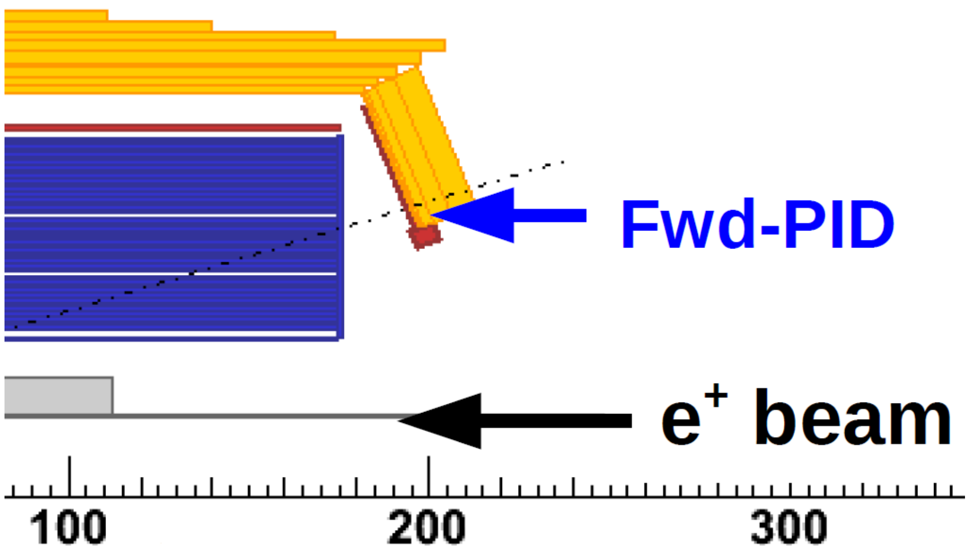
Photon absorber (p.a.) on the sides:

- makes pattern (time vs channel) simpler
- but the average number of the detected photoelectron (p.e.) is less then 10.

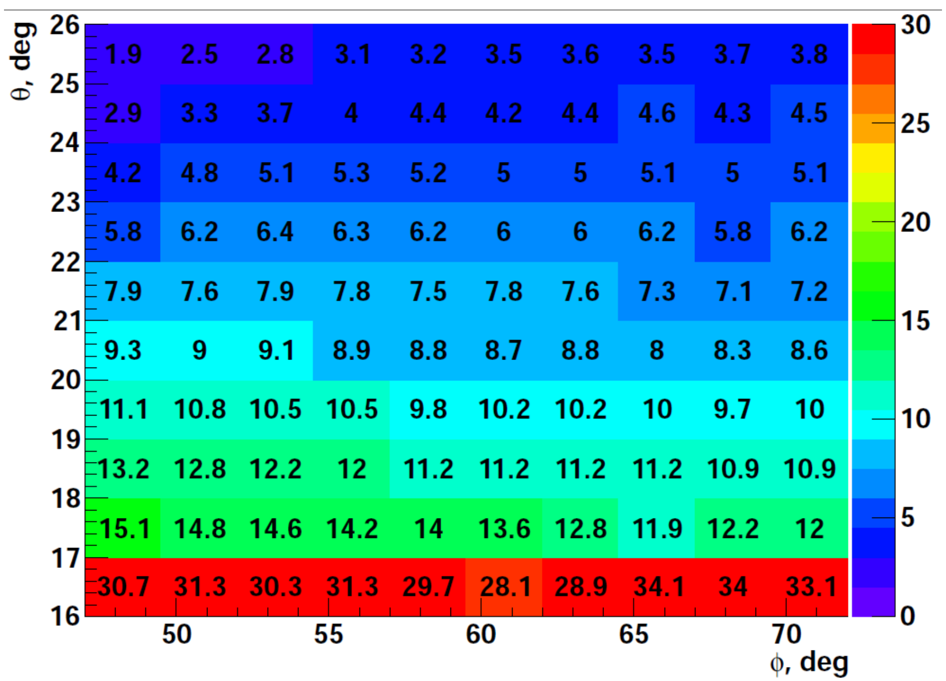
One has to use geometry without photon absorber

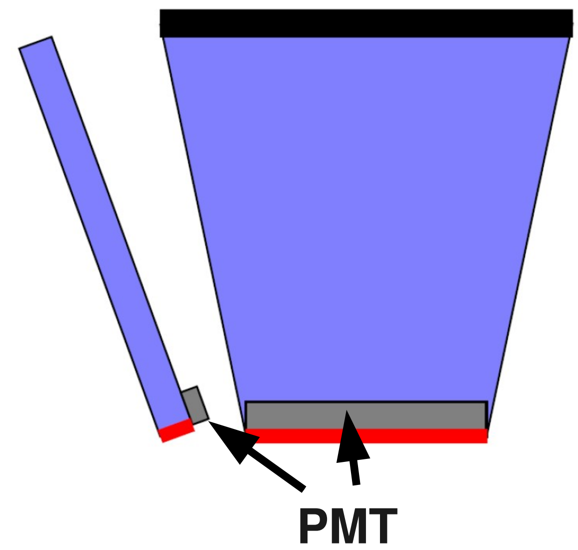
Position of the FTOF

Parallel to forward EMC



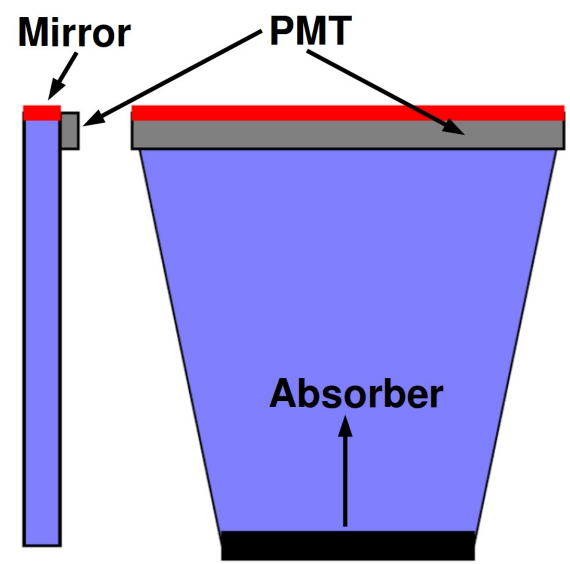
But: almost no photons



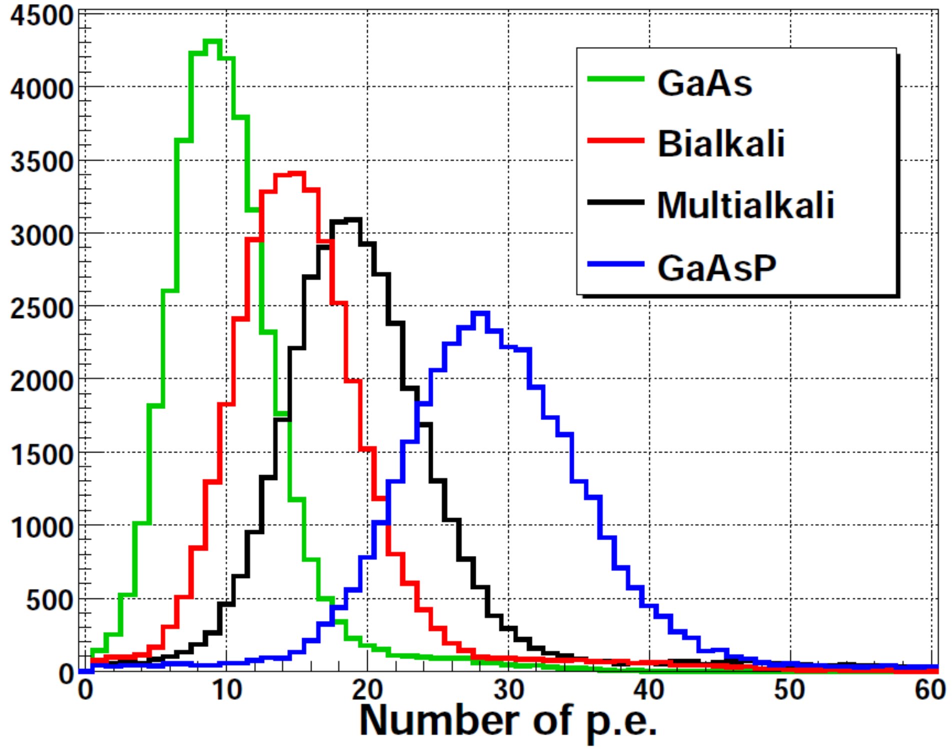


This configuration would be more compact and needs less readout channels

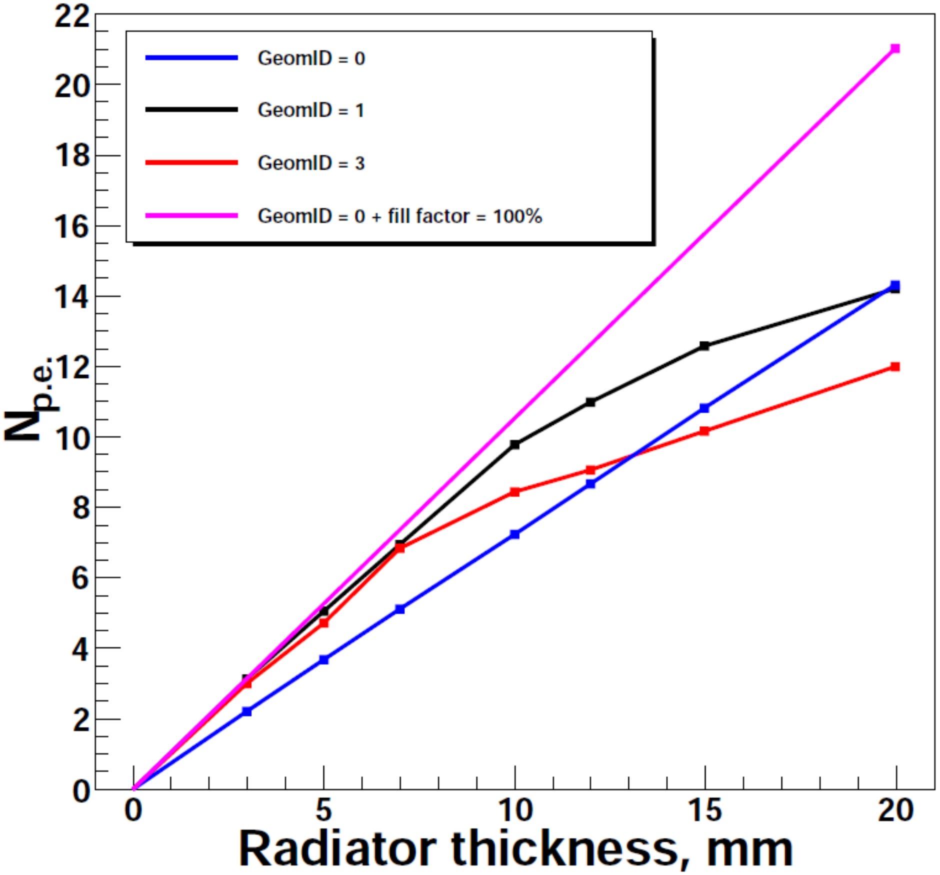
One has to use a geometry parallel to DCH



Number of p.e. for different photocathodes and thickness of the radiator



Study made with absorber configuration



The GaAsP photocathode is not commercially available with MCP-PMT

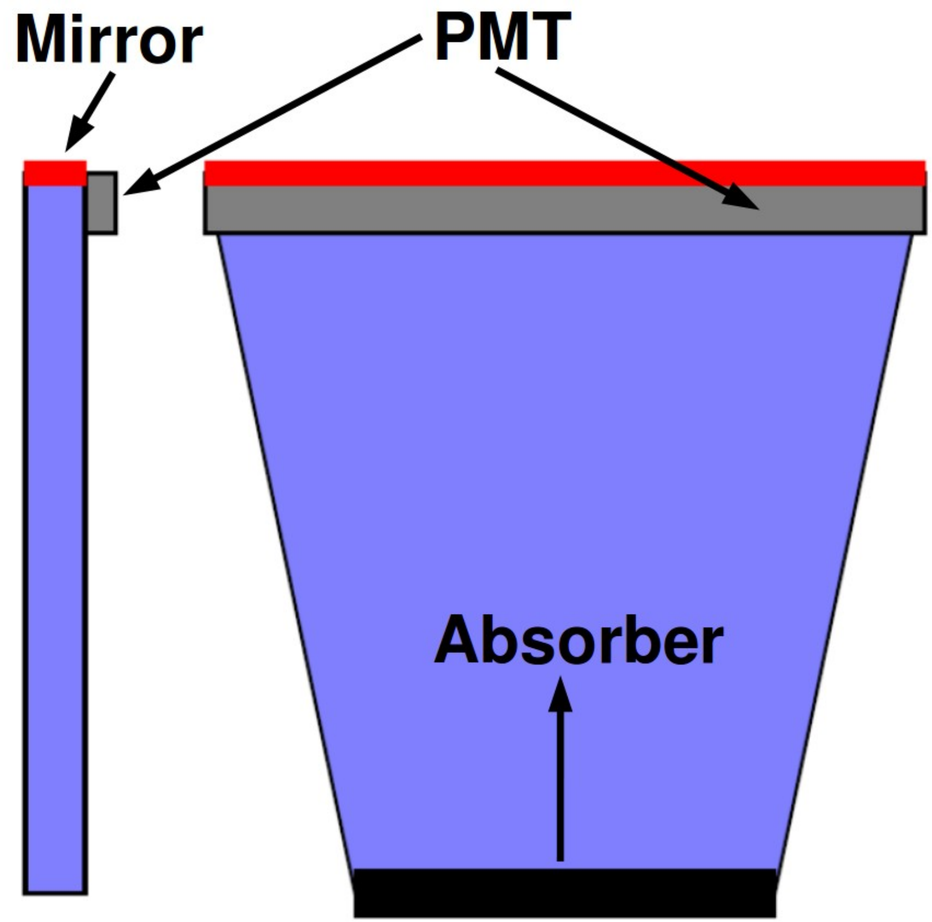
Baseline photocathode: Multialkali

Baseline radiator thickness: 15 mm ($12\ \%\ X_0$)

Optimal choice of the FTOF Geometry

See backup slides

Quantity	value
PMT position	B
PMT orientation	V or H
Mirror	+
Absorber	B
Tilting	-
Radiator thickness	15 mm
MCP-PMT	[illegible]
Number of channel per PMT	4
Total number of PMTs	168
Total number of channels	672
MCP-PMT photocathode	Multialkali
Reconstruction algorithm	complex
Time window	10 ns
$\sigma_{electronics}$	10 ps
σ_{TTS}	40 ps
$\sigma_{detector}$	80 ps
σ_{trk}	10 ps
σ_{t0}	20 ps
$N_{p.e.}$	>10
Total time resolution	<40 ps



σ_{tot} ~ 1/sqrt($N_{p.e.}$)

For 3 GeV/c momentum kaon, $N_{p.e.}$ ~ 18 => time resolution ~ 30 ps

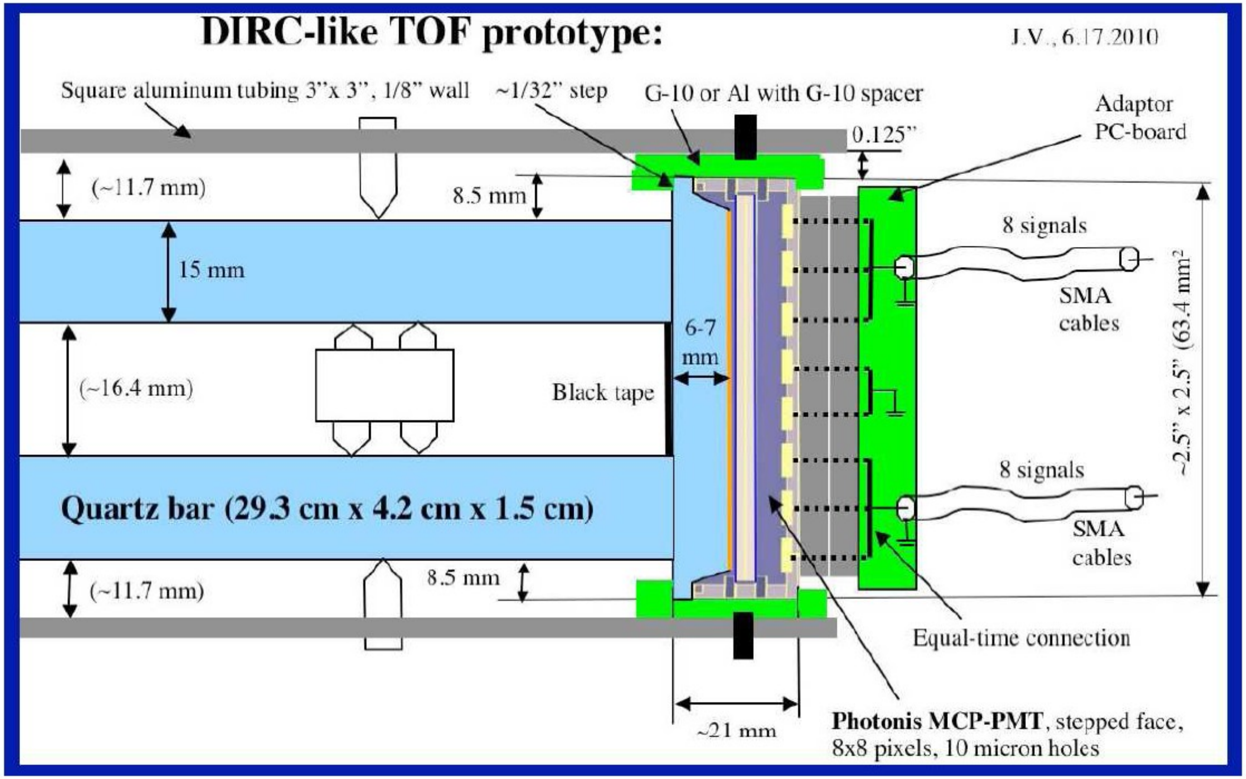
Test at SLAC of a FTOF prototype

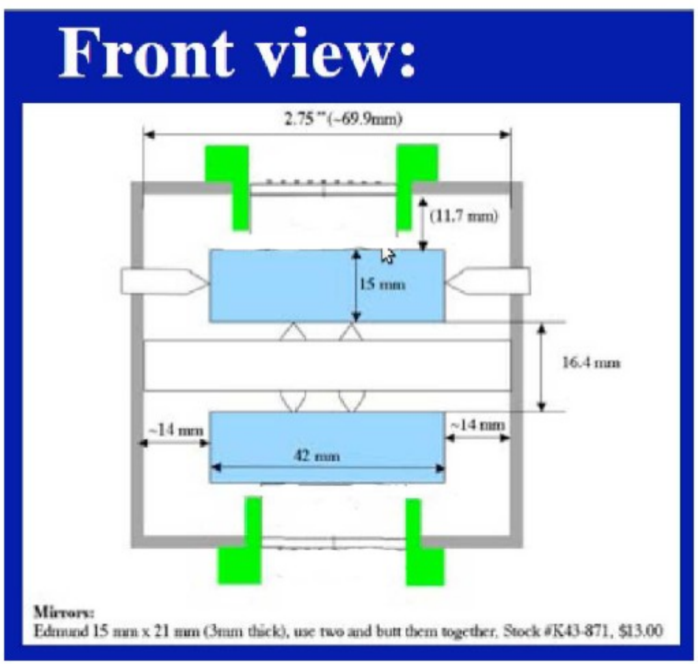
Test done between Fall 2010 and Spring 2011

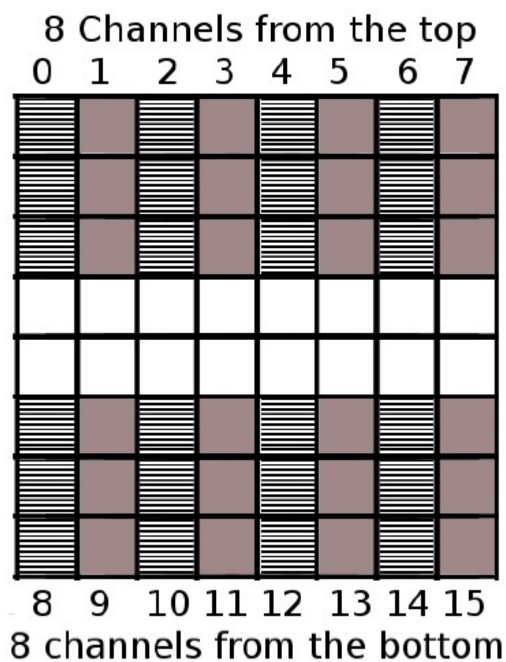
Main goals are:

1) **Test of the electronics**
2) **Estimate time resolution per channel**
3) **Prove the principles of FTOF detector for SuperB project**

The prototype of the FTOF detector



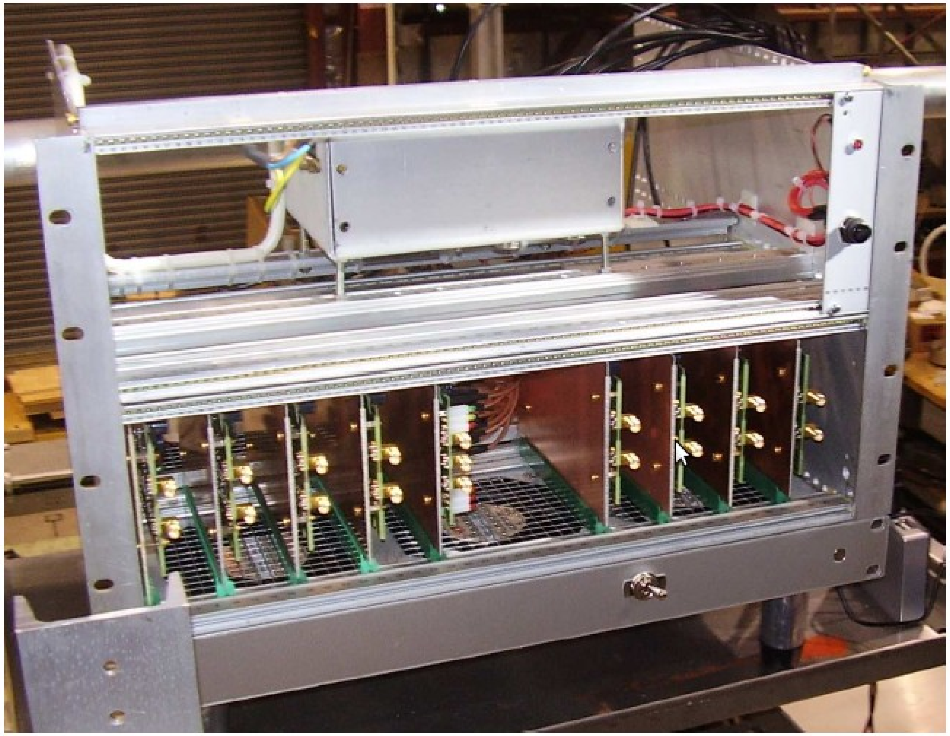




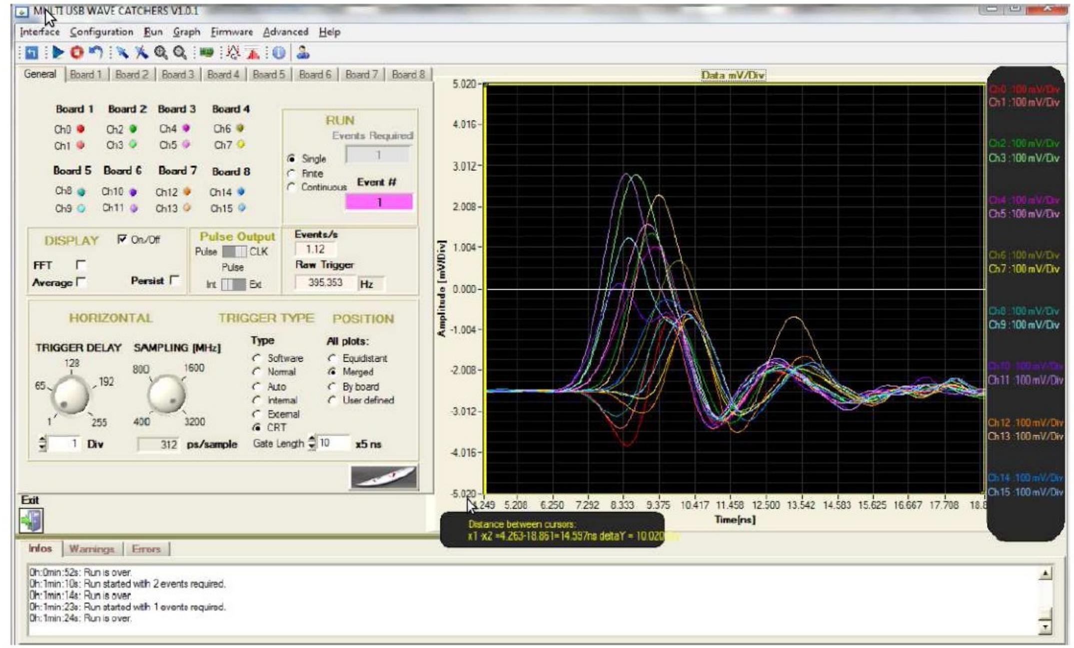
- Two quartz bars connected to one Photonis MCP-PMT (8x8 pixels, 10 micron holes).
- 16 channels connected to the USB-Wave Catcher electronics.
- Constructed at SLAC and installed in a cosmic ray telescope.
- Tube operate at gain ~ 7×10^5.
- Amplifiers (40dB), Filters (600MHz bandwidth).
- All connections done with SMA cables.

USB WaveCatcher electronics and DAQ software

Developed at LAL (electronics team) and CEA/IRFU



Developed at LAL (electronics team)



Data acquisition (DAQ) software

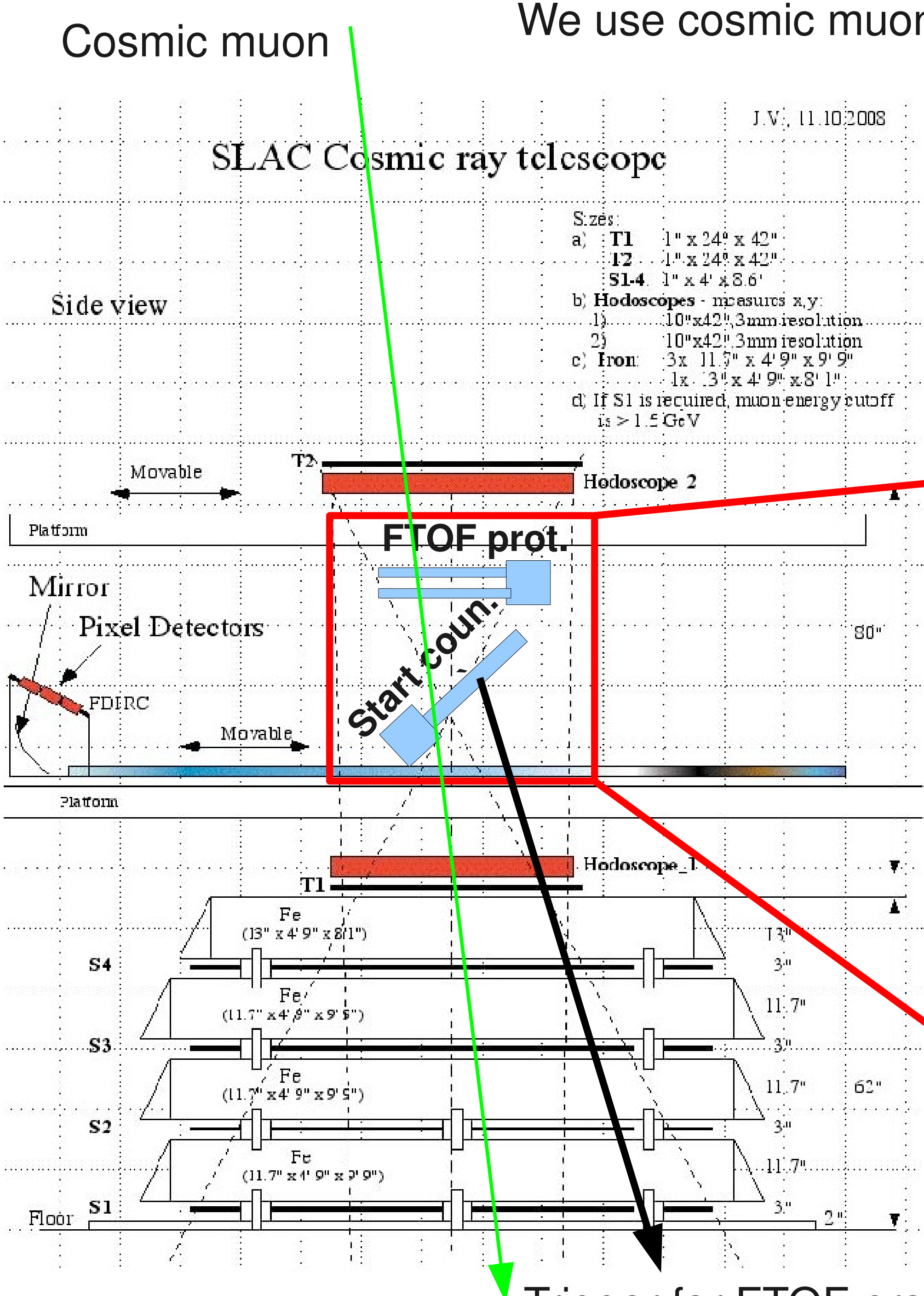
The whole system consists of eight 2-channel USB WaveCatcher (USBWC) boards plus one Controller board.

Oscilloscope – like graphical user interface (GUI) allows one to setup the 16-channel USBWC electronics.

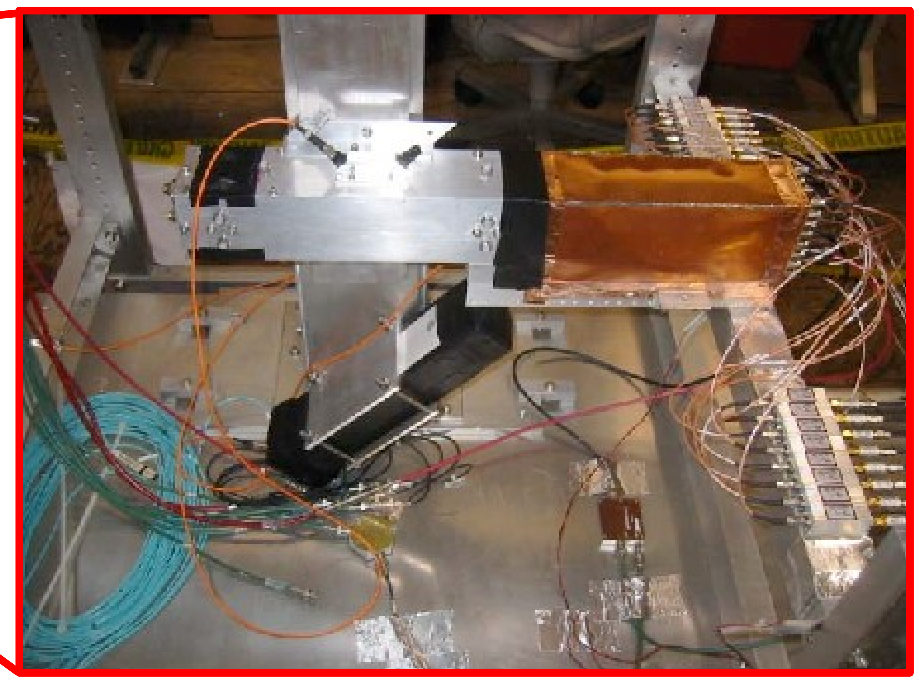
Electronics time resolution is measured to be around 10 ps per channel

SLAC Cosmic Ray Telescope (CRT)

We use cosmic muons for our measurements

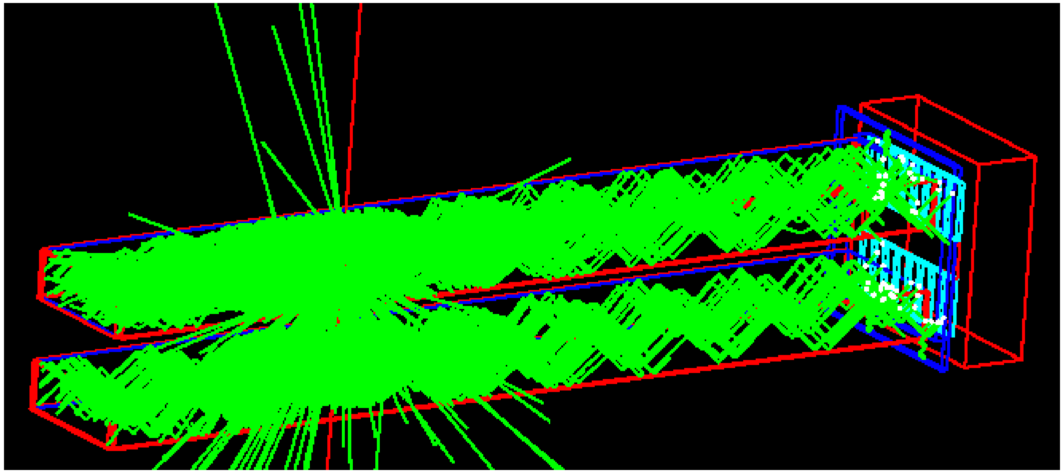


- Two hodoscopes (T1, T2), allow reconstruction of the muon tracks.
- Quartz start counter gives precise timing of the muon arrival.
- Stack counters (S1, S2, S3, S4) define muon energy.



- We use reconstructed muons which cross the FTOF prototype and the start counter

Geant4 Simulation of the FTOF prototype



- Precise geometry description
- Optical properties of the quartz
- Transit Time Spread of the MCP – PMT (TTS) = 35 ps / channel
- Electronics resolution = 10 ps / channel
- Bialkali photocathode
- Photo electron (p.e.) collection efficiency 70.0%
- Cosmic muon generator developed

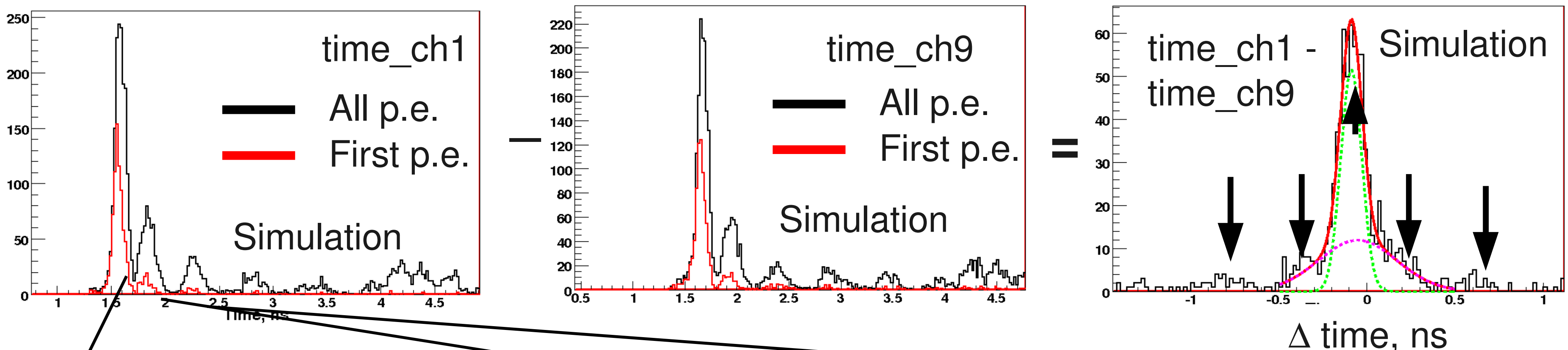
Time measurements:

Time of first p.e. arriving is taken as a time measurement for a given channel.

Simulation of the waveform based on the MCP-PMT response on single p.e. (laser run)

Simulated time distribution

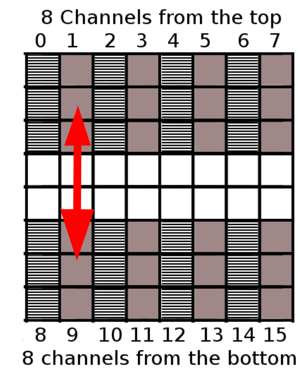
Generated muons have fixed position and direction in this slide



First population

Second population

...



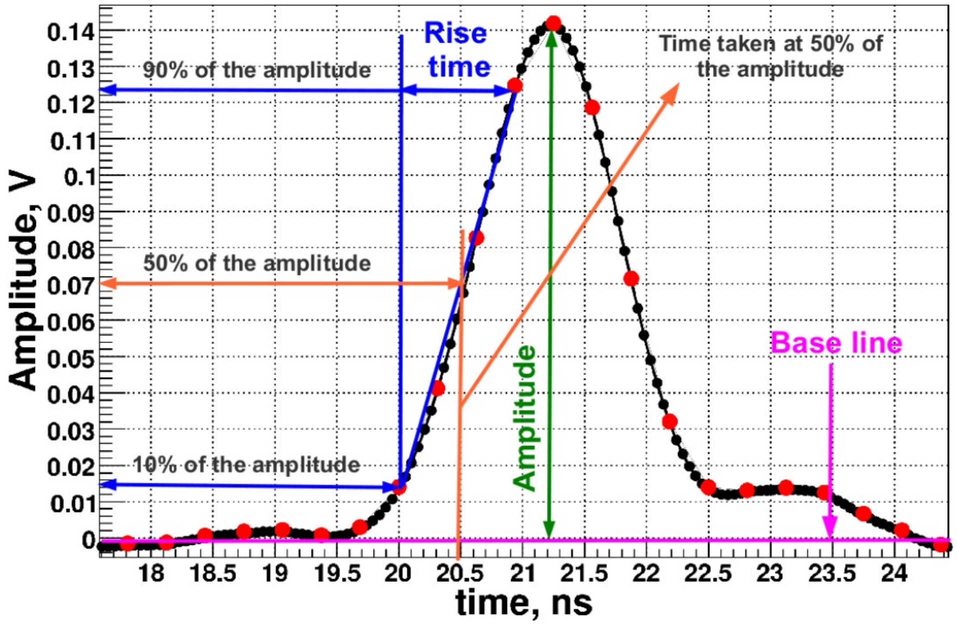
- Several possible photon paths the reach same PMT channel
- Due to geometry of the prototype (bars with 29.3 x 4.2 x 1.5 cm^3) the time distances between different peaks are small.
- Time difference between two channels have two components: narrow and wide. Narrow component corresponds to time difference between p.e. from first populations, while wide component corresponds to time difference between p.e. from different populations.

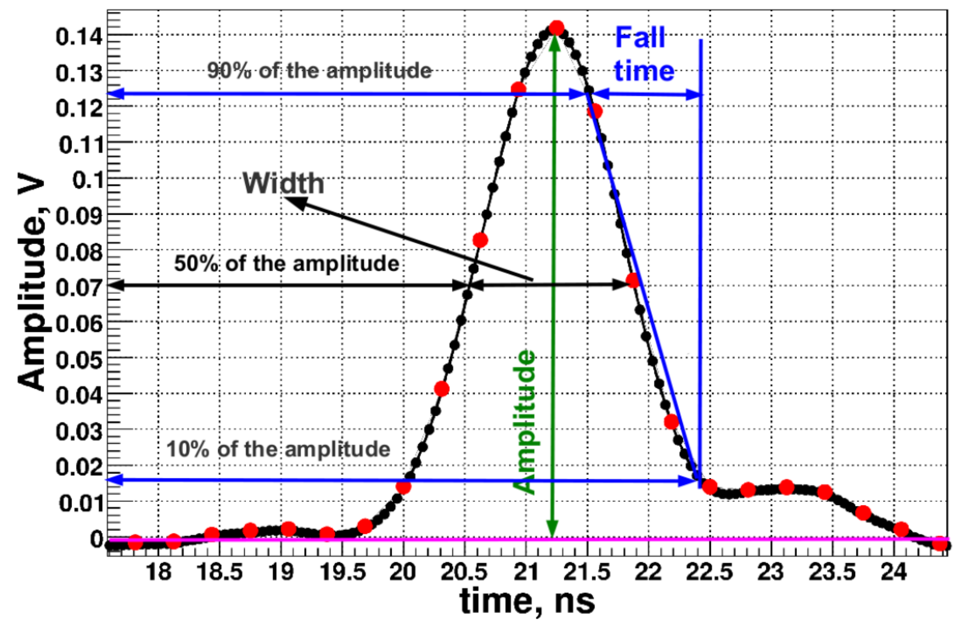
A simple way to estimate the time resolution per p.e.

We consider the RMS(of narrow component)/sqrt(2) as the time resolution per channel.

Waveform analysis

Timing measurements in real data





- Offline we add 5 additional equidistant points in between two sampling points, which are then joined by a straight line.
- We use the first 6 sampling points to compute the average baseline amplitude, which is then subtracted from the waveform.
- For each waveform we define 5 quantities which are used in the analysis.
  - Amplitude
  - CFD – time (constant fraction) taken at 50% of the amplitude
  - Rise time
  - Fall time
  - Wf identification number (wfID), which correspond to a given shape of the wf.

Waveform shape recognition algorithm

To clean the data sample

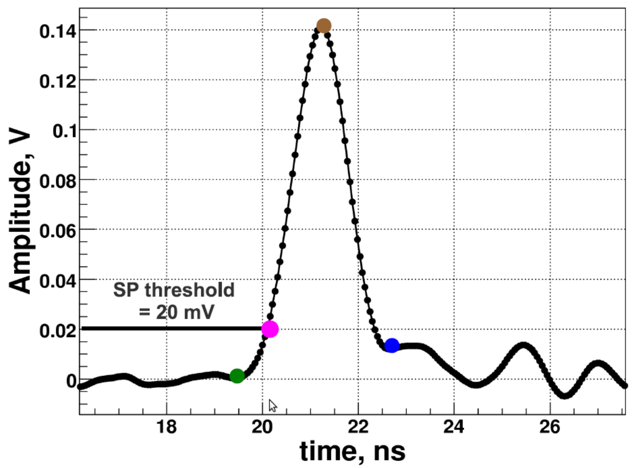
This algorithm uses 3 parameters:

Signal threshold	(SP threshold) =	20 mV
Crosstalk threshold	(CT threshold) =	-7 mV
Multi peak fraction	=	0.8

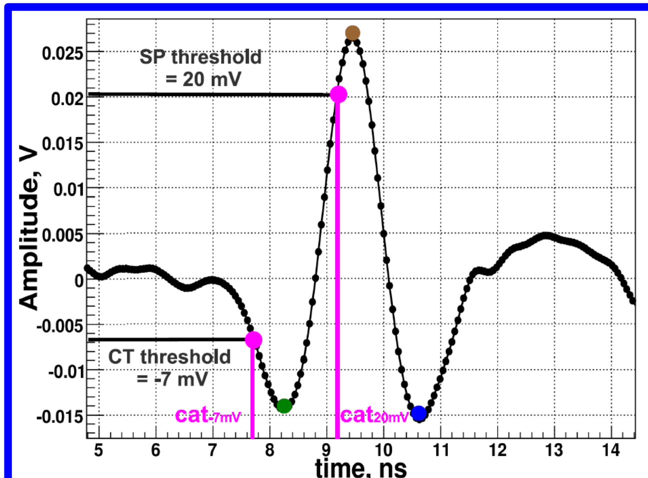
Three families of waveform shapes

Distortion of the rising edge

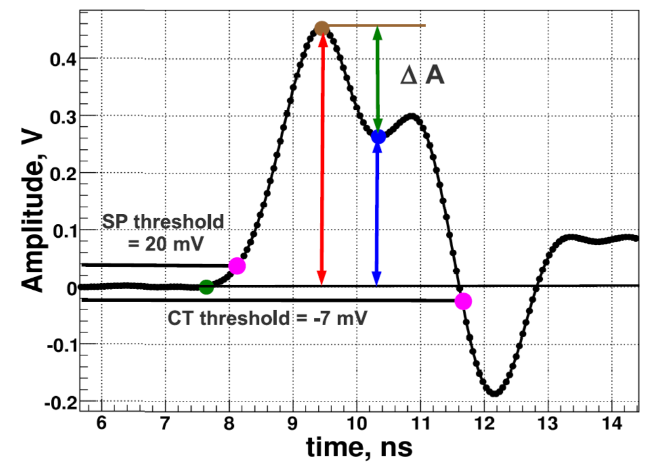
Amplitude is wrong: CFD does not work properly



Singlepeak-like



Crosstalk-like



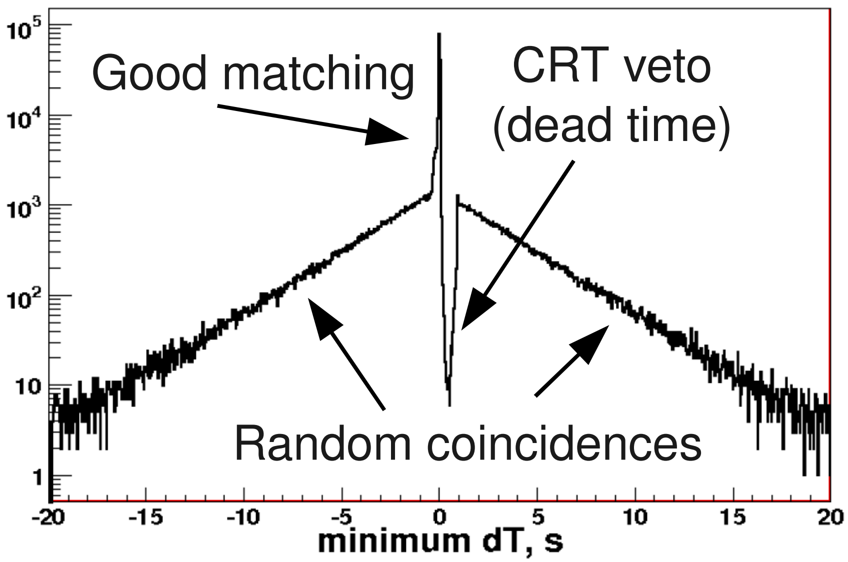
Multipeak-like

Selected waveform

Rejected waveforms

Matching USBWC and CRT DAQ systems

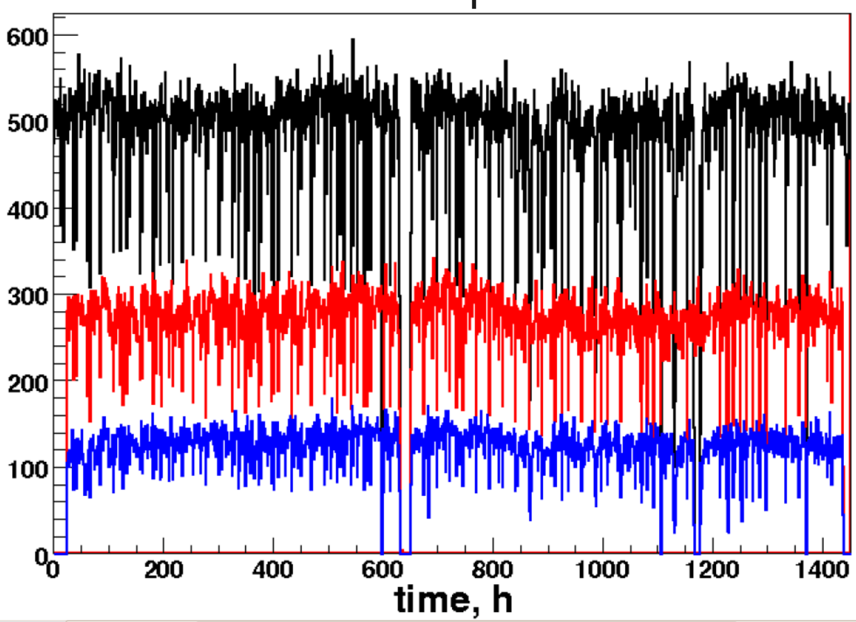
Minimum time difference between CRT and USBWC



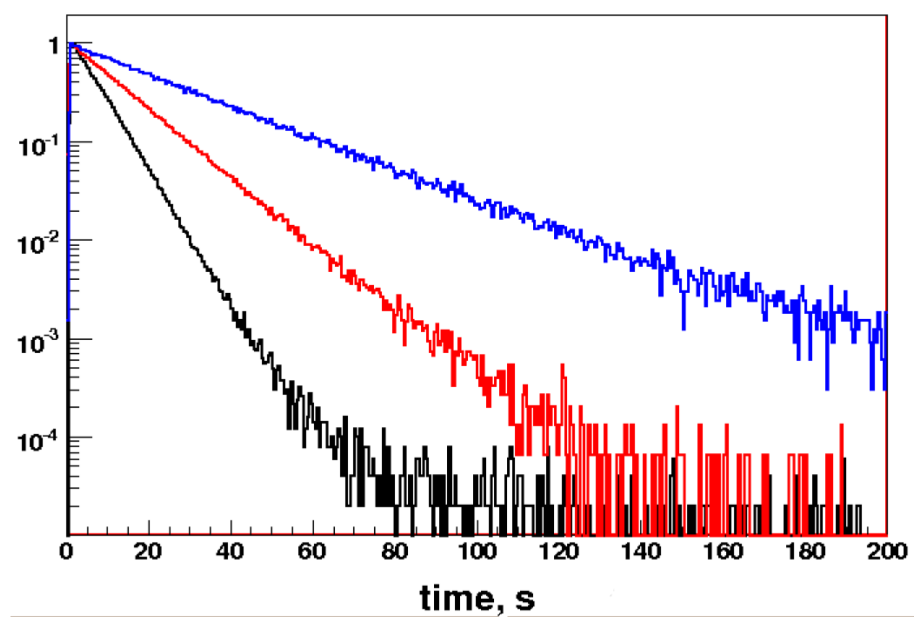
- USBWC and CRT DAQ systems are independent from each other.
- We use timestamps of the events to merge information from CRT and USBWC

Color plots	System	Rate events/h
black	CRT	490
red	USBWC	275
blue	matched	130

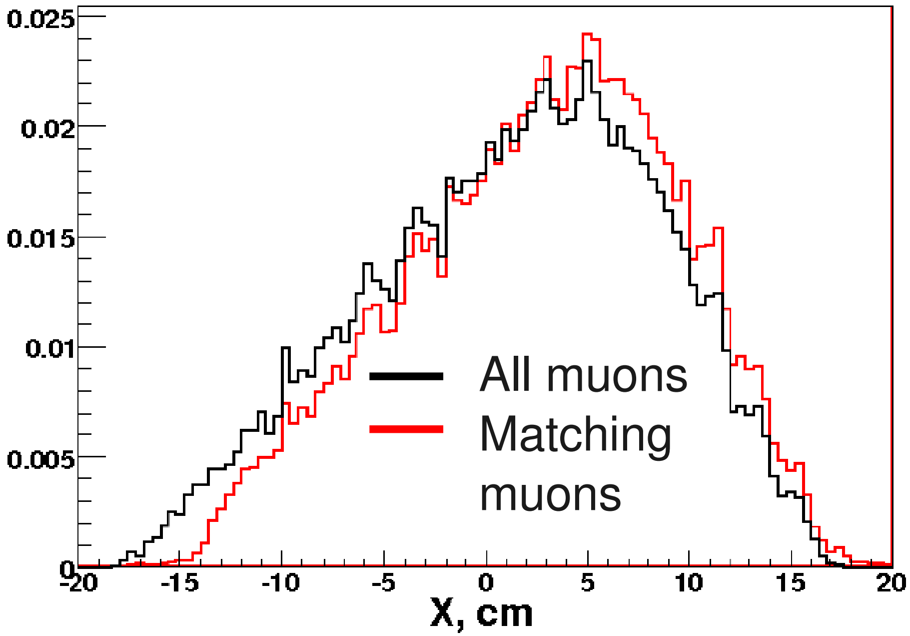
Event rate per hour

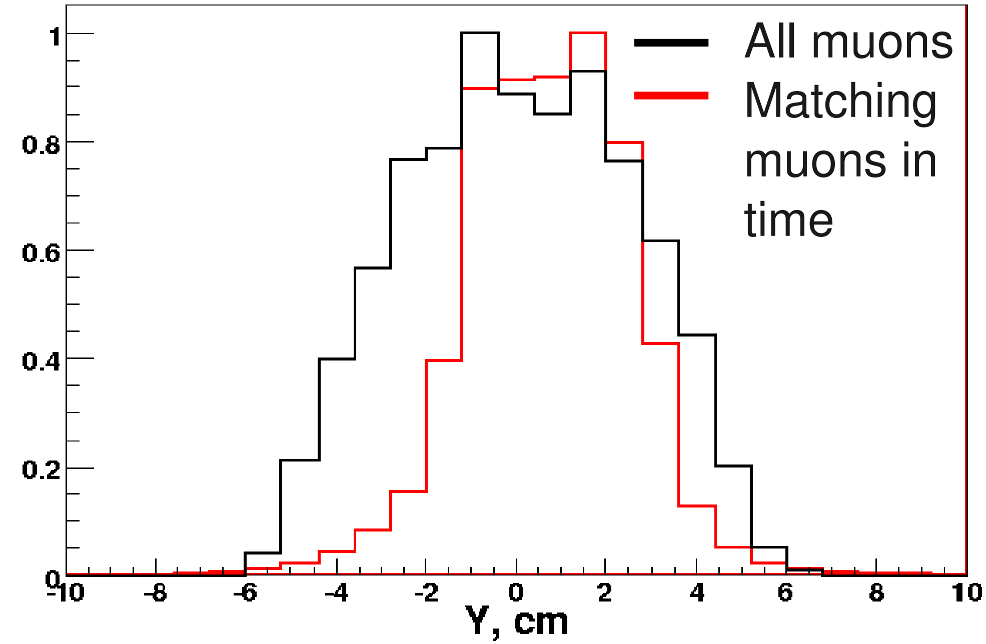


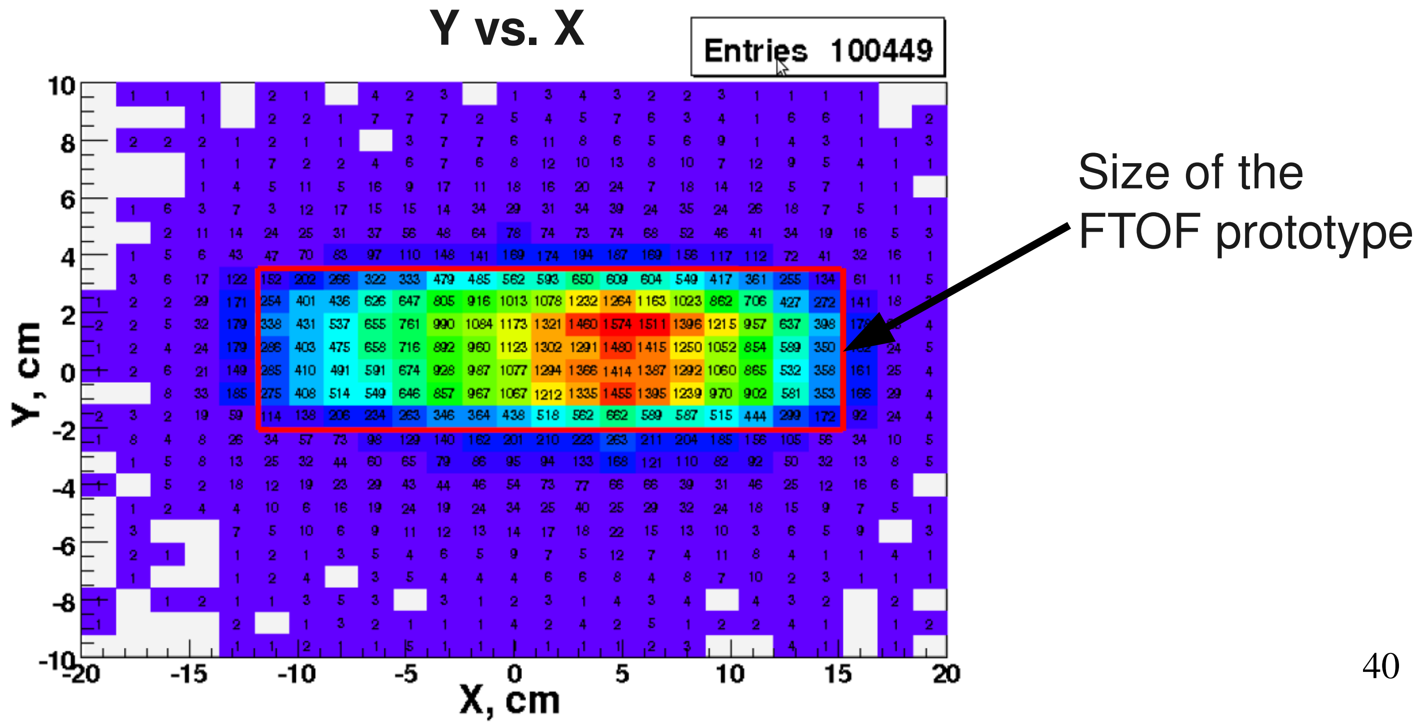
Distance in time between consecutive events



Muons intersecting with FTOF prototype







Selection Cuts

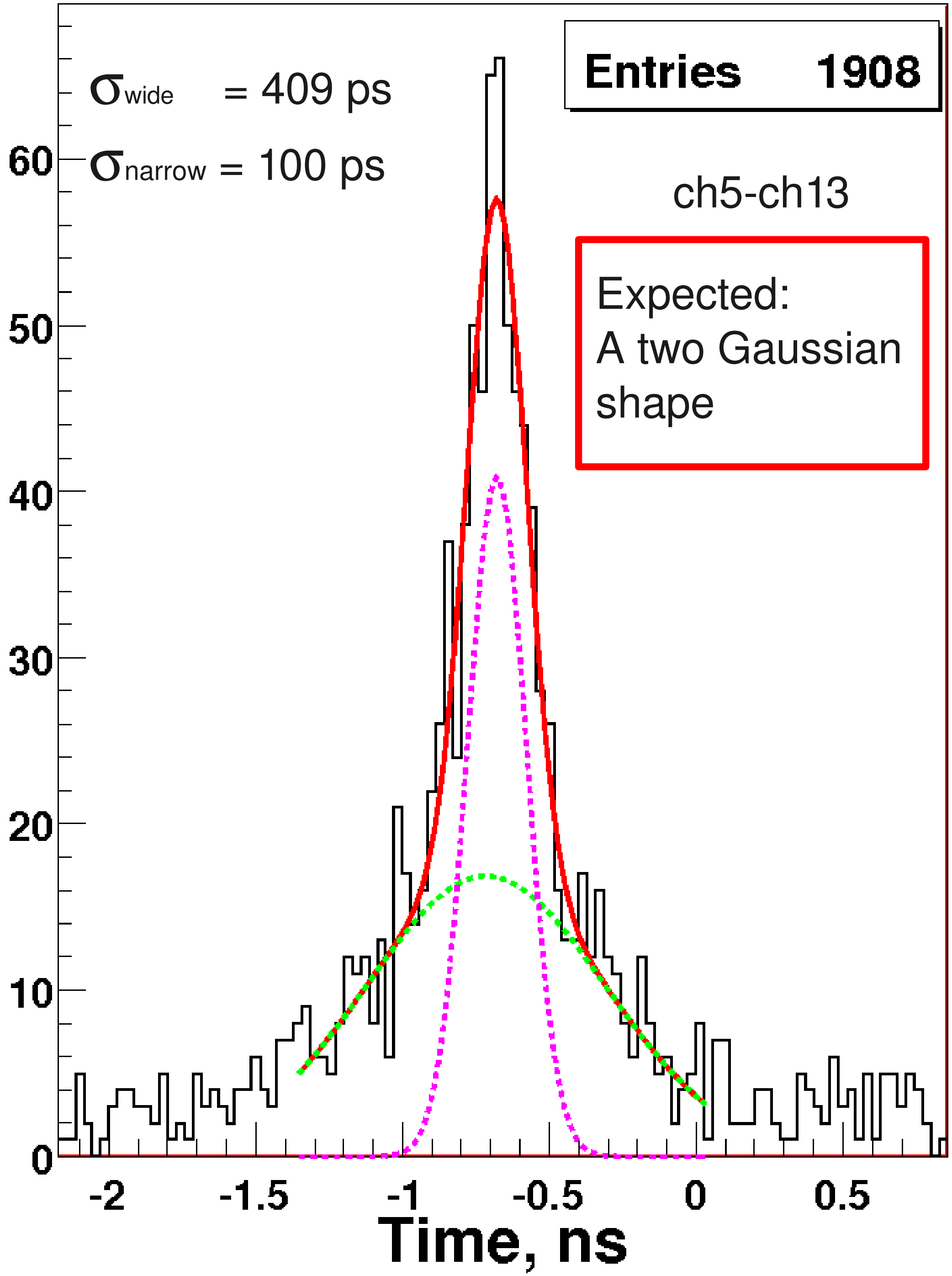
Cuts applied on the waveform

- Singlepeak – like Waveform
- Amplitude > 80mV
- Number of channels with signal < 6 (out of 16 channels)
  (to reduce effects coming from crosstalk)

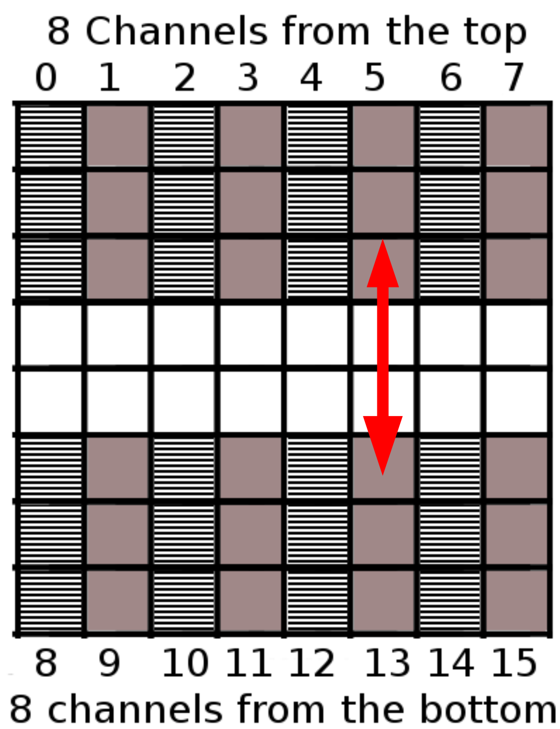
Cuts on data from CRT

- $-9 < X_{QSC} < 13$ && $-2 < Y_{QSC} < 3$
- $-14 < X_{FTOF} < 15$ && $-2 < Y_{FTOF} < 3.5$

Measured time resolution



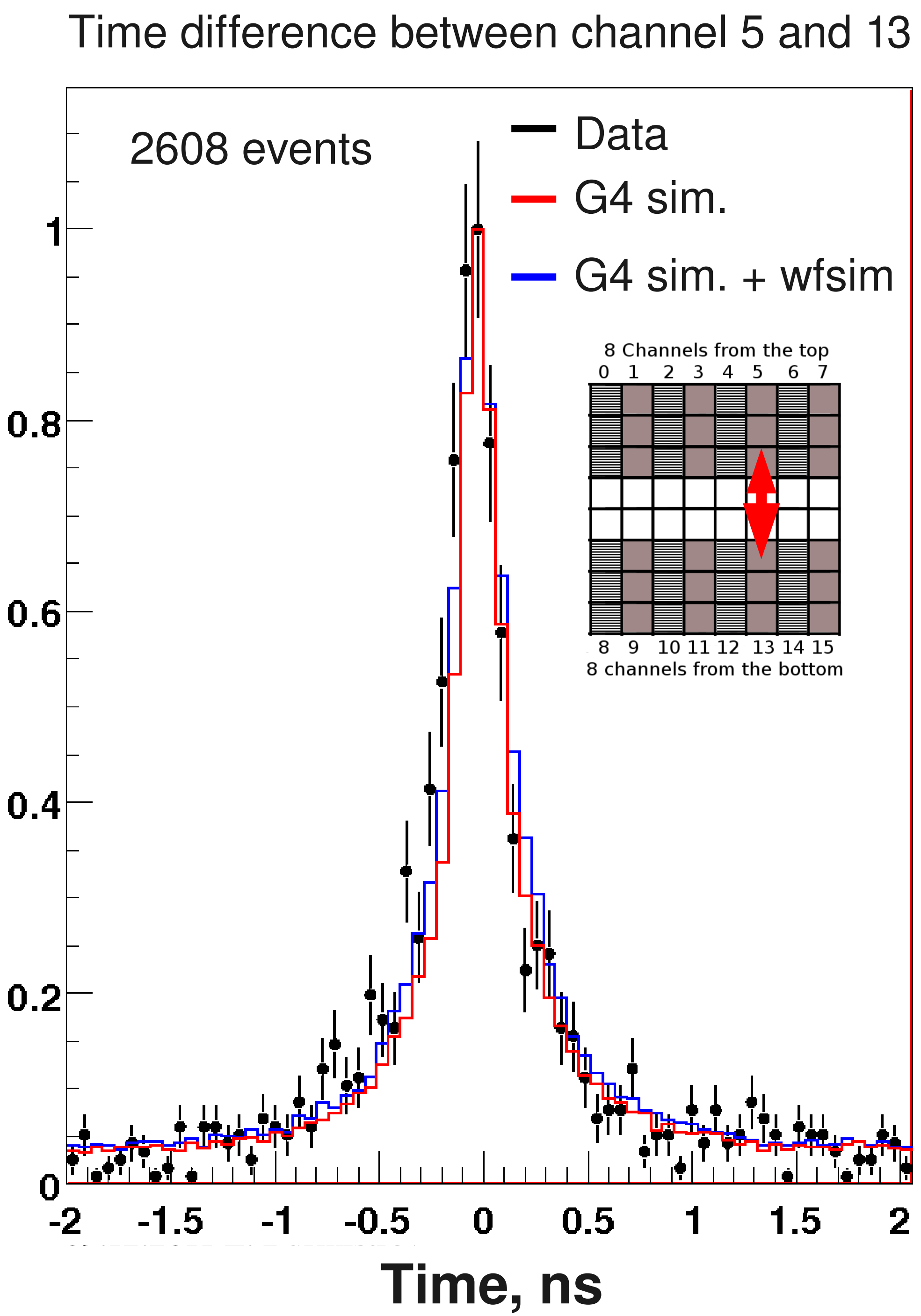
One example of time differences

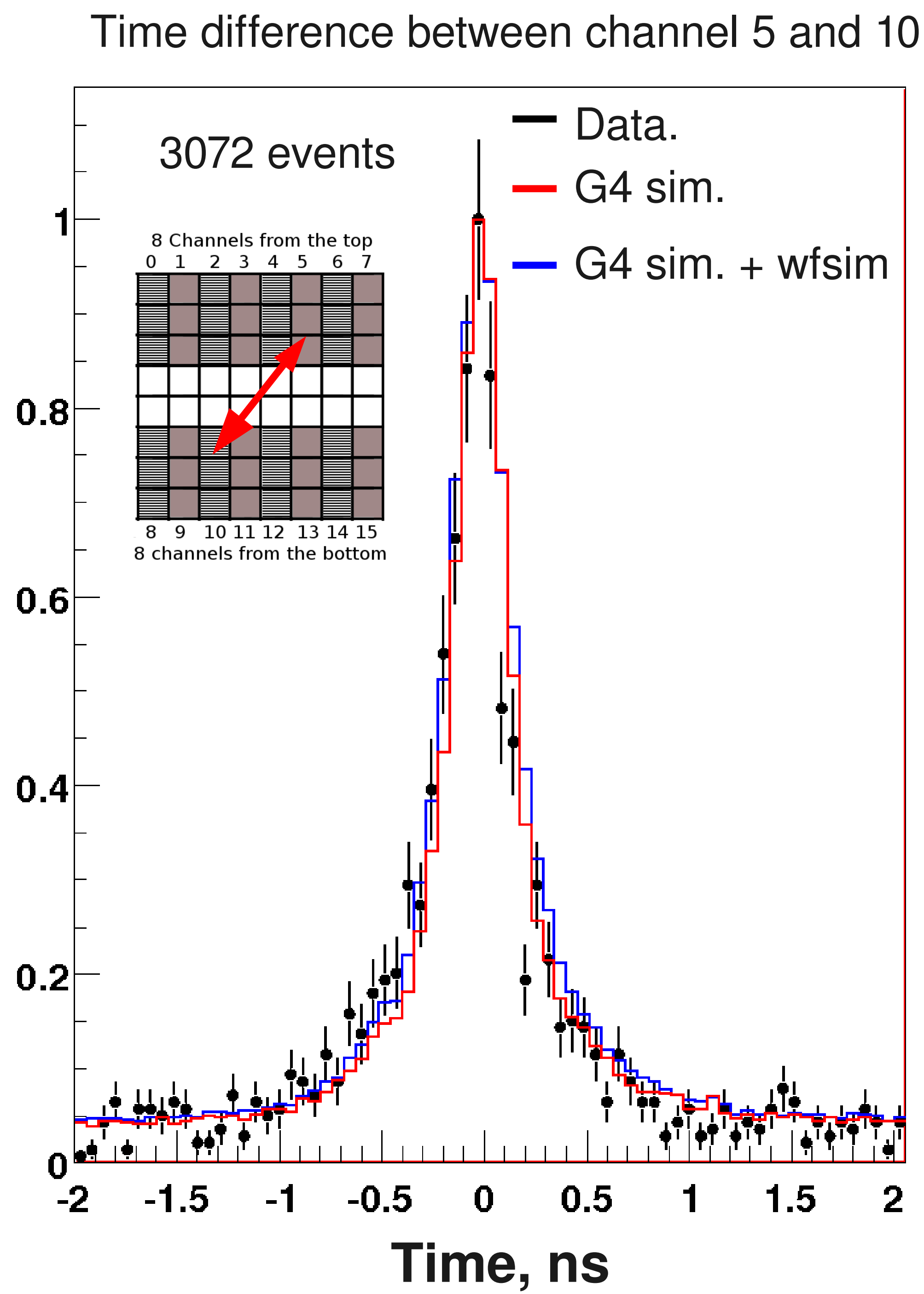


σ_{narrow} in average measured to be ~ 110 ps

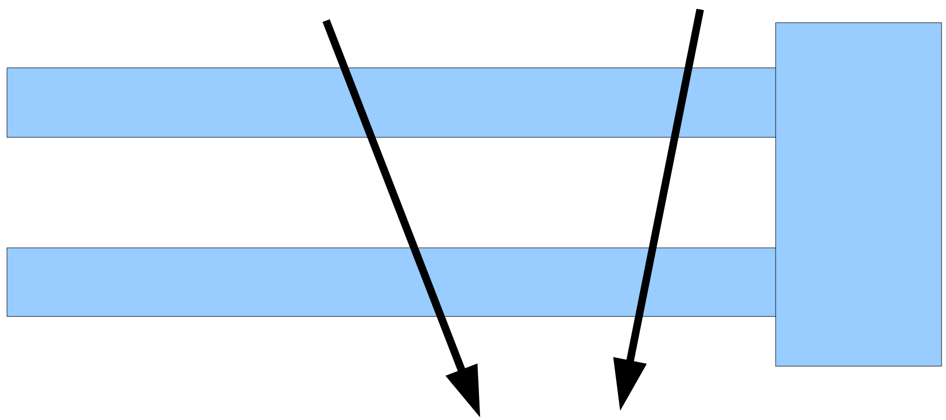
σ_{narrow}/sqrt(2) ~ 80 ps per p.e.

Measurement vs simulation

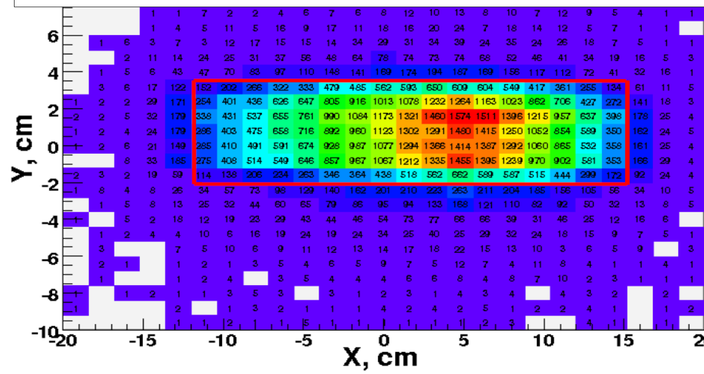


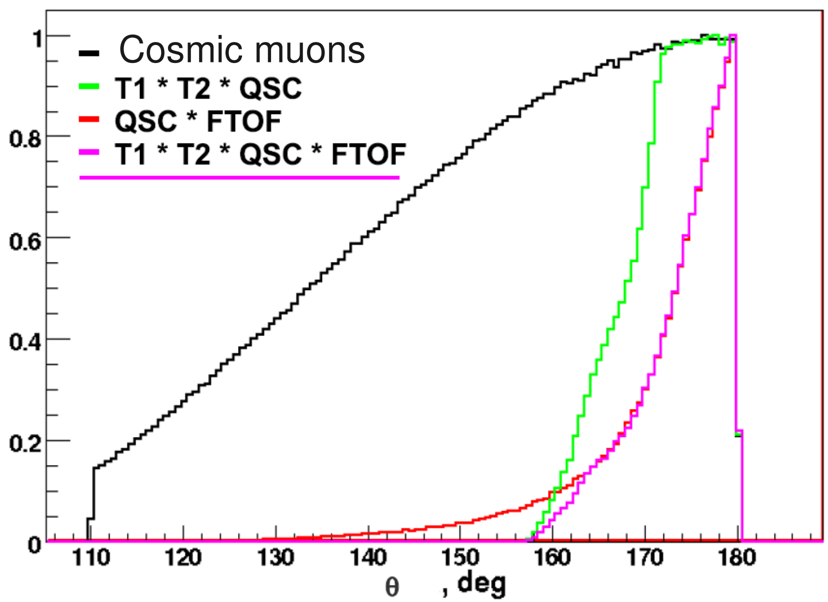


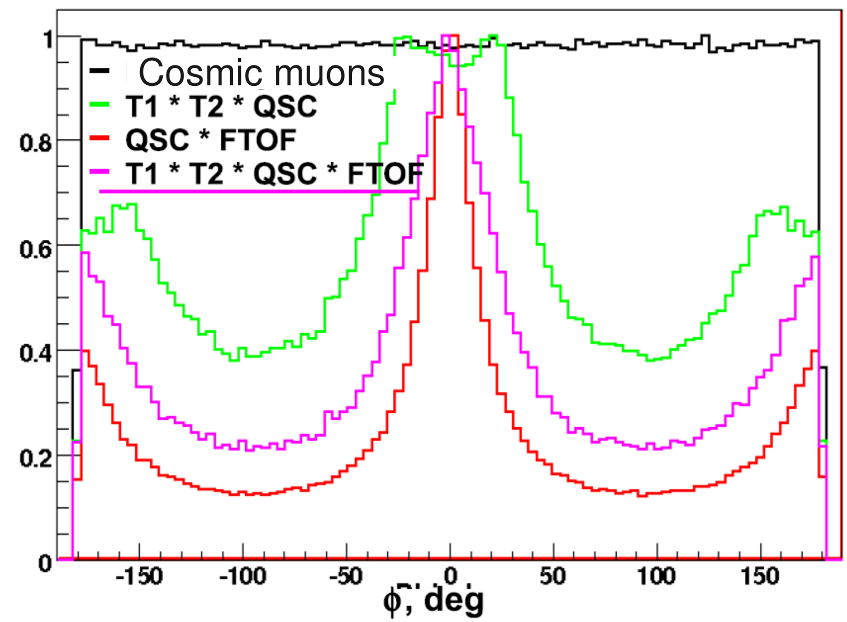
Muons which contributes to the measurements



We have used all reconstructed muons







We do not apply any additional selection or corrections using track informations

Thus we have an extra term contributing to the total time resolution $\sigma_{\text{muon kin}}$

To be evaluated

Discussion of the results

$$\mathbf{80\ ps} = \frac{\sigma_{\mathrm{narrow}}}{\sqrt{2}} = [\sigma_{\mathrm{detector}} \oplus \underbrace{\sigma_{\mathrm{TTS}}}_{35\ \mathrm{ps}} \oplus \underbrace{\sigma_{\mathrm{electronics}}}_{10\ \mathrm{ps}}] \oplus \sigma_{\mathrm{muonkin}}$$

$$\sigma_{\mathrm{detector}} \oplus \sigma_{\mathrm{muonkin}} = 70\ \mathrm{ps}$$

- The FTOF has recently been identified by SuperB collaboration as the best candidate for forward particle ID.
- This test encourages us to construct one full-size sector of the FTOF detector.

- However there is an open question about the background hardness of this device in the SuperB environment

Background studies

Bruno: Geant4 simulation of the SuperB detector

Side view of the FTOF geometry implemented in Bruno

- At the present phase of the SuperB project it is crucial to have a full simulation of the whole detector

- FTOF implementation

- Bruno output: information about the particles which enter different subsystems

- The main goal: study the backgrounds

Radiative Bhabha is the main background affecting the FTOF

Quantities we need to determine

→ PMT count rate

→ Dose deposited in the front end electronics

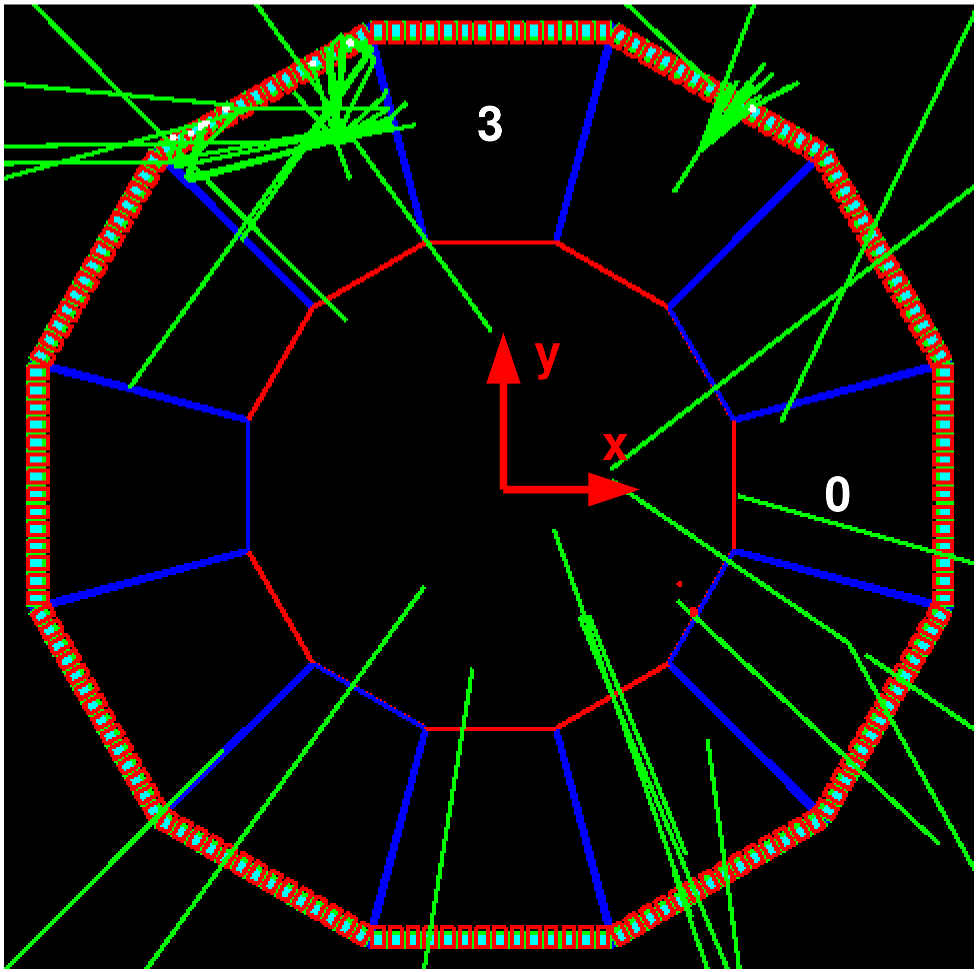
→ Incoming particles rate

Background photoelectron estimation

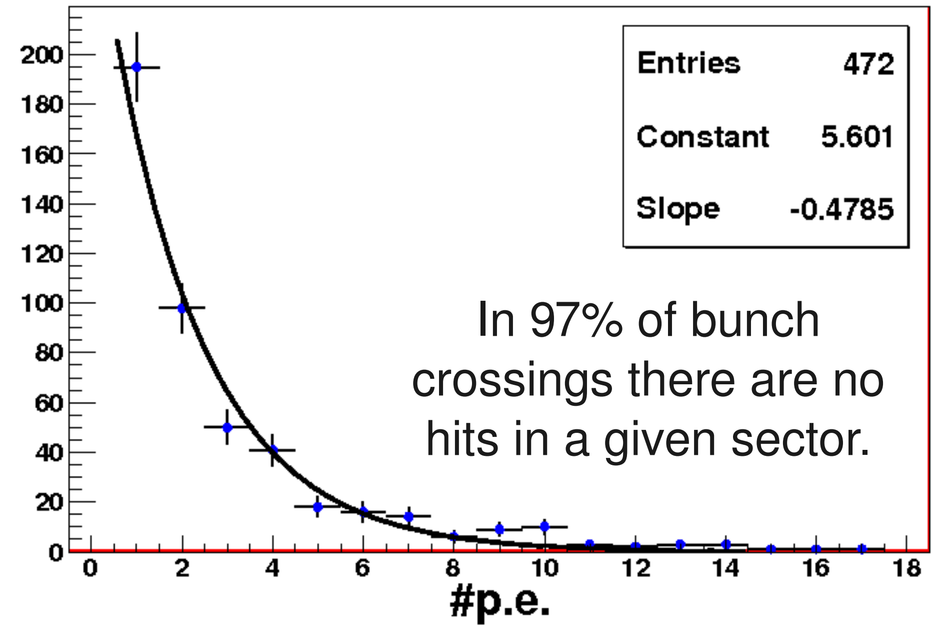
Optical physics is not yet implemented in Bruno

We use our simulation with input from Bruno

One bunch crossing



Distribution of p.e. in sector 3



<u>1.8 p.e. per bunch crossing in whole FTOF</u>

480 kHz/cm^2 or 530 kHz/channel

1.8 background p.e. vs. 20 signal p.e.
Does not have an effect on PID performances

Background (Conclusions)

- This study has been done with Bruno
- Main source of background is Radiative BhaBha process
- Incoming particles are gammas (~ 85 %) and neutrons (~ 15 %)
- PMT count rate **480 kHz/cm^2**. Which corresponds to 2 C/cm^2 of integrated anode charge in 5 years

---

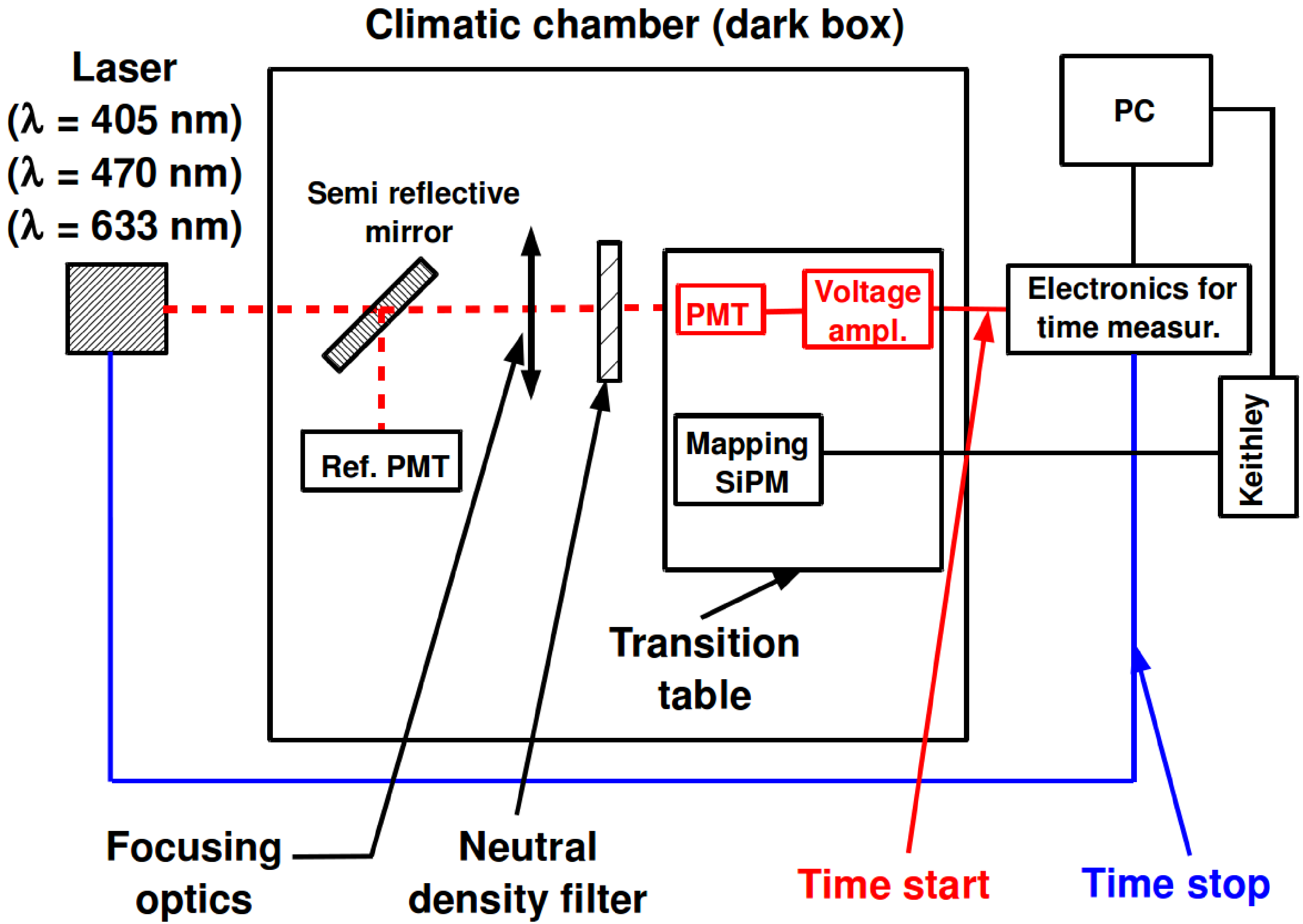
Electronics can handle these conditions

- Dose deposited in the front end electronics **0.9 kRad in one year**
- Incoming particles rate:

  Gammas: ~ 77 kHz/cm^2
  Neutrons: ~ 10^{11} /cm^2/year

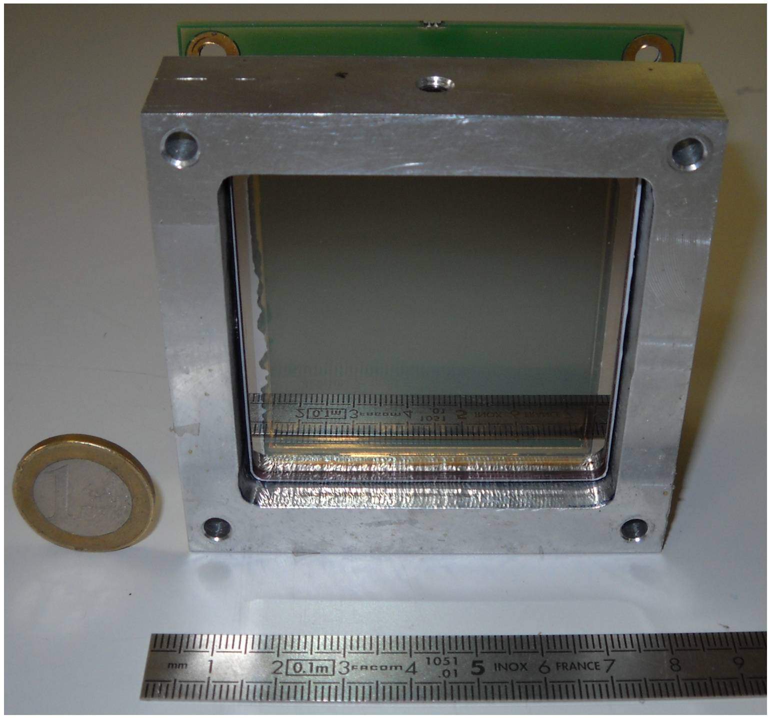
Selection of the photon detector

LAL test bench for photon detector characterization



Studied MCP-PMT

Burle



Hamamatsu

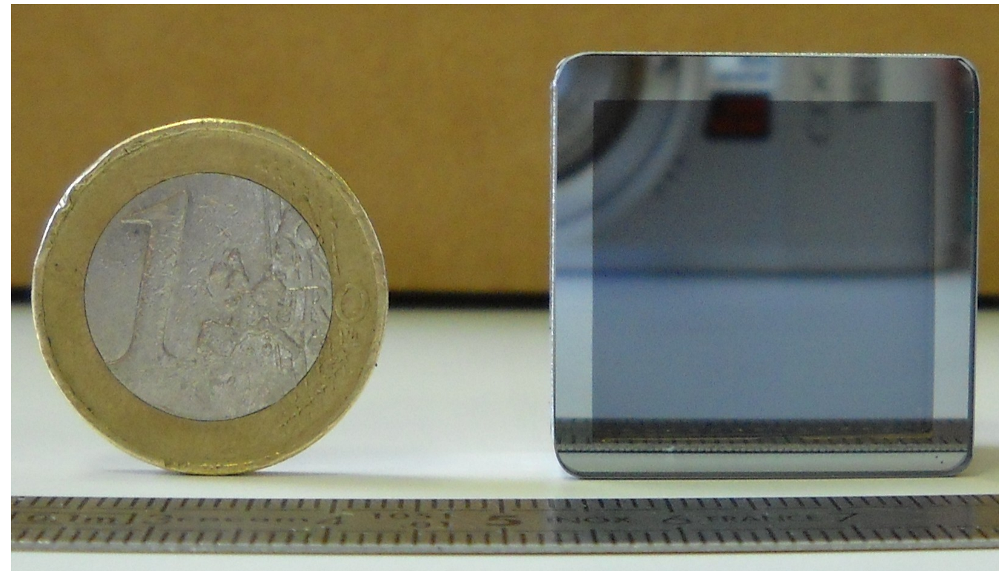


Table 6.1: Planacon MCP-PMT photon detector (XP85012)

Model	XP85012
Window material	UV-Glass, Schott 8337B or equivalent
Photocathode	Bialkali
MCP pore diameter	25 μm
MCP pore length to diameter ration	40:1
Initial anode structure	8 $\times$ 8 array, 5.9/6.5 mm (size/pitch)
Active area	53 $\times$ 53 mm^2
Open-area-ratio	80 %

Table 6.2: Hamamatsu SL-10 MCP-PMT with 4 channels

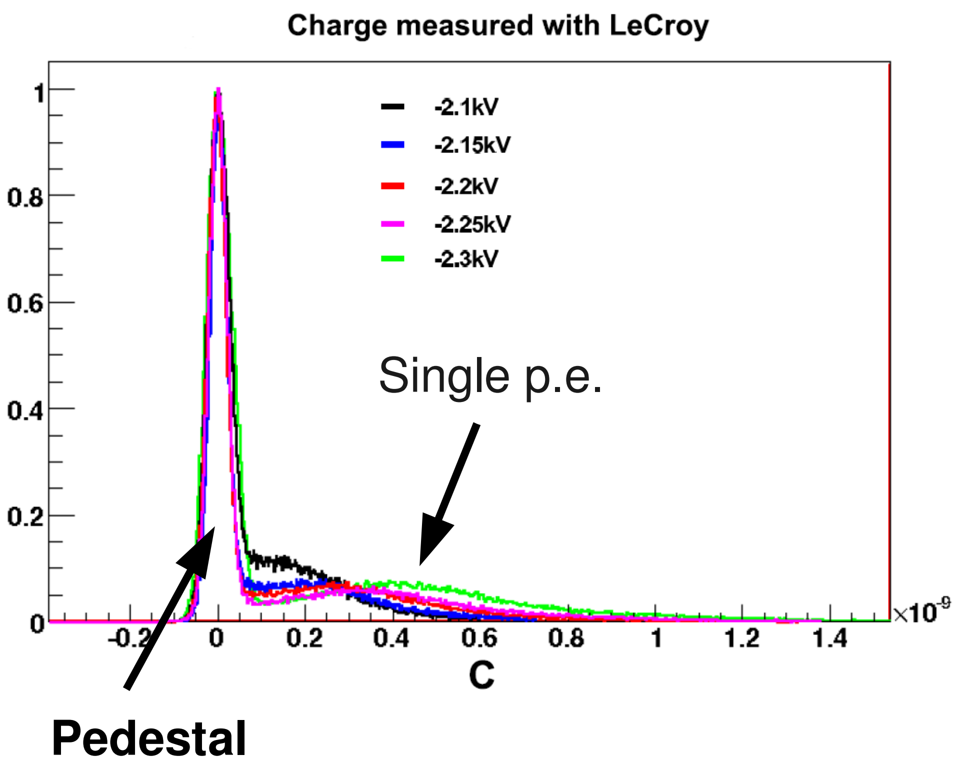
Model	SL-10
Window material	borosilicate glass
Photocathode	Bialkali
MCP pore diameter	10 μm
MCP pore length to diameter ration	40:1
Initial anode structure	4 channels, 22 $\times$ 5.5 mm^2 size
Active area	22 $\times$ 22 mm^2
Open-area-ratio	70 %

Burle XP85012 MCP-PMT

λ = 405 nm

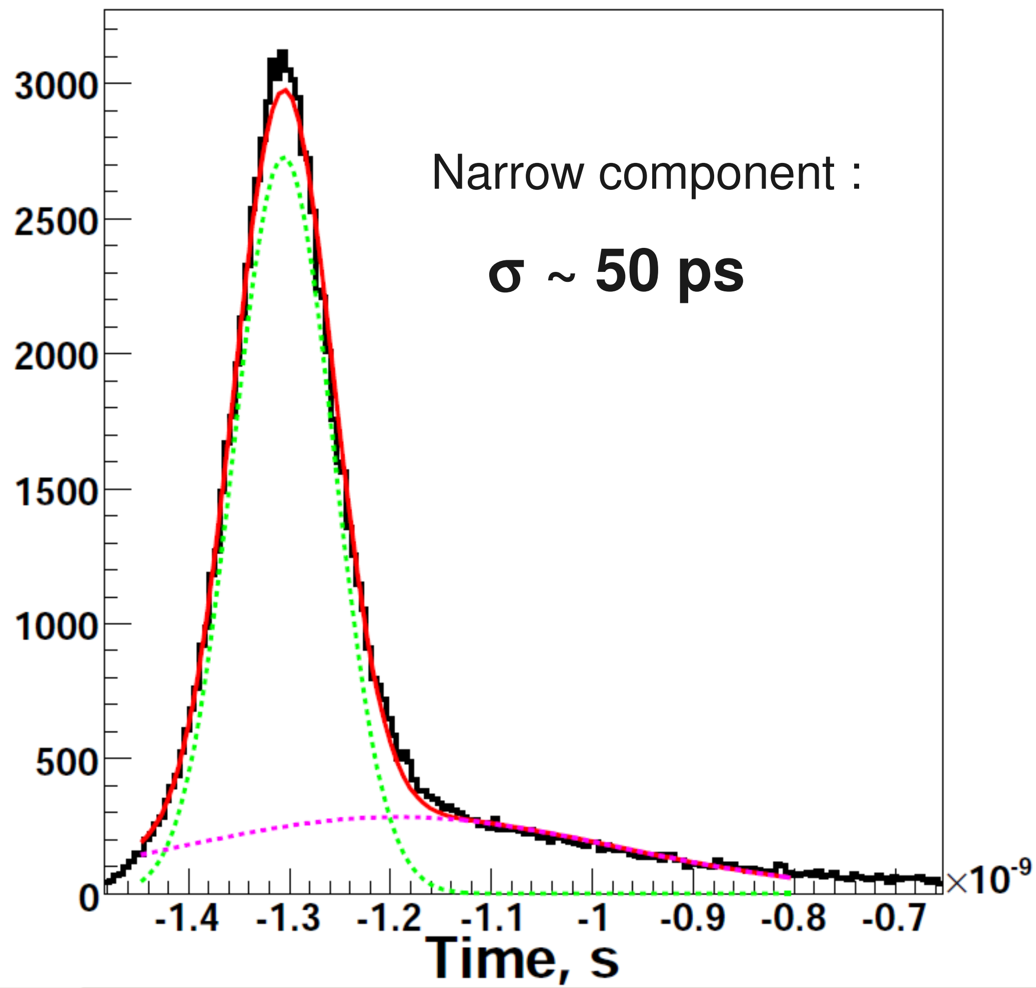
Gain = 4.5 x 10^5

~100 times voltage amplification



Expected shape of the amplitude

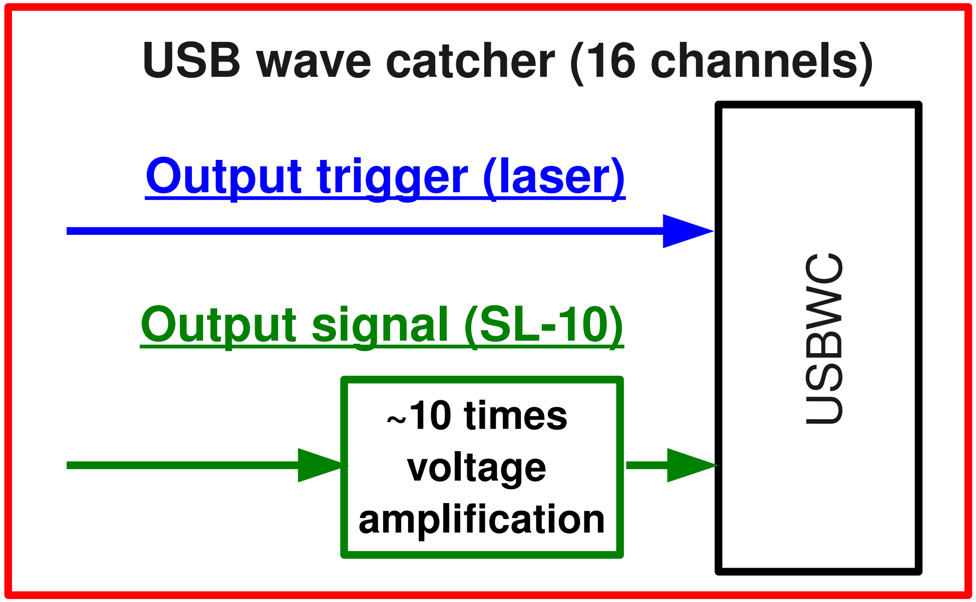
Single photo electron timing

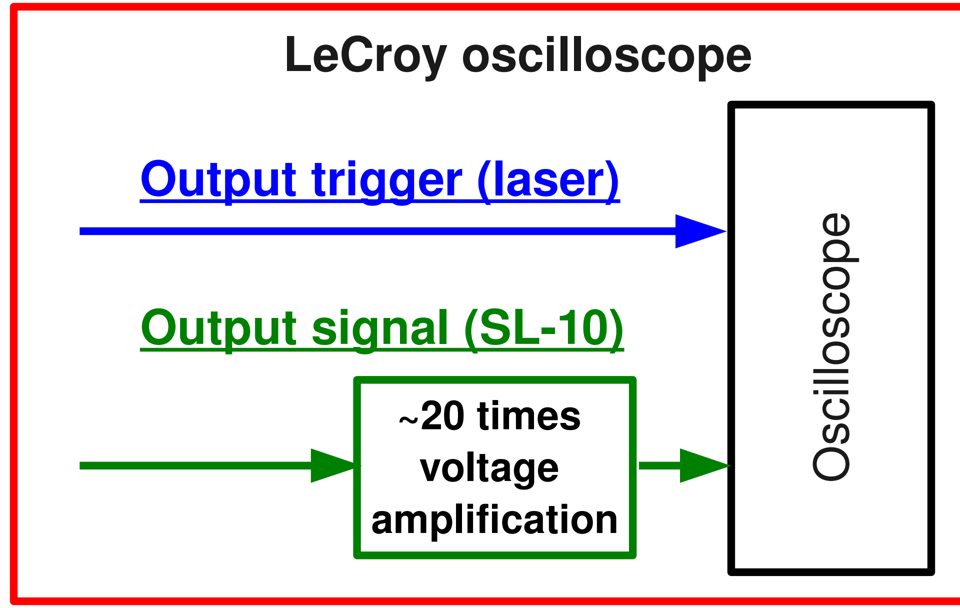


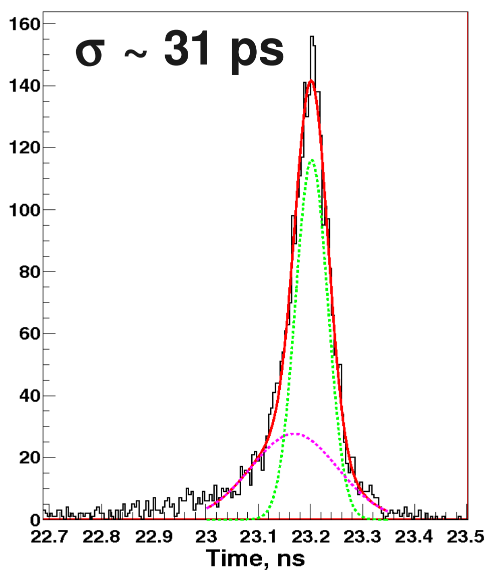
Expected shape of the time distribution

Hamamatsu SL-10 MCP-PMT

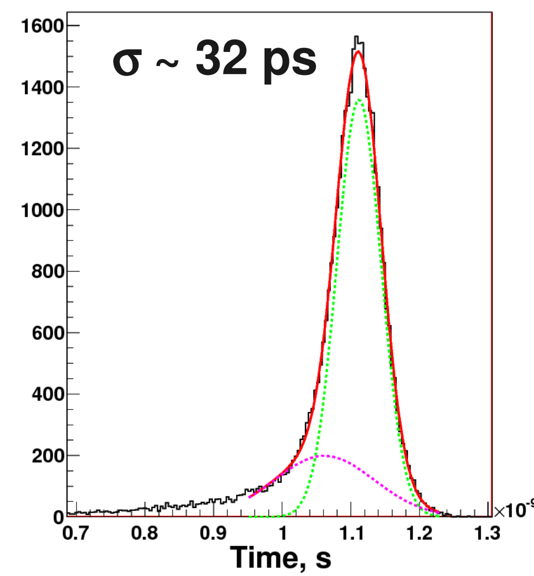
λ = 405 nm; Gain ~ 10^6







Note: Only 60% events are with single photoelectrons



n condition when 99% events are with single photoelectrons we measure
σ ~ 37 ps (with USCWC and LeCroy oscil.)

Hamamatsu SL-10 vs. Burle XP85012 MCP-PMT

	Single photoelectron time resolution	Maximum acceptable integrated anode charge	Collection efficiency
XP85012	**50 ps**	**<1 C/cm^2**	**70 %**
SL-10	**37 ps**	**1 – 2 C/cm^2**	**60 %**

SL-10 is baseline MCP-PMT

Conclusions

Conclusions

- The FTOF is a promising device for particle ID in the forward region of SuperB.
- 30 ps time resolution of the FTOF would allow to perform a good K/π separation.

The FTOF detector at SuperB

Time resolution

$\sigma_{\text{electronics}}$	10 ps
σ_{TTS}	40 ps
σ_{detector}	80 ps
σ_{trk}	10 ps
σ_{t0}	20 ps
$N_{\text{p.e.}}$	>10
Total time resolution	<40 ps

Geometry

Mirror	+
Absorber	B
Tilting	-
Radiator thickness	15 mm

Photon detector

MCP-PMT	SL10
Number of channel per PMT	4
Total number of PMTs	168
Total number of channels	672
MCP-PMT photocathode	Multialkali

- We have tested this technology (detector + PMT + electronics) in the SLAC CRT (2010 - 2011).

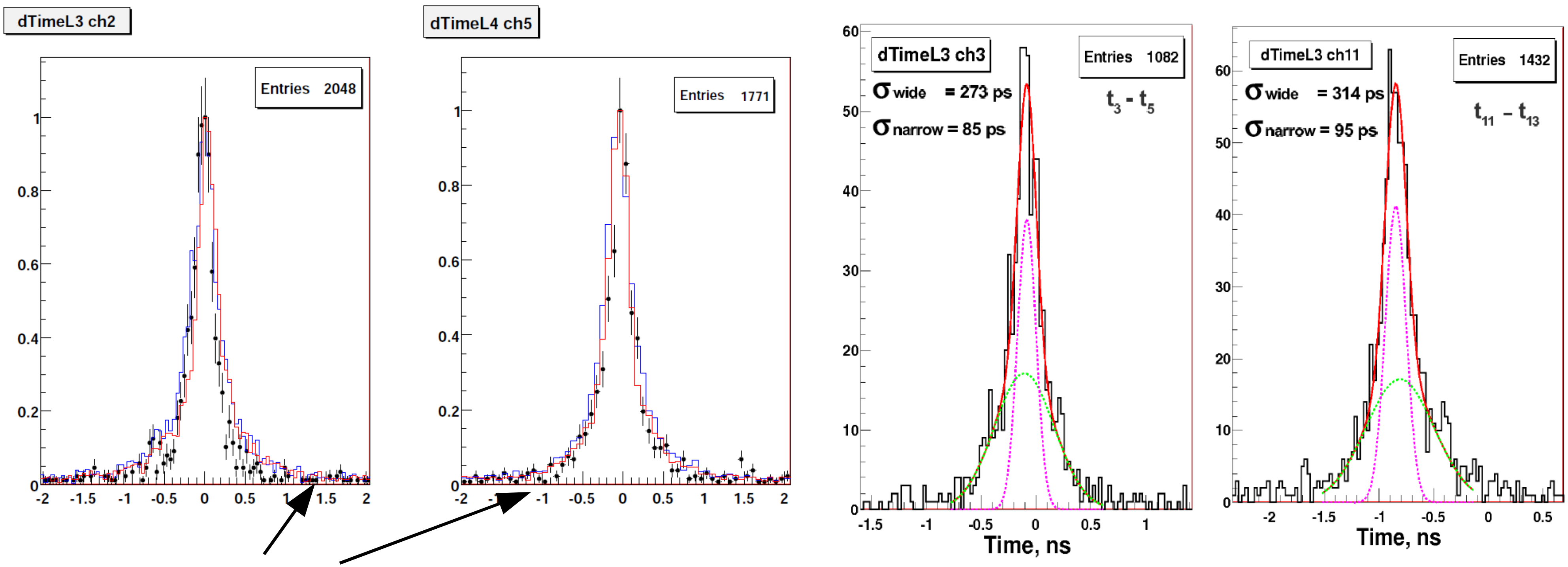
- Photoelectron background rate in SuperB is estimated to be 480 kHz/cm^2

- FTOF is the baseline detector for the forward PID of SuperB

Backup

Cuts on the muon direction

As we know from simulation, muons with 'bad' angles are not suitable for precise timing measurements as the Cherenkov photons they emit are detected in the MCP-PMT on the a wide timing range.



Decrease the tail

σ_{narrow} in average measured to be ~ 90 ps

$$\sigma_{\mathrm{detector}} \oplus \sigma_{\mathrm{muon}} =$$ **55 ps**

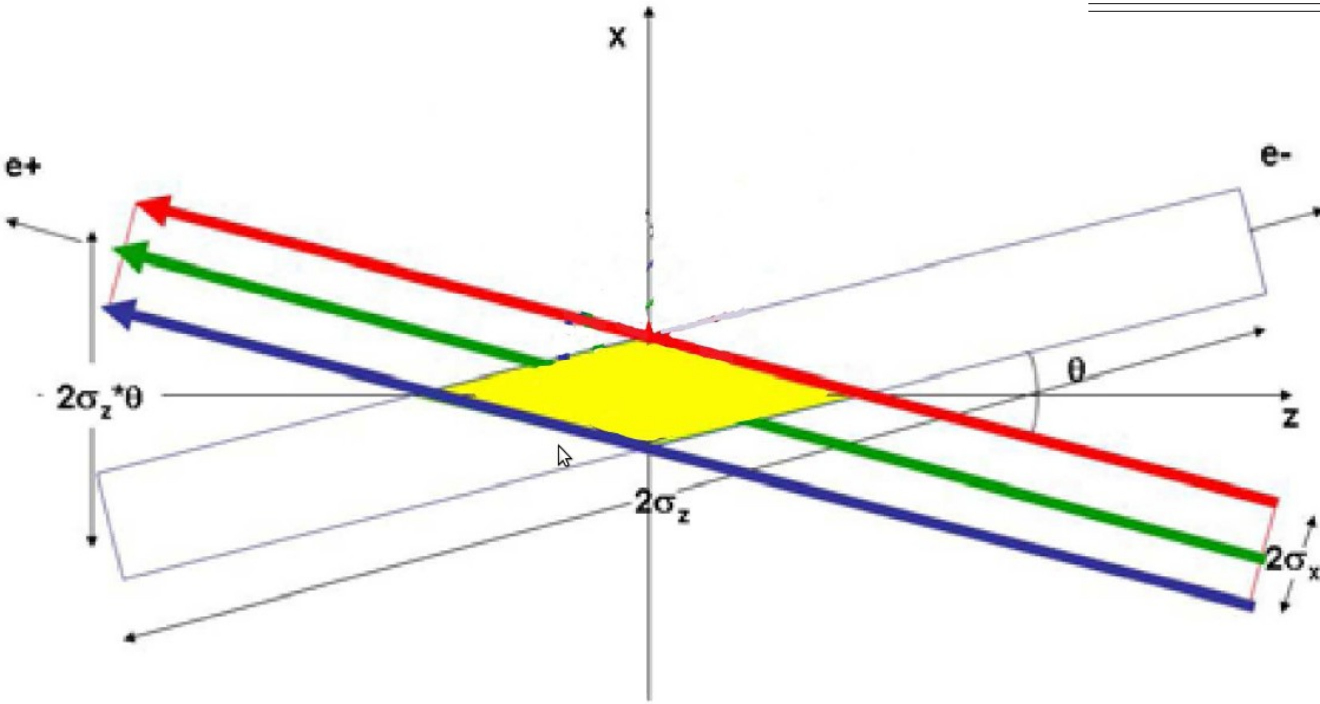
Bunch crossing scheme with large Piwinski angle

$$L = \frac{N^+ N^-}{4\pi\sigma_y \sqrt{(\sigma_z \tan\theta/2)^2 + \sigma_x^2}} f_c$$

$$\sigma_{x,y} = \sqrt{\beta_{x,y}\varepsilon_{x,y}}$$

Table 2.2: *SuperB* accelerator parameters.

Parameter	Units	HER (e^+)	LER (e^-)
Energy	GeV	6.7	4.18
β_x @ IP	cm	2.6	3.2
β_y @ IP	cm	0.0253	0.0205
Emittance x	nm rad	2.0	2.46
Emittance y	pm rad	5	6.15
Bunch length	mm	5	5
σ_x effective	μm	165.22	165.30
σ_y @ IP	μm	0.036	0.036
Energy spread (10^-4)	dE/E	6.43	7.34
CM energy spread (10^-4)	dE/E	5.0	5. 0
Total beam lifetime	min	4.23	4.48
Luminosity	cm^{-2}s^{-1}	10^{36}	

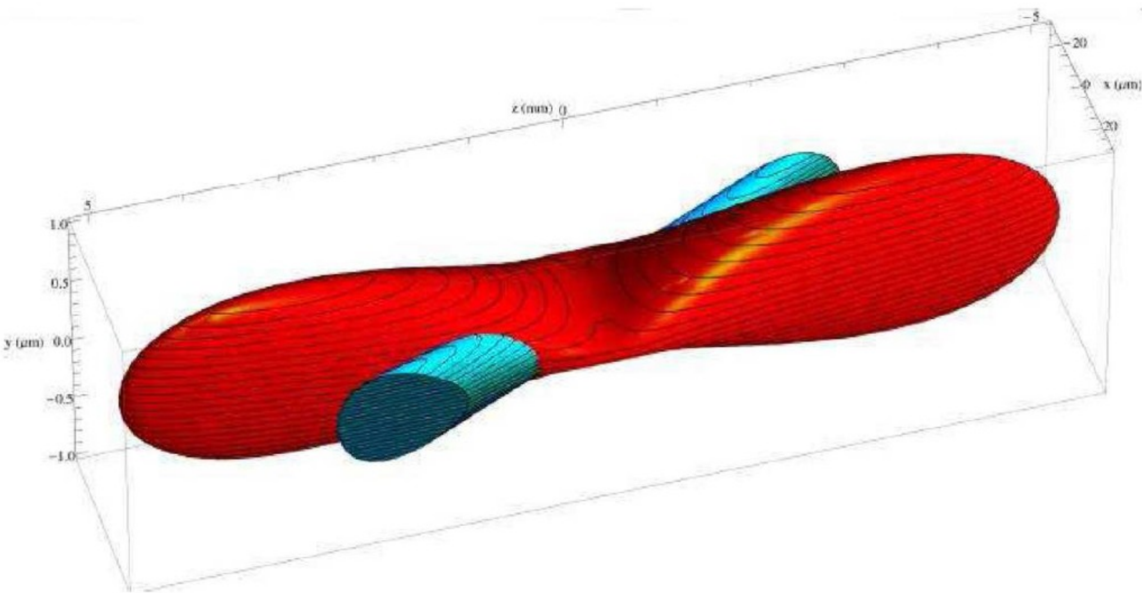


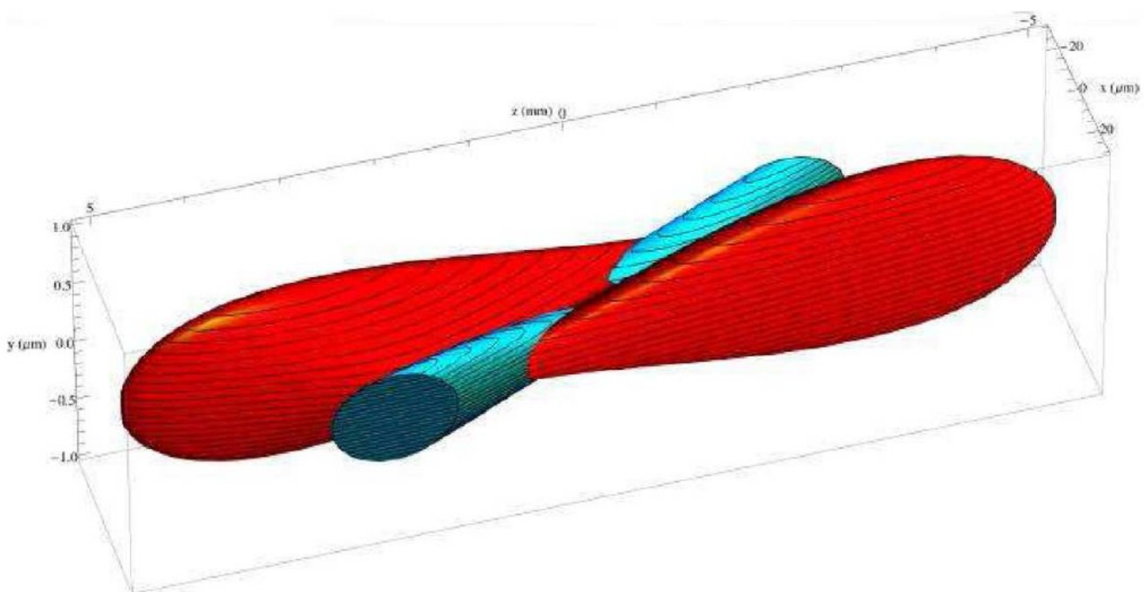
However, reduction of the β_y requires very short bunches to keep the "hourglass" effect small. The use of large Piwinski angle (φ) allows to decrease the effective bunch length

$$\phi = \frac{\sigma_z}{\sigma_x} \tan\frac{\theta}{2}$$

Crabbed waist bunch transformation

Bunch charge density envelops at the IP when colliding



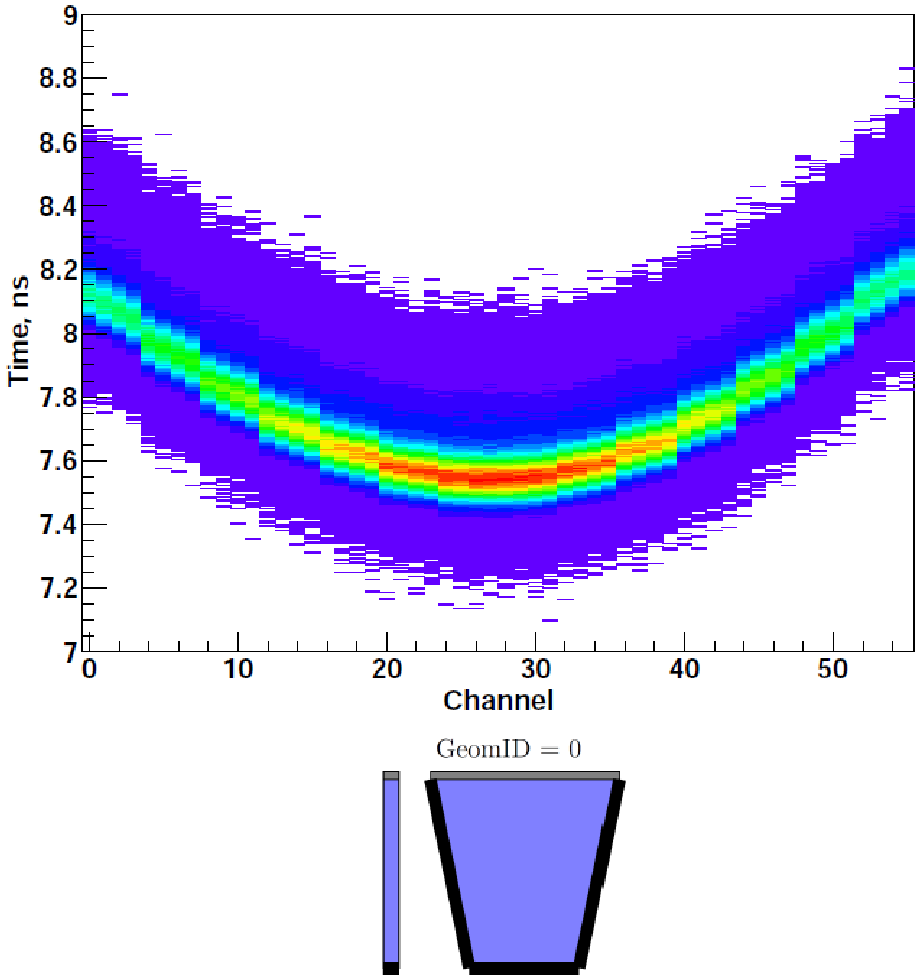


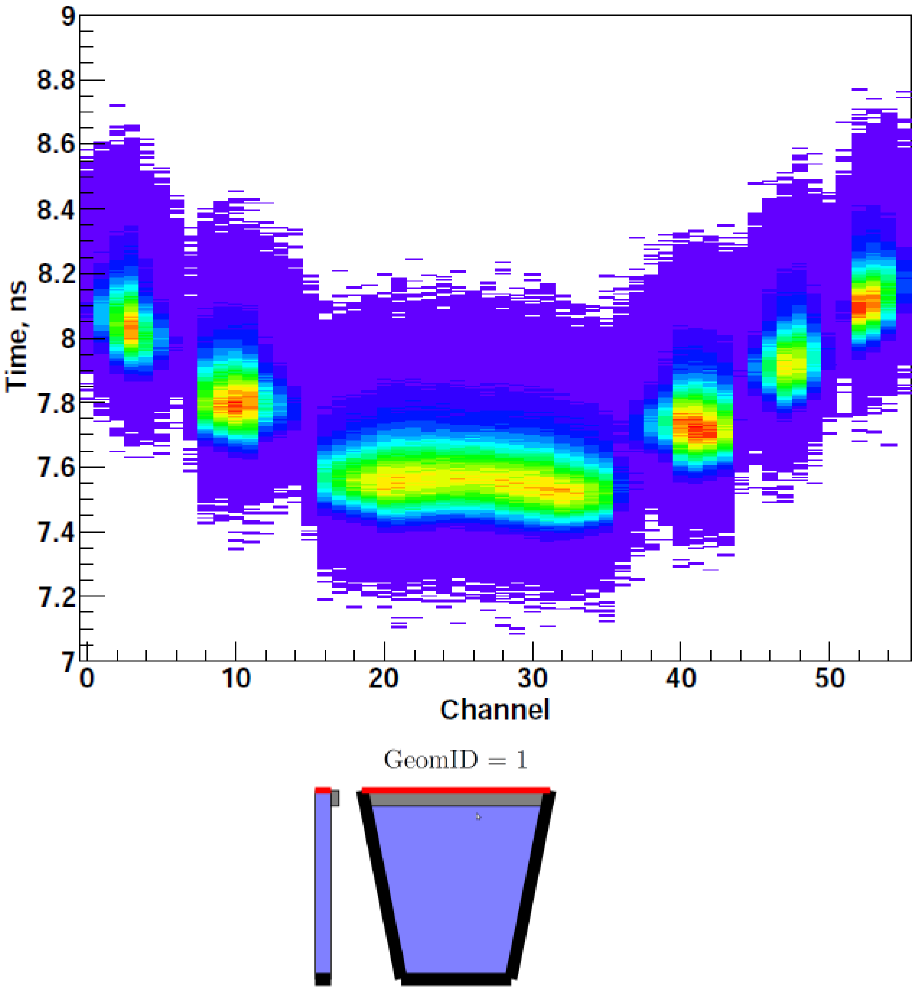
Low energy beam (in red) and high energy beam (in blue).

← **Without**

← **With**

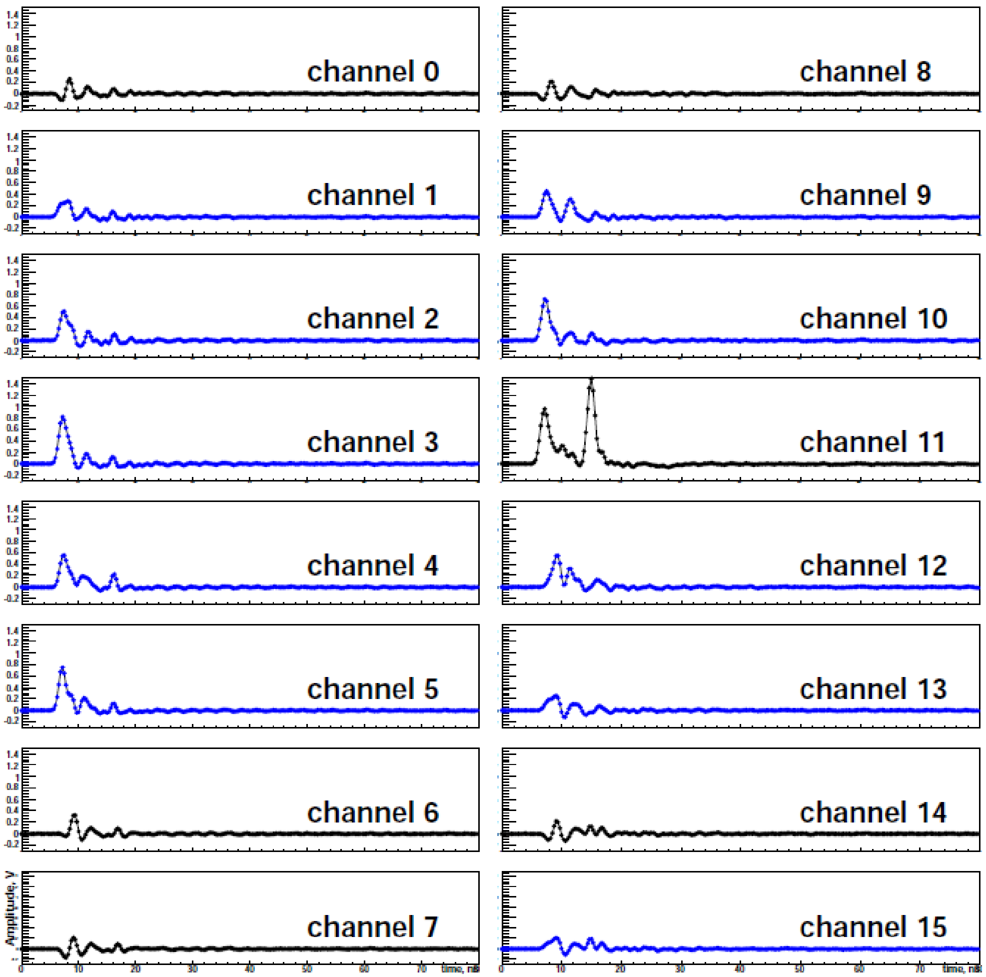
Time vs. channel



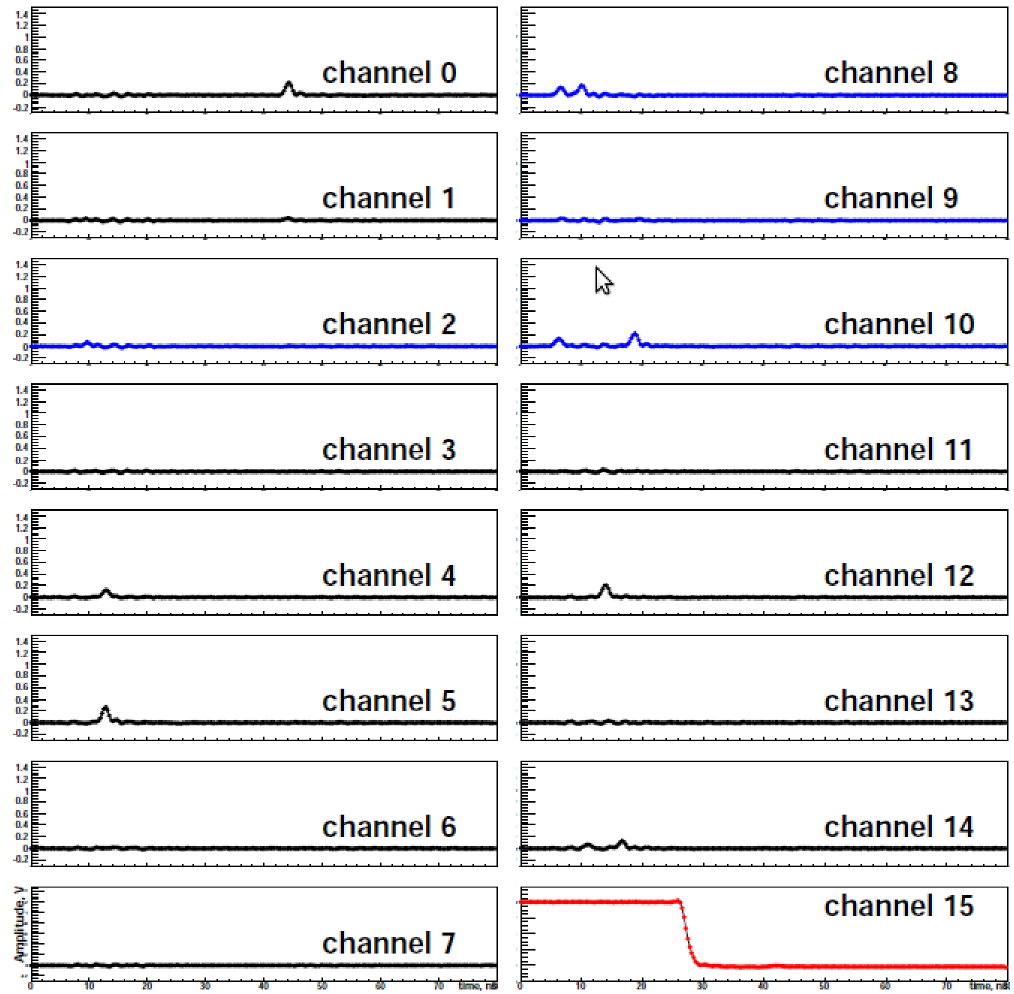


Event display

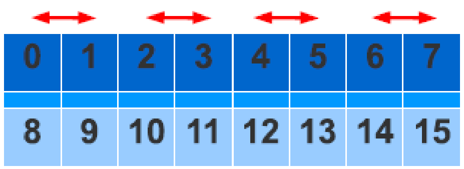
No absorber



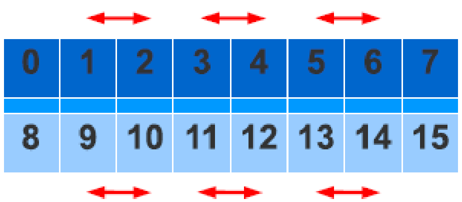
Absorber



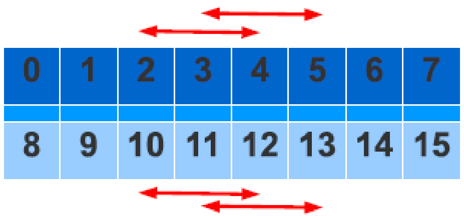
Time differences



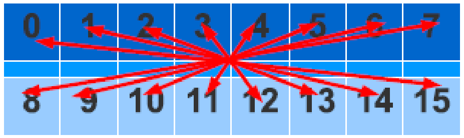
Type L: neighbor channels from one board



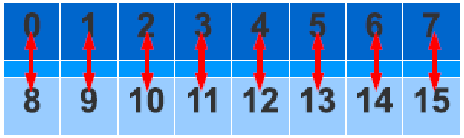
Type L2: neighbor channels from different boards



Type L3: not neighbor channels connected to same quartz bar

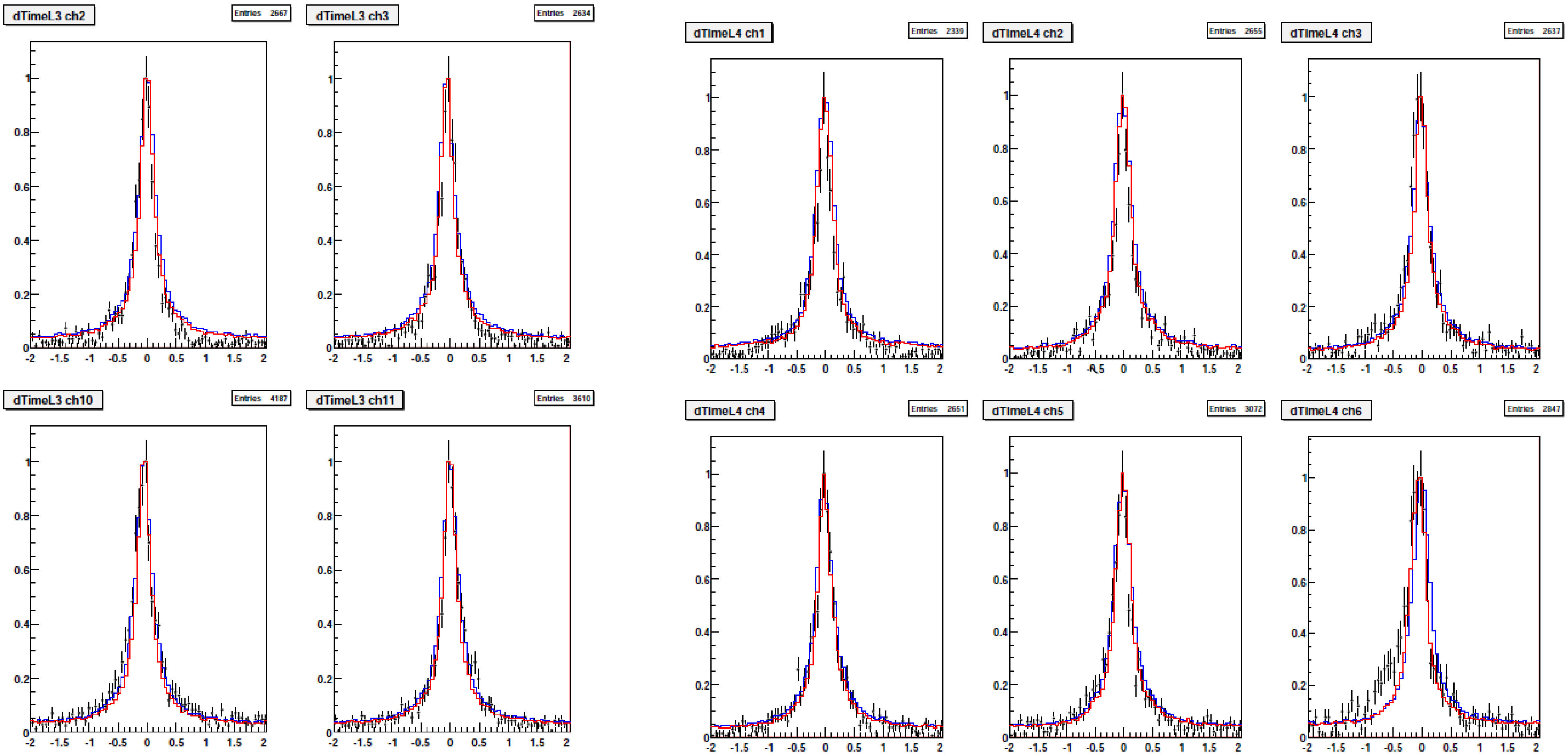


Type L4: not neighbor channels connected to different quartz bars



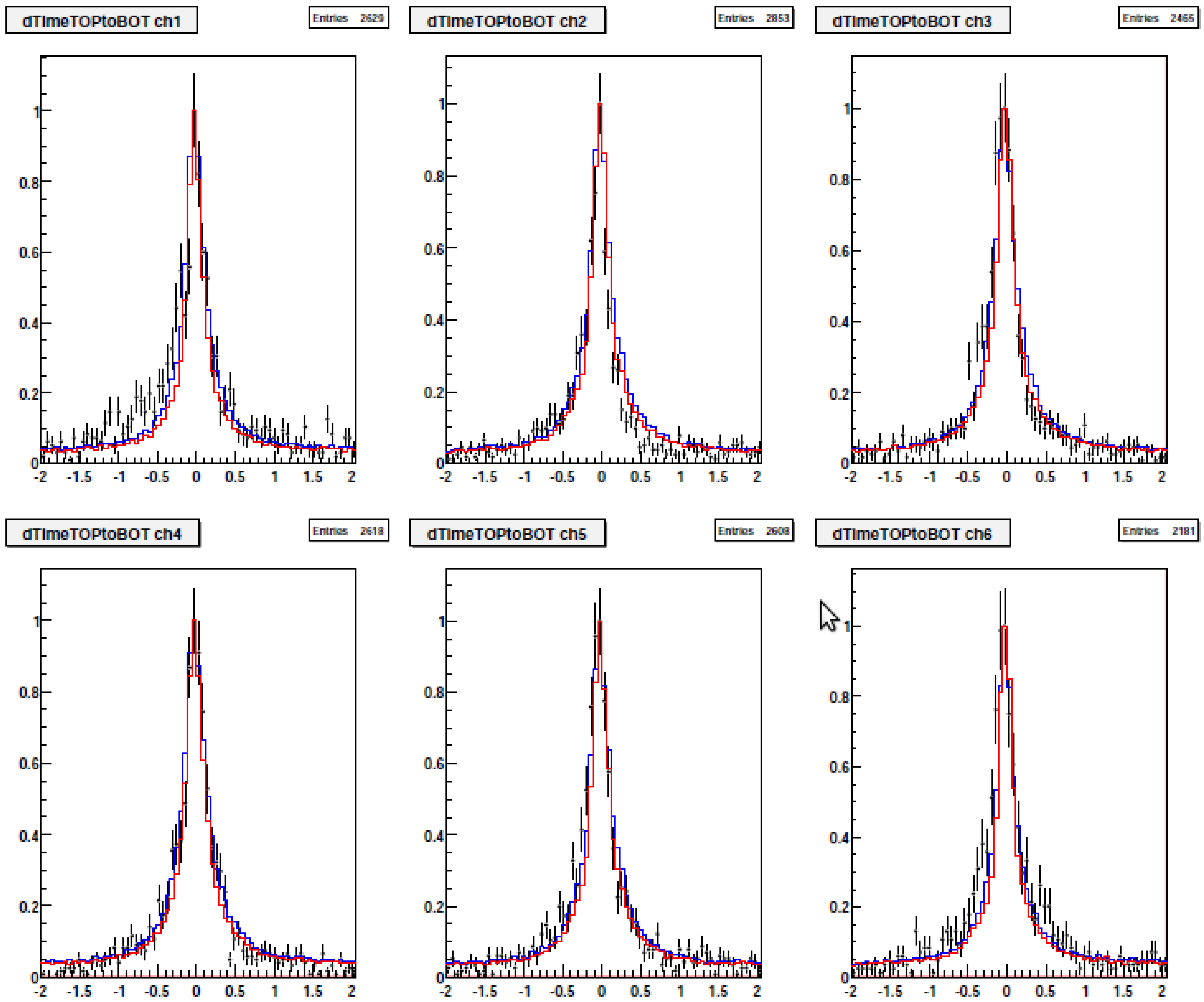
Type TtB: top to bottom time difference

Time differences



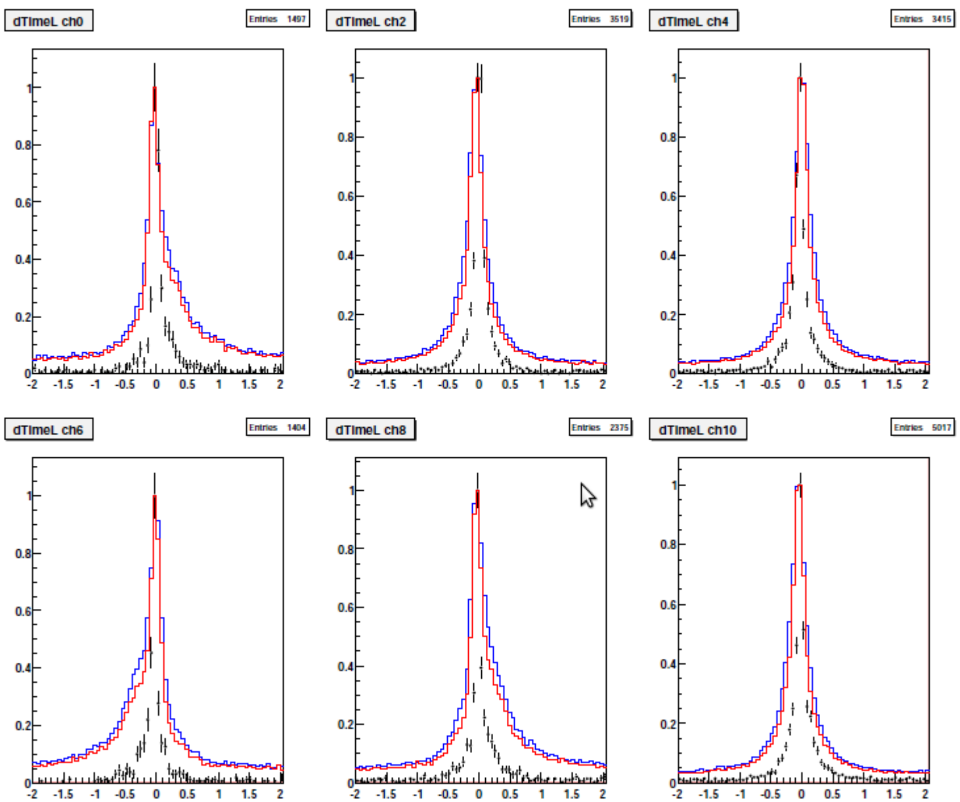
Absorber

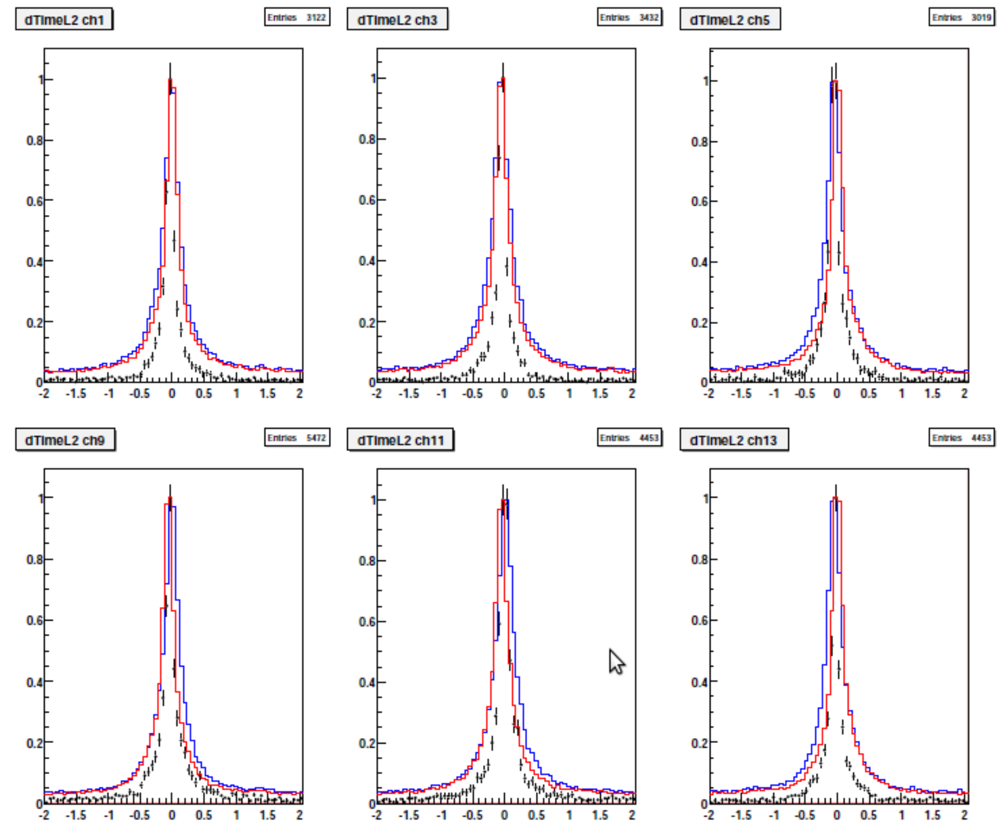
Time differences



Absorber

Time differences

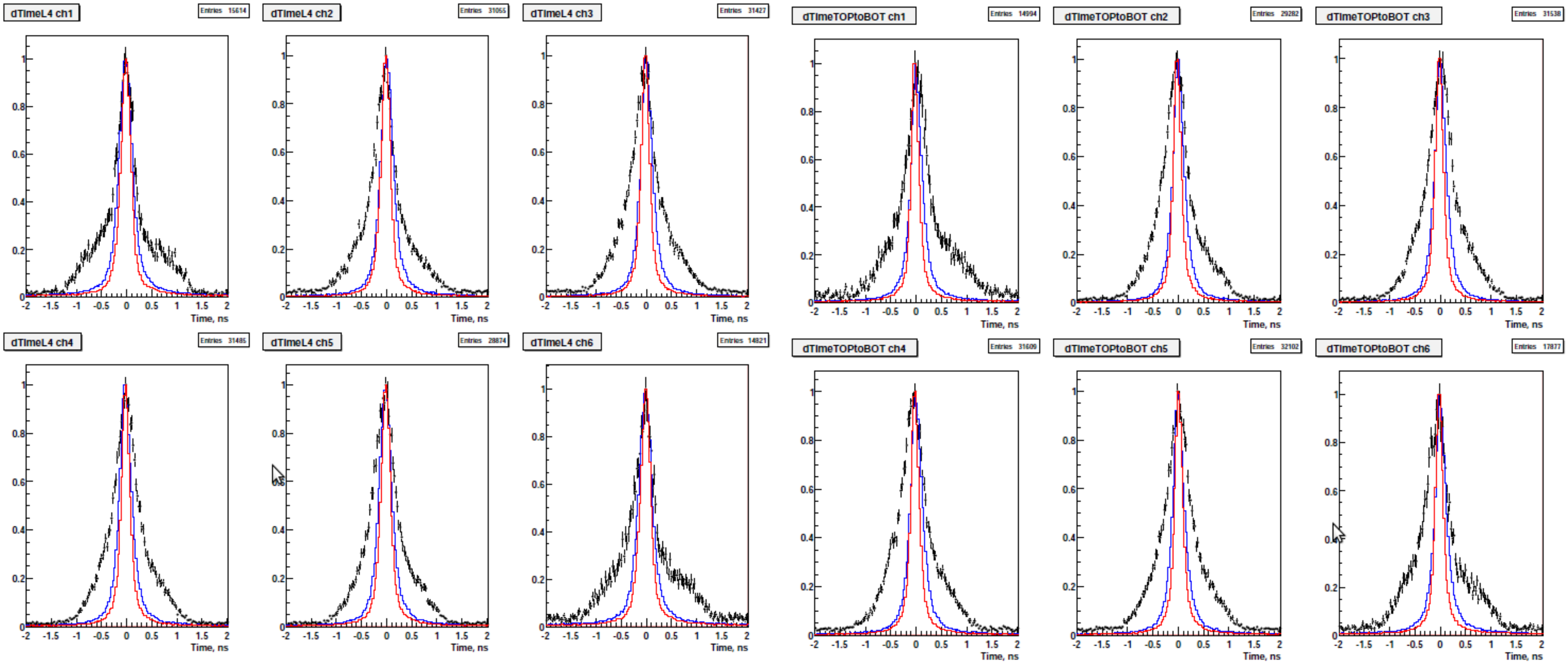




Absorber

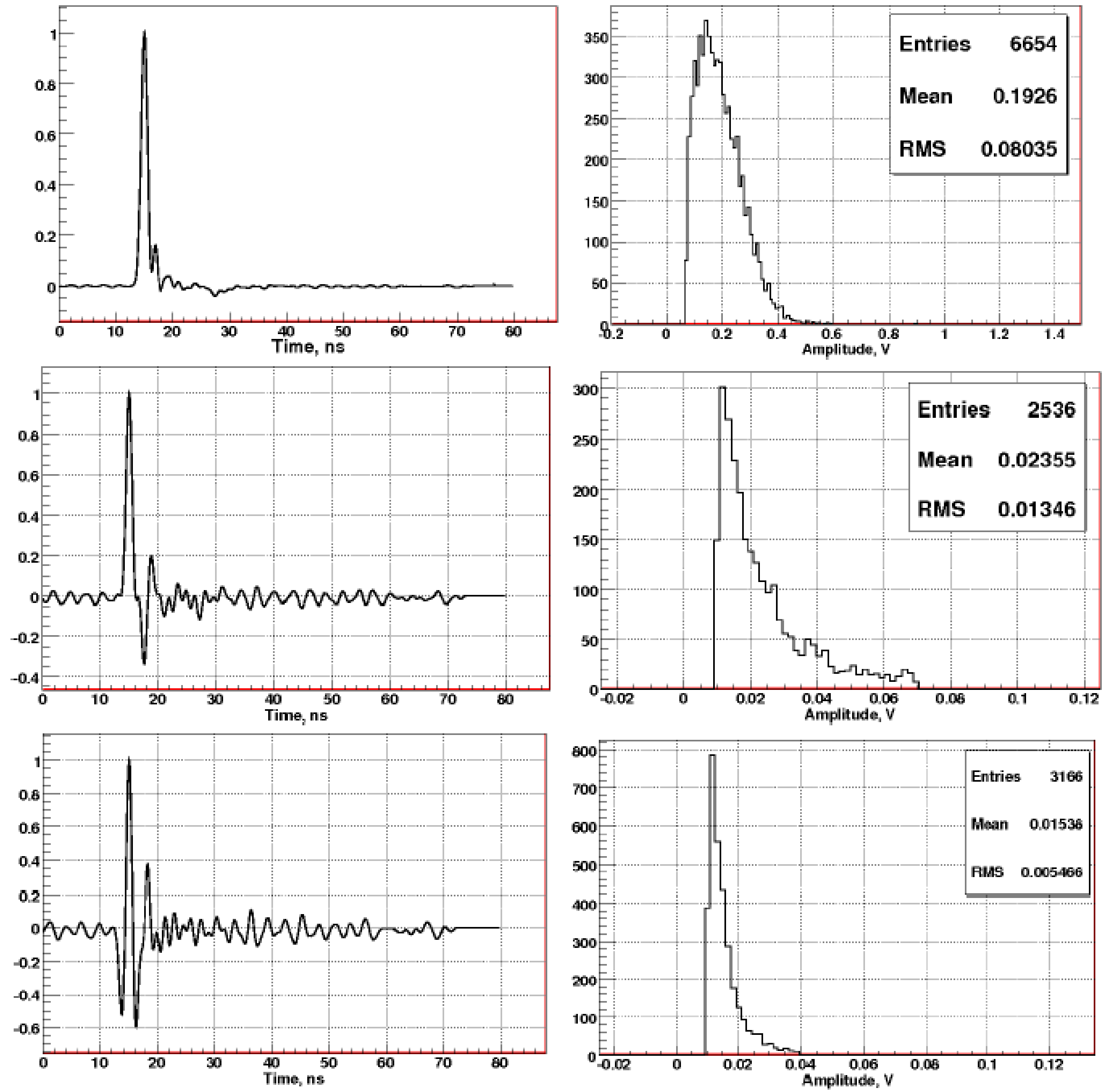
Neighbor
channels

Time differences



No absorber

Charge sharing and crosstalk



PMT channel orientation

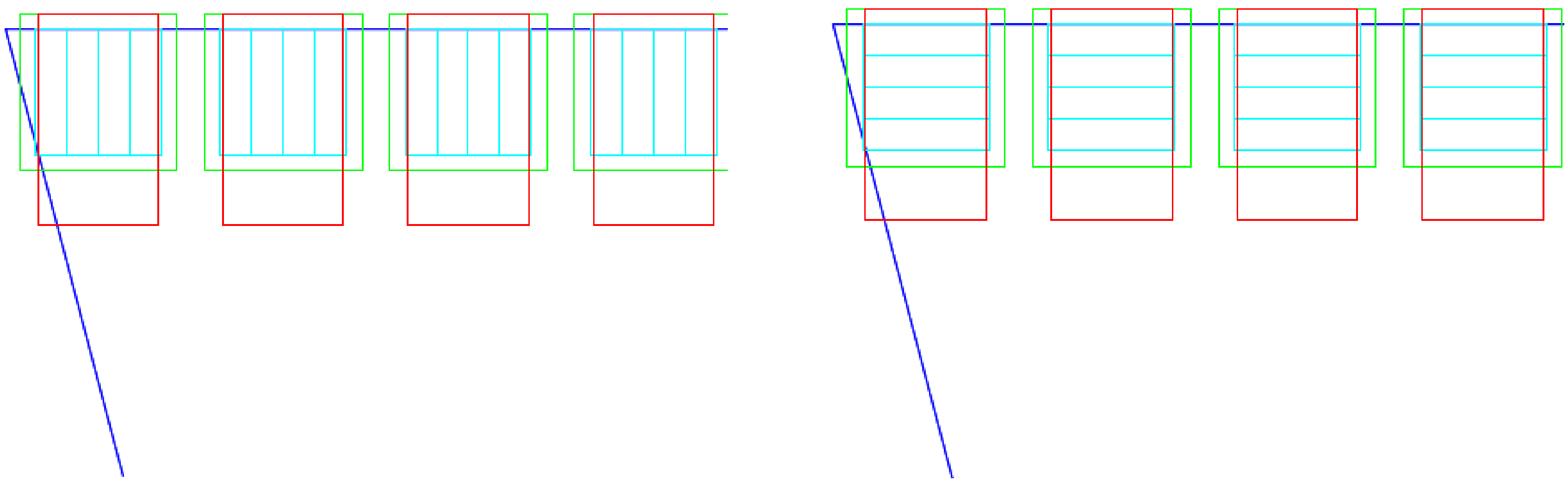
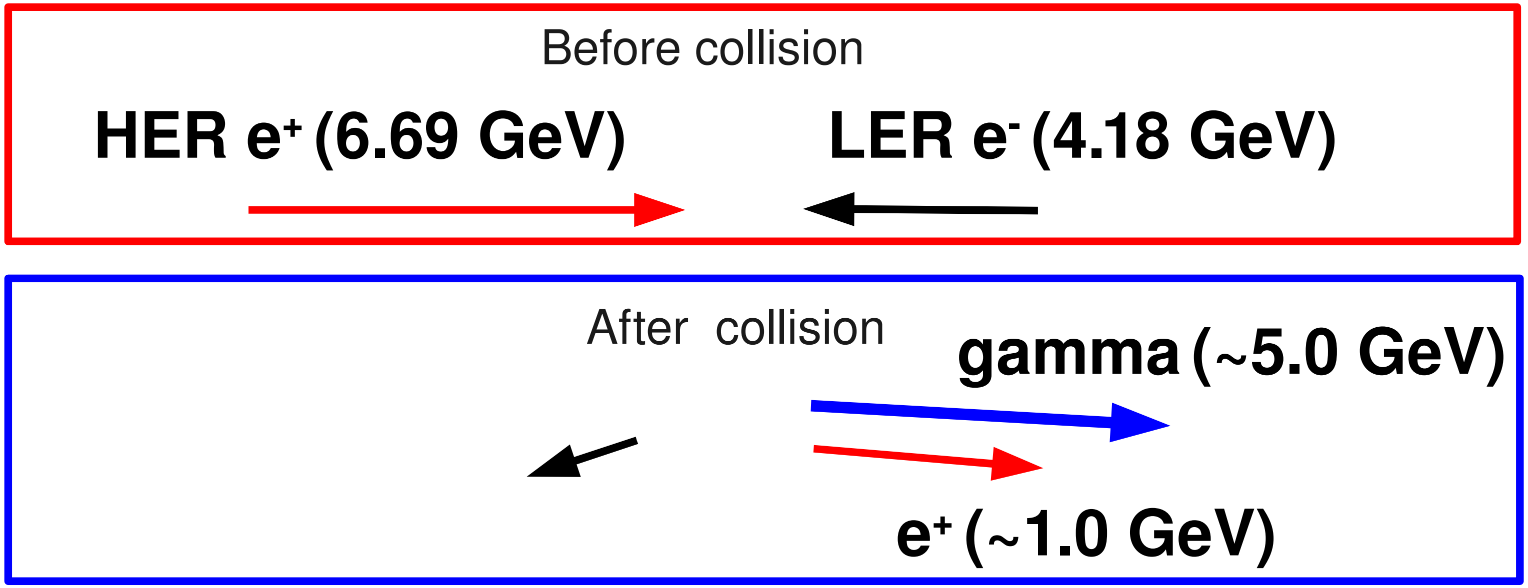


Figure 1.20: The PMT channel orientation vertical (V) from the left and horizontal (H) from the right. In dark blue is the quartz tile radiator, the light blue correspond to the sensitive area of the PMT, green box is the PMT body and in red the electronics are shown.

Deeper look at the source of background
Final focus (sf11) layout



High energy gammas (5 GeV) produced via radiative BhaBha process by positrons go straight and hit the bending magnet ~10m away from IP, while ~ 1 GeV positrons get a kick from the nominal trajectory and hit the beam pipe 1 m away from IP. This create EM showers which then affect the FTOF detector.

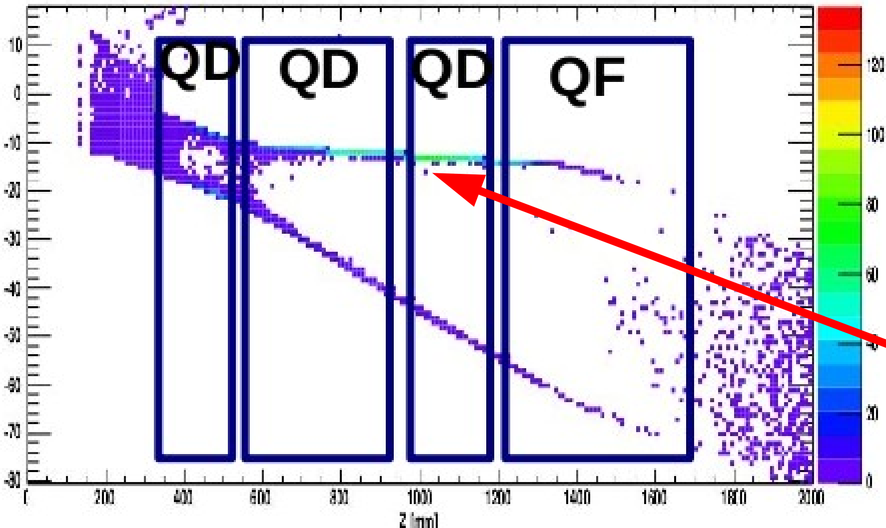
~90% of the FTOF background comes from this effect.

Thanks to tungsten shield around beam pipe and 1.5 T magnetic field the charged particles from EM shower will not reach the FTOF.

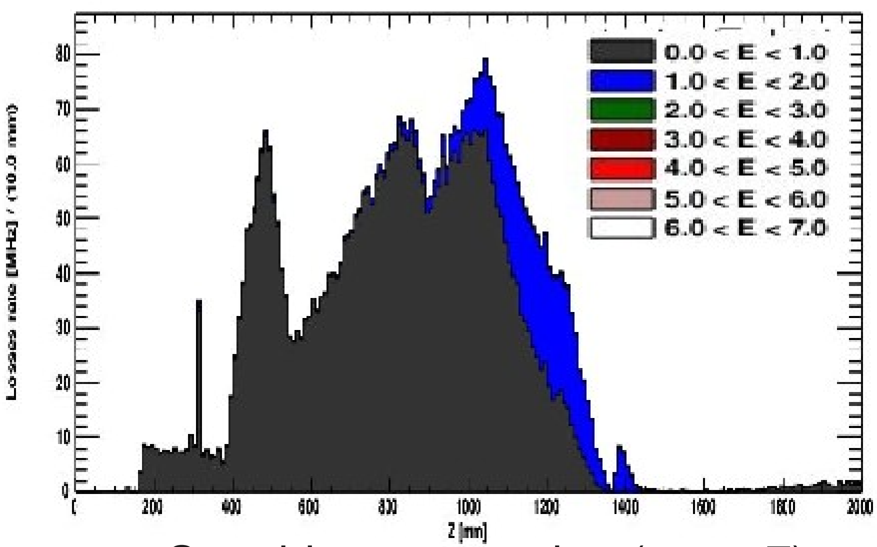
The main particles entering FTOF are gammas ~ (85%) and neutrons (~14%).

Hot spot caused by Radiative Bhabha effect

Positron losses along beam pipe



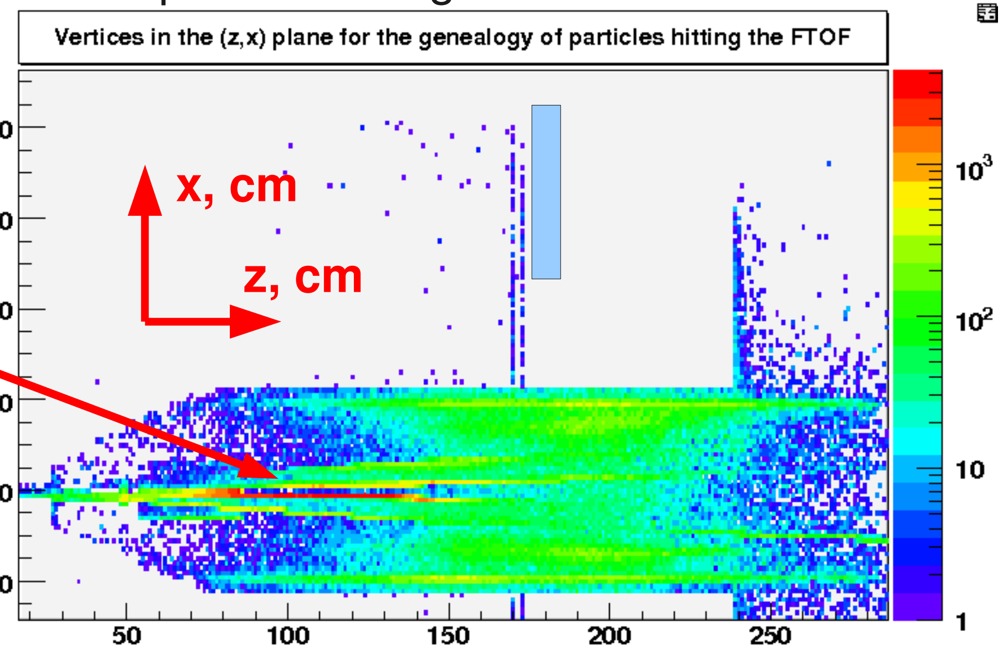
z ~1m from IP

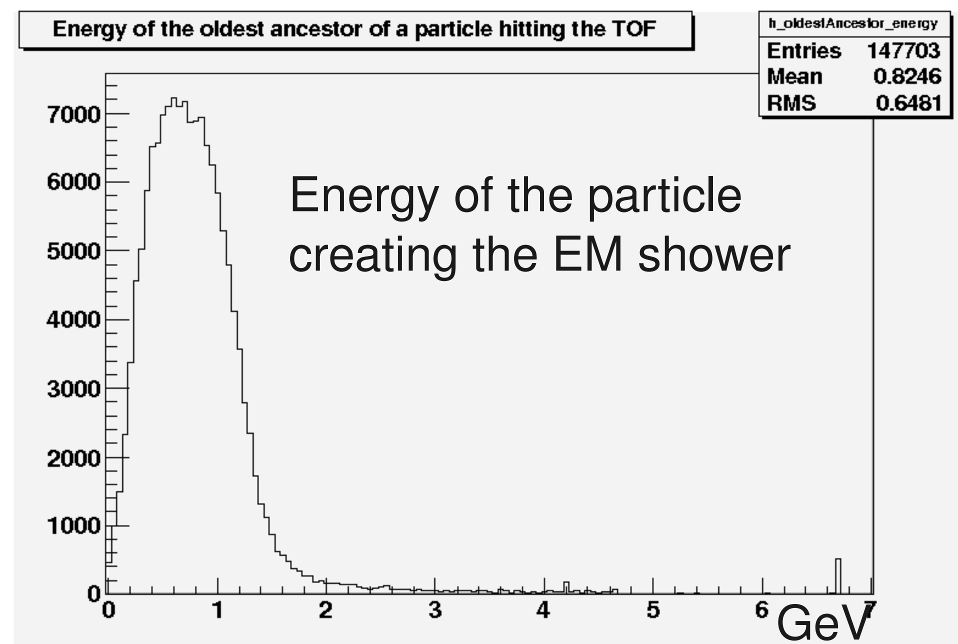


See this presentation (page 7)

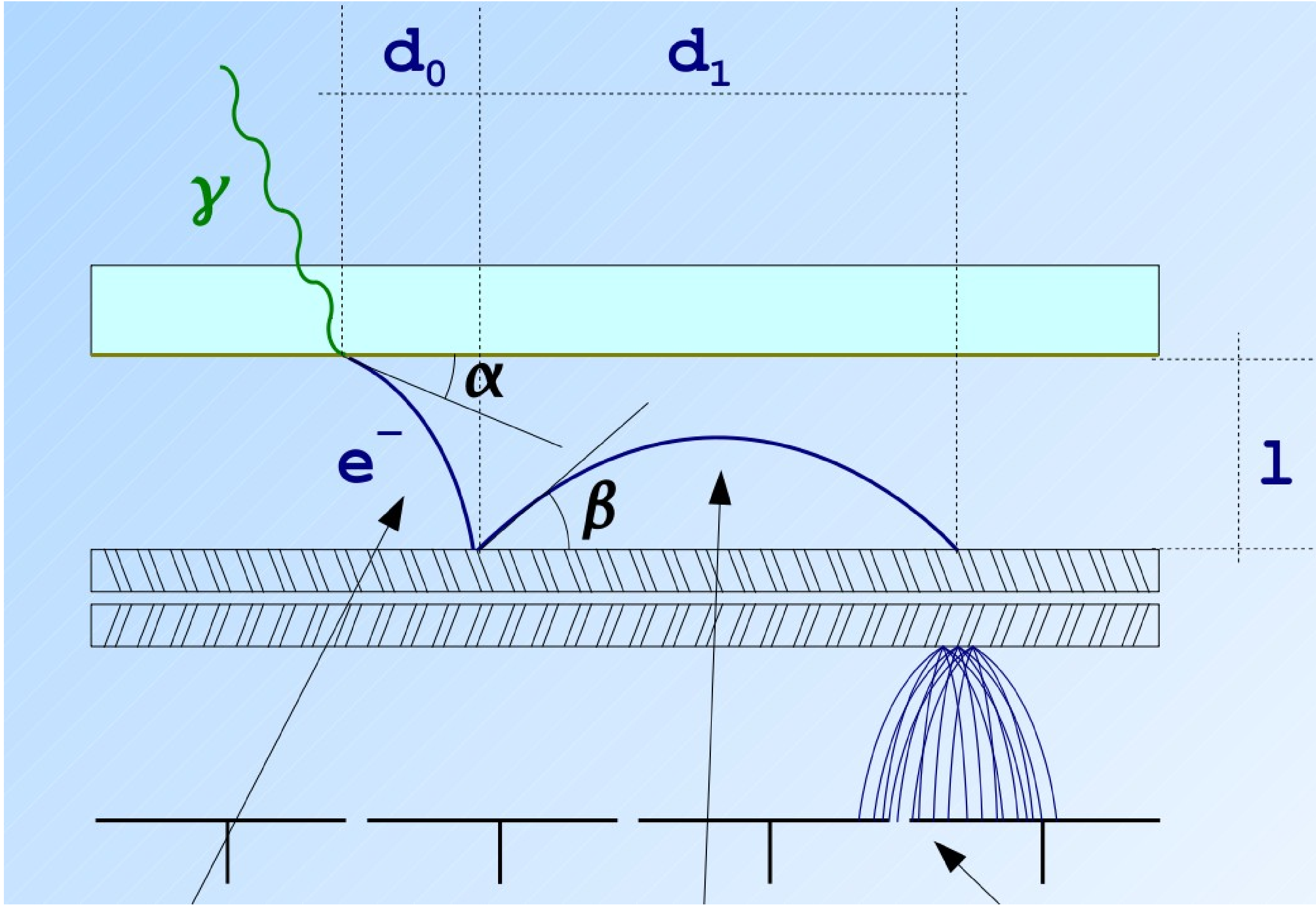
http://agenda.infn.it/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=3808

Vertices of the genealogy of particle hitting the FTOF





Recoil p.e.



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