PANDA experiment and PNPI in PANDA

Antiproton proton collision @ 1.5-15 GeV HESR

- PANDA physics
- Status of FAIR/ HESR/PANDA
- PNPI Forward TOF with 70ps resolution
- FTOF TDR

С. Белостоцкий Сессия УС ОФВЭ 2015

FAIR Facility for **A**ntiproton and **I**on **R**esearch

HESR

ANTI PROTONS

Momentum range

1.5 -8.9 Gev

L= $2x10^{31}$ $cm^{-2}s^{-1}$

$\Delta p/p=5x10^{-5}$

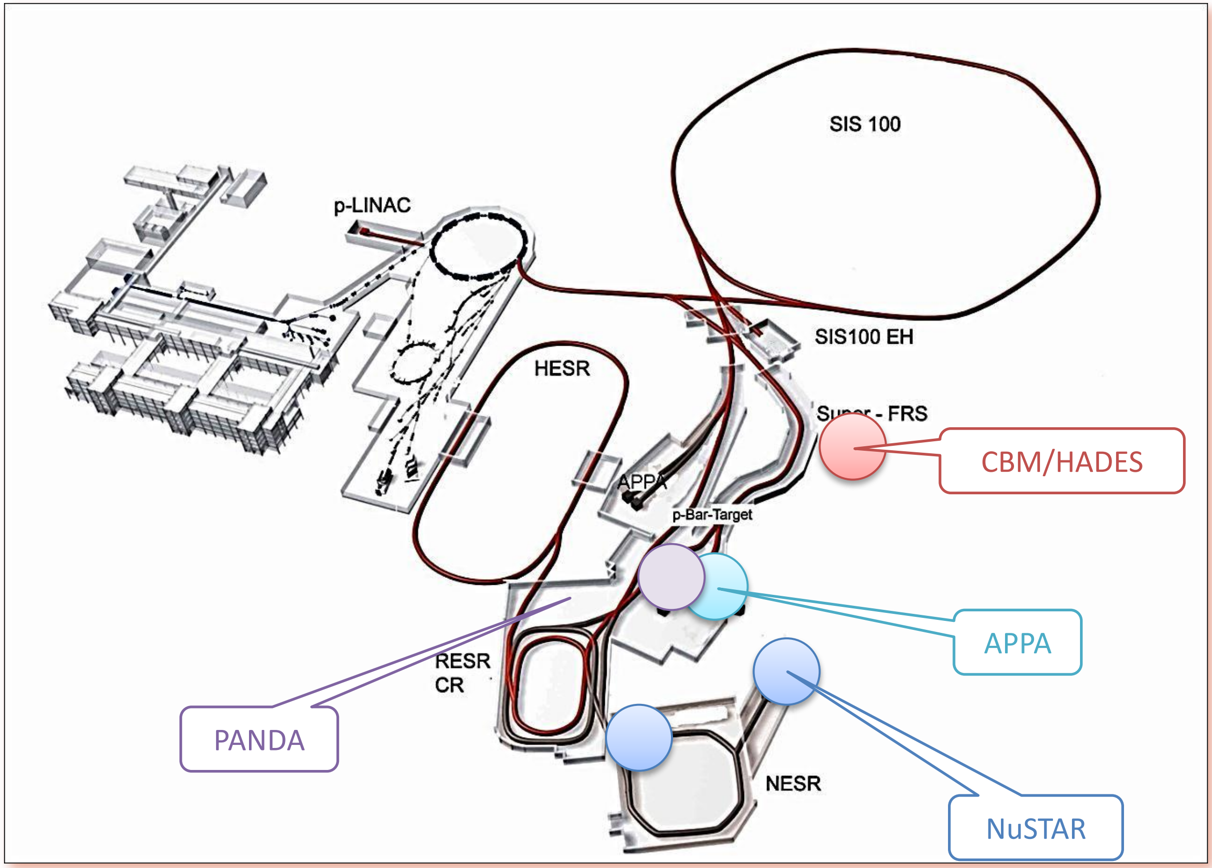
at 5 GeV ΔE=250 KeV !!

Momentum range

1.5 -15 GeV

L= $2x10^{32}$ $cm^{-2}s^{-1}$

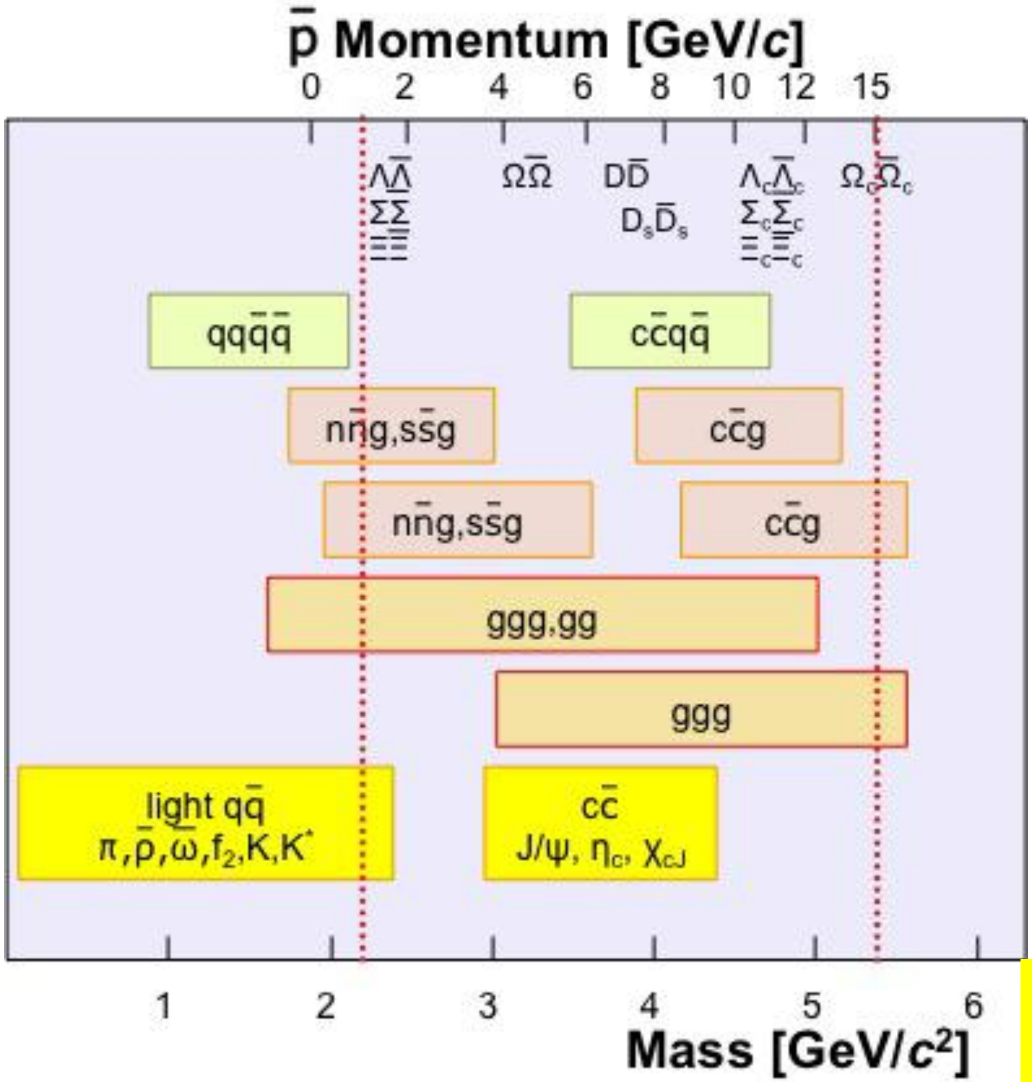
$\Delta p/p=5x10^{-4}$



Current Baseline FAIR Schedule

From December 2015

PANDA exotic states: hybrids, gluonic excitations,…



Measuring of resonance width is crucially important for understanding its nature

$$X(3872) \quad J^{PG} = 1^{++}$$

seen by BarBa, CDF, D0, LHCb, BESIII

$$\bar{p}p \to X(3872) \to J/\Psi\, \pi^+ \pi^-$$

$$\Gamma_{exp} < 1.2\,\text{MeV}, \text{BR} > 0.026$$

Scan resonance excitation function with unprecedented precision !!

PANDA detector

- ❑ 100 KeV mass resolution by beam momentum scan
- ❑1% produced particle momentum resolution
- ❑ $2x10^{7}$ s^{-1} event rate capability
- ❑stand 10^{32} cm^{-2} s^{-1} inst. luminosity
- ❑nearly 4π acceptance, high detection efficiency
- ❑secondary vertex reconstruction for D, K^0_S, Λ ($c\tau$ = 317 μm for $D^{\pm}$)
- ❑PID (γ, e, μ, π, K, p)
- ❑photon detection 1 MeV – 10 GeV

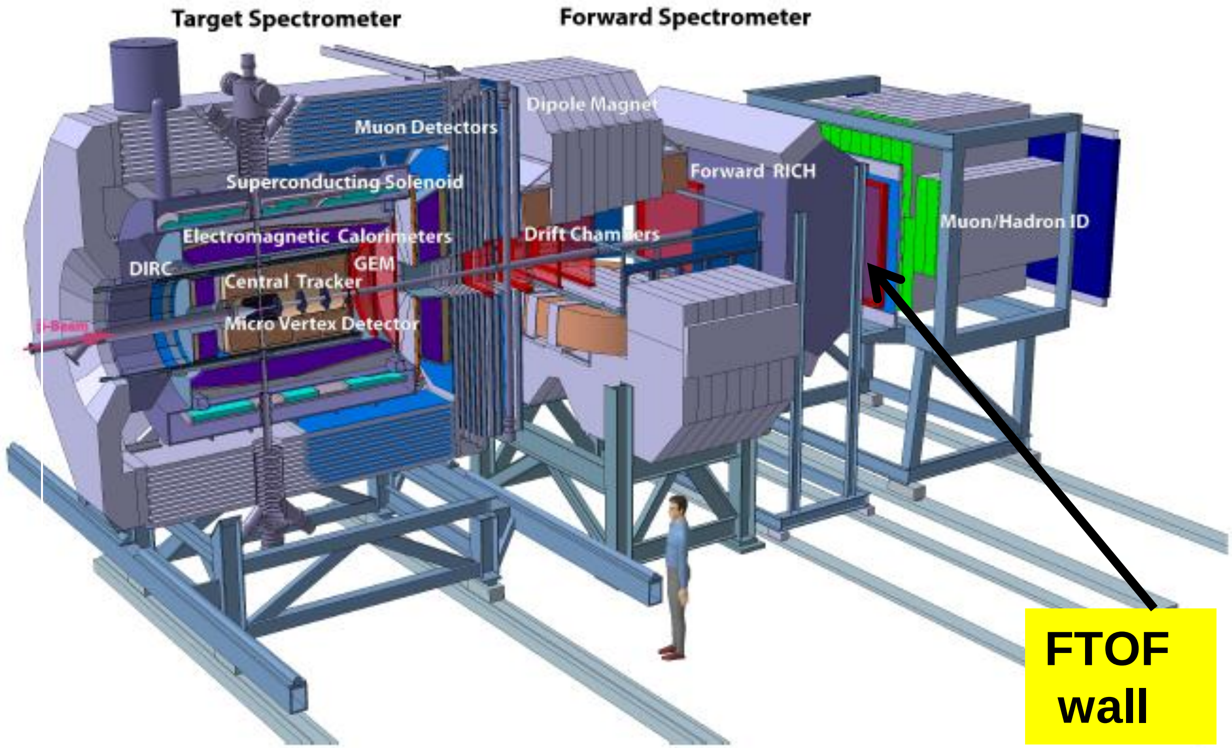


Figure 2.1: Artistic view of the $\overline{\text{P}}$ANDA Detector

Targets: pellet H(D) target

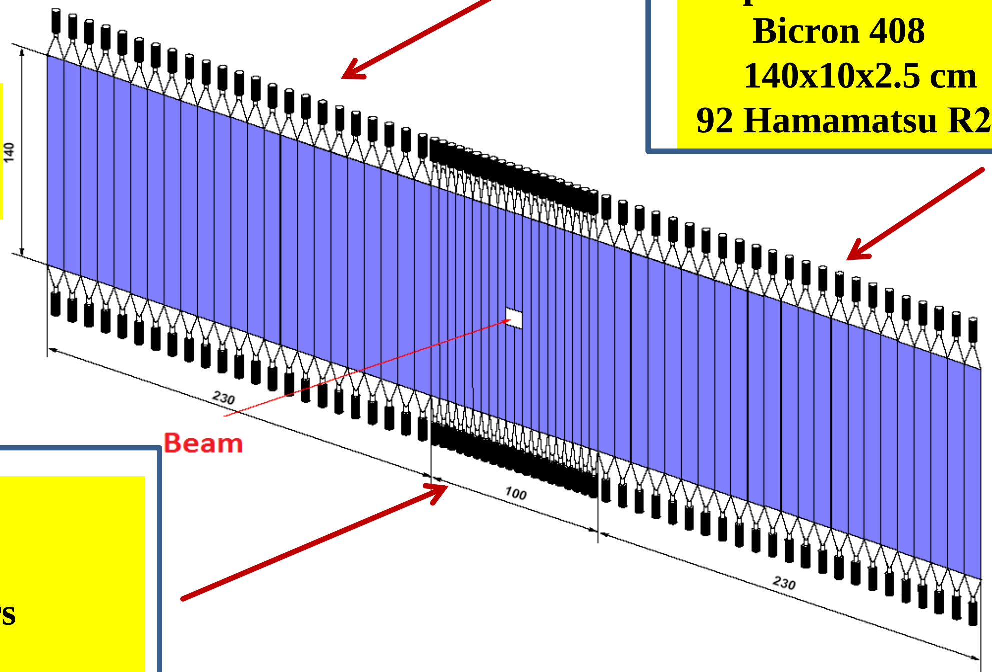
frozen drops of 25-40µm, controlled position;
Target station for hyper-nucleus physics;
Wire targets for pbar-A interaction

Total integrated luminosity about 1.5 fb-1/year

Forward TOF wall configuration

February 2014   470 k€

positioned at 7.5 m from IP



Side parts
2x23 counters
46 plastic scintillators
Bicron 408
140x10x2.5 cm
92 Hamamatsu R2083 (2”)

Central part
20 counters
20 plastic scintillators
Bicron 408
140x5x2.5 cm
40 Hamamatsu R4998 (1”)

Sensitive area
width = 5600 cm
height= 1400 cm

Bicron 408
(recommended for large TOF counters)

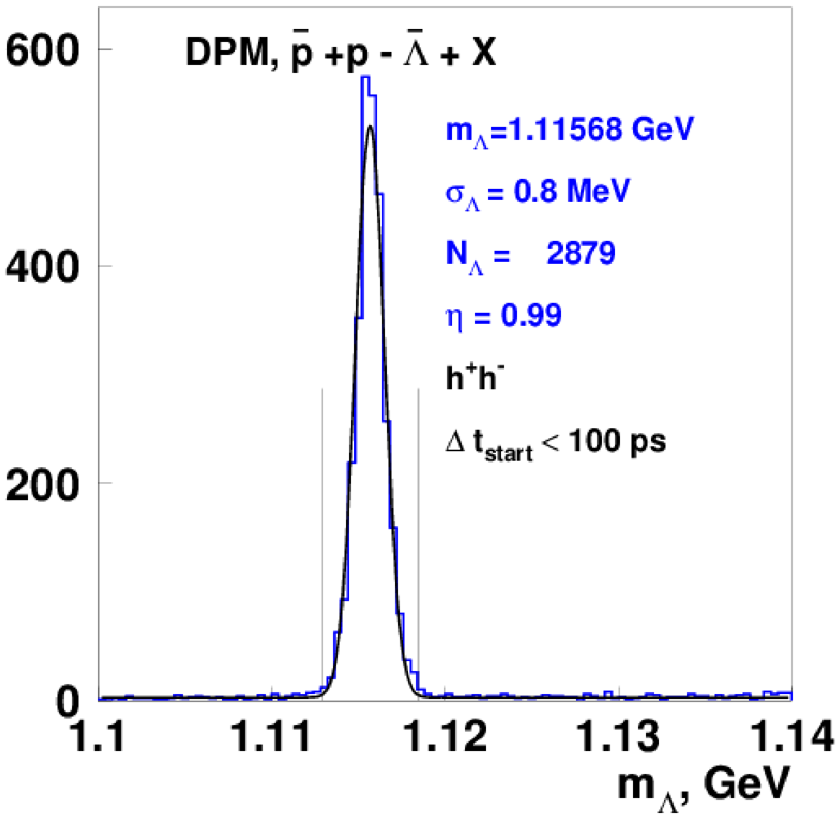
Rise time	0.9 ns
Decay time	2.1 ns
1/e light attenuation length	210cm

Fast PMTs *(hamamtsu)*
R4998 1” (R9800) , R2083 2” (R9779)

Anode pulse rise time	0.7-1.8ns
TTS	250-370ps (FWHM)
Gain	$1.1\text{-}5.7 \times 10^6$

$\bar{\Lambda}$bar detection with FTOF

$$\bar{p} + p \rightarrow \bar{\Lambda} + X \quad \bar{\Lambda} \rightarrow \bar{p} + \pi^{+}$$



$0.72\times10^{6}\ \bar{p}p$ interactions,10 GeV

$\bar{\Lambda}$ detected with high efficiency (20%) at weak selection criteria

$N_{\Lambda} / N_{\bar{\Lambda}} \simeq 1/40$

Λ events also well detected

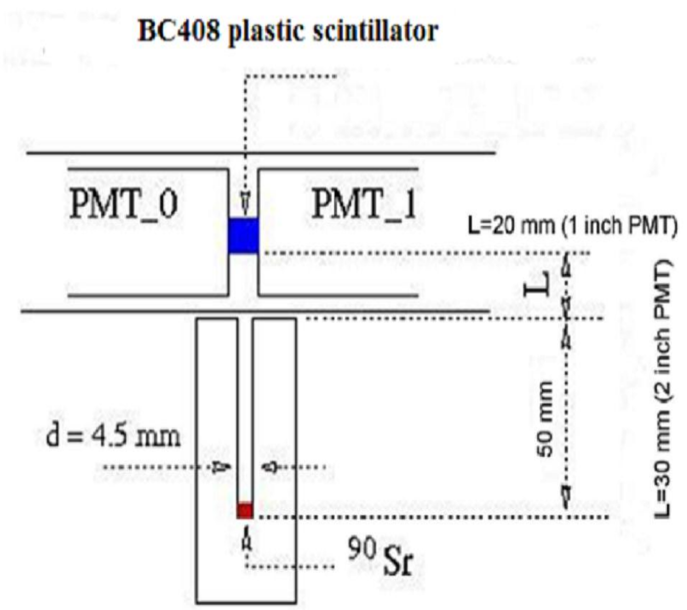
@$10^{6}s^{-1}$target interactions ($L \approx 10^{31}s^{-1}cm^{-2}$)

$N_{\bar{\Lambda}} = 4\times10^{3}\,s^{-1}$!!

can be used to tag exclusive reactions, e.g.,

$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ production 25×10^{6} events / 7days

Prototyping at test station



After offline amplitude corrections

PMT_1	σ TDC_1 (ps)	σ PMT (ps)
R4998 (4998/4998)	72.	44.4
R9800 (4998/9800)	86.	64.6
R2083 (2083/2083)	72.6	44.9
R9779 (2083/9779)	64	56.5
XP2020 (2.5, 2.36kV)	82	52,3

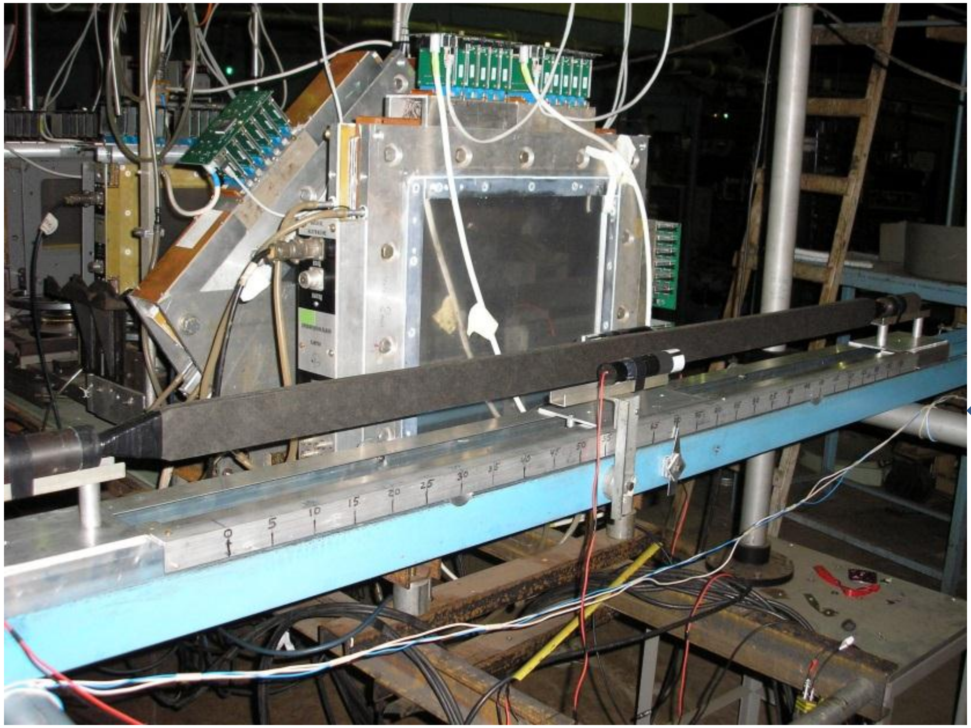
After corrections for electronics and track walk

2 MeV energy deposition, $2x10^4$ photons
Track walk in scintillator $\sigma_{tr.w.}$ = 15 ps
Electronics contribution σ_{el} = 30 ps

Prototyping using proton beams

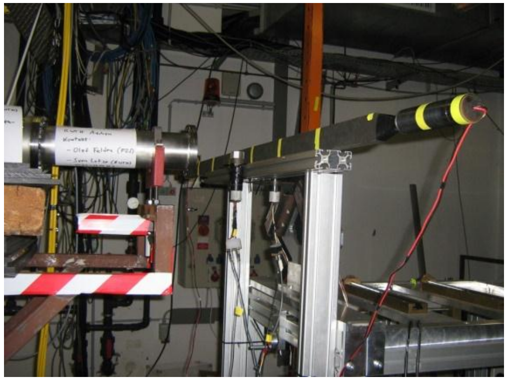
PNPI 1 GeV synchrocyclotron

740 and 920 Mev protons selected with magnetic spectrometer



COSY test beam in Juelich 2 GeV

MIP protons



Slab put horizontally
in spectrometer focal plane
at movable frame.
MWPCs provide hit position
with $\delta x \approx 1$ mm

Prototyping summary

- The time resolution of 60–65 ps was obtained for the scintillation counters recommended for prototypes for the FTOF wall.
- It has been experimentally shown that optimal thickness of the scintillation slabs is 2.5 cm (slab length is 140 cm, width is 50 or 100 cm).
- The time resolution of 50 ps was obtained for the slabs of 2.5 cm width. Practical application of such slabs however would result in increase of number of channels which may confront the detector cost limitation.
- A precise measurement of the hit position seems crucial for time resolution on the level of 60 ps. Without independent information on hit position, the time resolution of 80 ps has been measured. .
  - A satisfactory result was obtained for KETEK PM6660 (6x6 mm^2) samples at test station. A raw timing resolution of σ = 71 ps (per a SiPM sample) was directly measured , and after corrections it was obtained σ_{PM6660} = 66 ps.
  - A very tentative test of radiation hardness of SiPMs has been made in PNPI using not powered S0931-50p SiPM sample exposed to 1 GeV proton beam. It was found that the radiation dose equivalent to 0.45 x 10^{11} protons having passed through the active area of the sample is crucial for its operation capabilities.

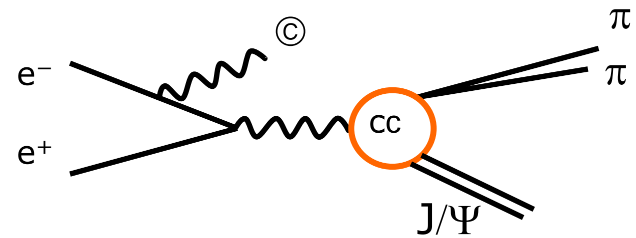
Conclusion

- MC simulation demonstrates important functions of FTOF wall:
  - PID of forward emitted particles with momenta below 3-4 GeV
  - determination of event start time stamp
  - possibility to use Λbar for detector calibration
- Maximum count rate in central part of FTOF wall at L $=10^{32}$ cm^{-2} s^{-1} is below $3x10^6$ s^{-1} . Background related to e^+e^- pairs production peaked at very low momenta is small.
- Prototyping is completed. Timing resolution of 60 ps is measured. The measurements were performed using 920 MeV protons selected by the magnetic spectrometer.
- Without hit position precise information, timing resolution of 80 ps has been obtained.

- TDR drafting has not yet been finished. It is planned to circulate within Collaboration in March.

Supporting slides

PANDA Physics



Charmonium Spectroscopy. $\bar{P}P \to \bar{C}C$

Measurement of masses and width of charmonium states with unprecedented precision of 100-200 KeV

Search for Gluonic Excitations. $\bar{P}P \to \bar{C}Cg$ (hybrids)

objects with exotic quantum numbers J^{PC}

X, Y, and Z (like) states, pure glue, multiquark states

Electromagnetic Processes $\bar{P}P \to e^-e^+, e^-e^+\gamma$

proton form factors in the time-like region

up to S=14 $(GeV/c)^2$

Hyperon biner reactions. Production cross section and mechanism, polarization

$\bar{P}P \to \bar{\Lambda}\Lambda, \Xi\Lambda, \bar{\Omega}\Omega, \bar{\Lambda}_C\Lambda_C, \ldots \bar{\Omega}_C\Omega_C$

Hypernuclei with more than one strange hadrons.

1^{--} states only !!

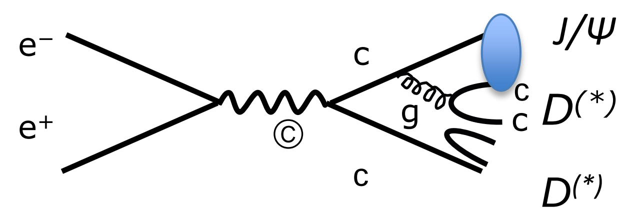
X(4008)? Belle

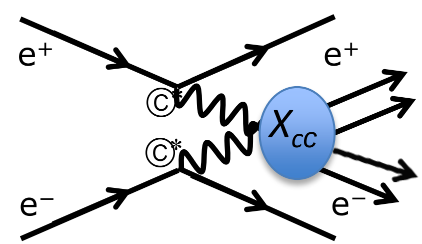
Y(4260) BaBar, Belle, Cleo

Y(4350) BaBar, Belle

Y(4660) Belle

BESIII





Competing with → LHC → e^+e^- colliders

TDR Schedule

Submission 2015:
- Forward Shashlyk: June 17

Shifted to early 2016:
- Luminosity Detector
- Forward Time of Flight
- Forward Tracking
  Caveat: Simulation!

Submission 2016/17:
- Barrel DIRC
- Hypernuclear Setup
- Pellet Target Addendum
- GEM Tracker
- SciTil / Barrel ToF
- Detector Controls
- DAQ and Computing
- Disc DIRC

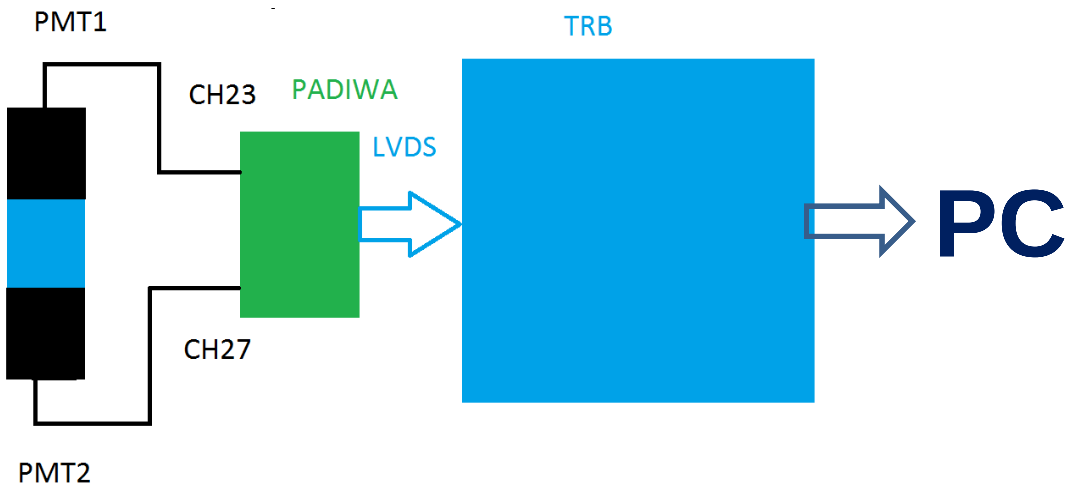
System	Submission *Expected*	M3 (Approval) *Expected*
Target Spectrometer EMC		08/08/2008
Barrel EMC		08/08/2008
Backward Endcap EMC		08/08/2008
Forward Endcap EMC		08/08/2008
Solenoid		05/21/2009
Dipole		05/21/2009
Micro Vertex Detector (MVD)		02/26/2013
Straw Tube Tracker (STT)		01/29/2013
Cluster Jet Target		08/28/2013
Muon System		09/22/2014
Forward Shashlyk Calorimeter	17/6/2015	*1/2016*
Luminosity Detector	*3/2016*	*9/2016*
Forward TOF	*3/2015*	*9/2016*
Forward Tracking	*3/2015*	*9/2016*
Barrel DIRC	*6/2016*	*12/2016*
Hypernuclear Setup	*6/2016*	*12/2016*
Pellet Target	*6/2016*	*12/2016*
Planar GEM Trackers	*9/2016*	*3/2017*
Barrel Time of Flight (TOF)	*9/2016*	*3/2017*
Controls	*6/2017*	*12/2017*
DAQ	*6/2017*	*12/2017*
Endcap Disc DIRC	*6/2017*	*12/2017*
Computing	*9/2017*	*3/2018*
Silicon Lambda Disks	tba	tba
Forward RICH	tba	tba

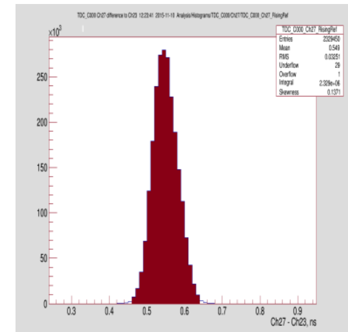
tba: to be announced

Status 3/11/2015

For the items "Interaction Region", "Supports" and "Supplies" no TDRs are planned, only specification documents.

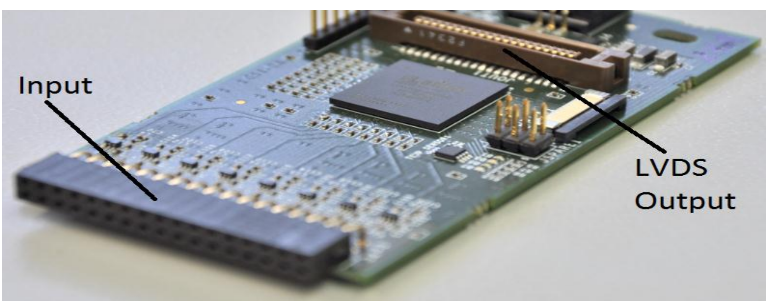
Application of TRB-3 readout underway in PNPI





generator

mV	Peak posit.	σ ps
100	540	31.5
75	530	31.5
50	520	33.
40	520	34.
30	520	36.
25	510	36.



Needs more expertise

Forward TOF wall functions

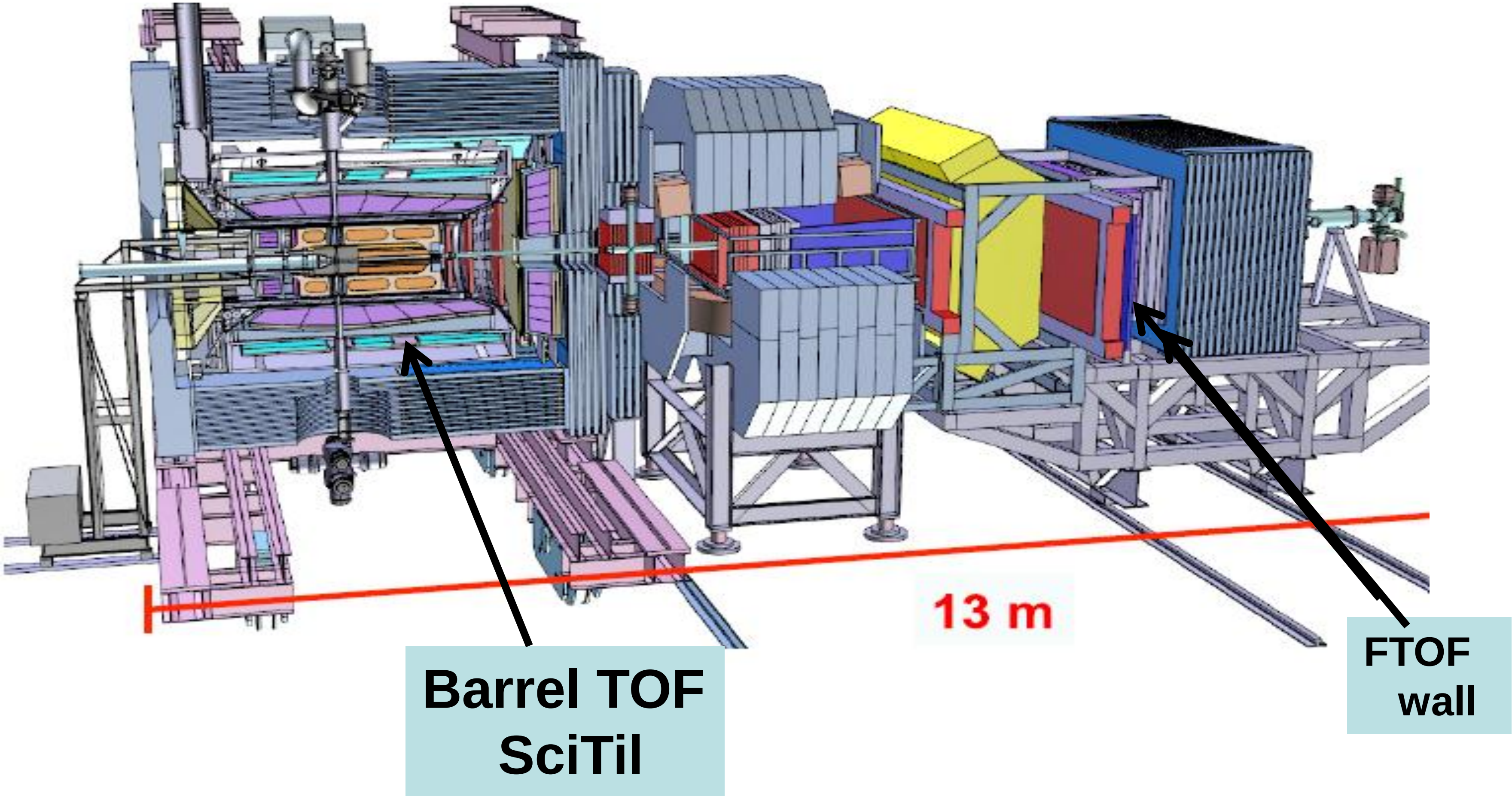
- **PID of forward emitted particles** using   time-of-flight information:
  protons   < 4.5 GeV, kaons < 3.5 GeV, pions < 3. GeV
  where forward RICH is not effective
  time resolution of 50-100 ps required
  FS   momentum resolution 0.01

- **Event start stamp reference time**

- **Possibility to use Λbar for detector calibration**

- Can be used as start for determination of the drift time in DCs

PANDA Time-of-Flight detectors



Open questions

- **MC simulation.**

  - time dependent event reconstruction analysis **?? lack of manpower**

- **Related to FSTT.**
  - FS momentum resolution Δp/p must be 1%
  -vertical hit position uncertainty ? Δy=1 mm corresponds 5.3 ps (BC-408)
  expected at present design FSTT Δy=5-10 mm → up to Δ(tof) ≈ 60 ps
  -uncertainty in track reconstruction? $\Delta L_{track} / L_{track} = 0.1\% \rightarrow \Delta(tof) \approx 30$ **ps**

- **FTOF wall position behind RICH.**
  - RICH width is smaller than sensitive area of FTOF wall, deterioration of track information at FTOF wall side slabs
- **FTOF wall width is 5.6 m while FSTT last station width is 3.9 m, thus side parts of FTOF wall are out of FSTT acceptance.**
  reduce FTOF wall width ??

- **Hardware:**
  - finalize TRB-3 readout tests
  - definitive decision on Hamamatsu PMs (type, housing, divider, price,.).
  - on-line laser calibration system (??)
  - HV-power supply: commercial or PNPI production HVDS3200

Count rates of FTOF wall and $e^+ e^-$ background at 5 GeV (3.5 MHz)

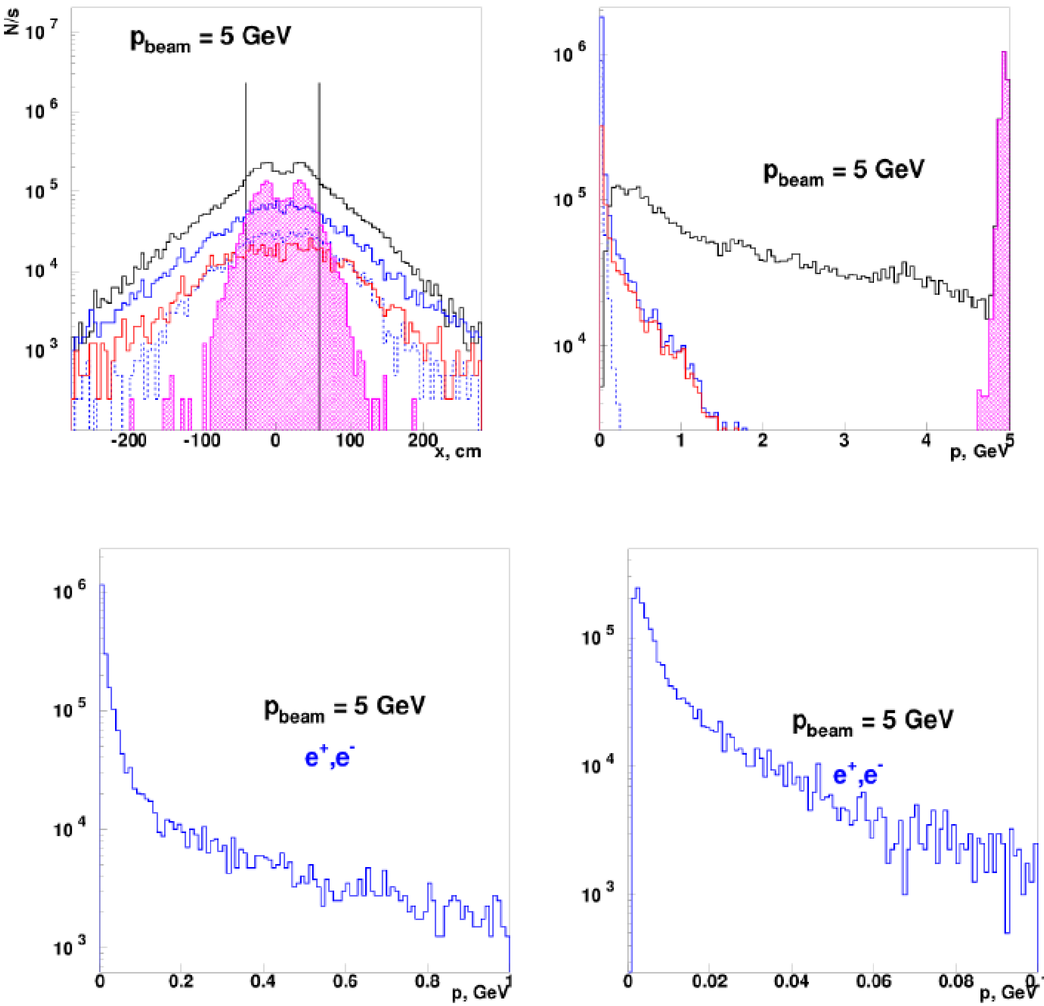
All

Pbar forward peak

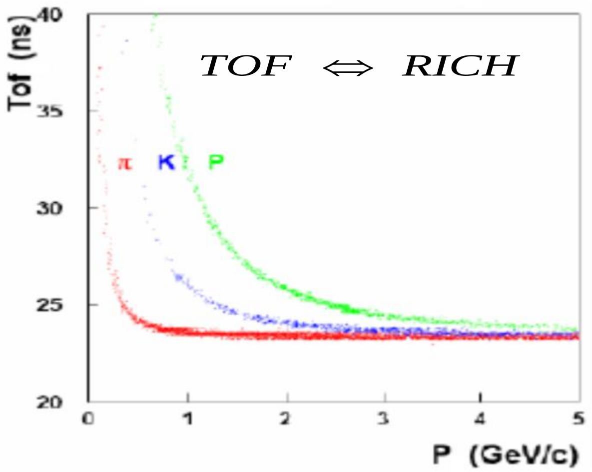
$e^+ e^-$ all

$e^+ e^-$ produced in vacuum pipe

$e^+ e^-$ backward scattering from EMC (dashed)



FTOF wall hadron ID

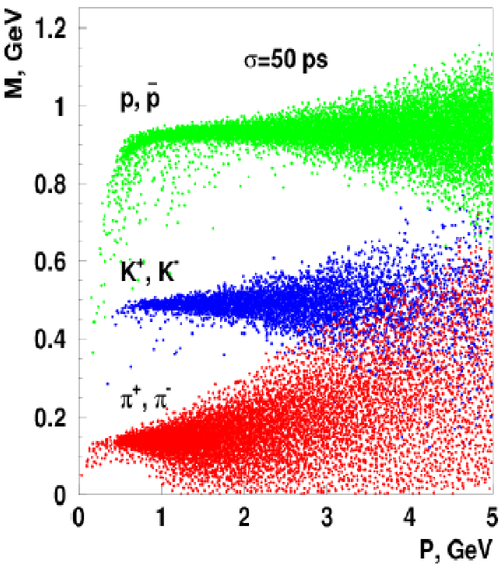


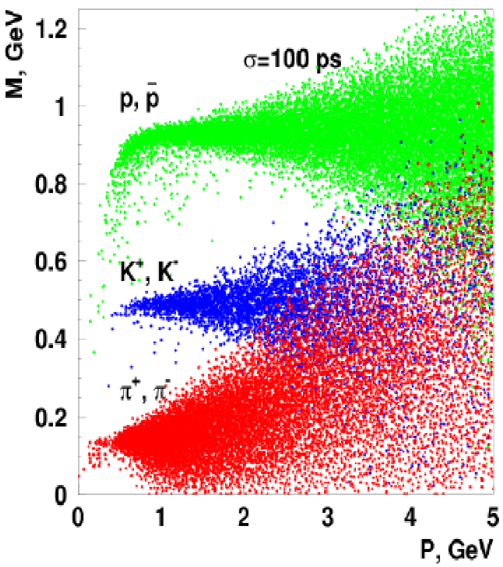
TOF resolution σ_{TOF} = 50 or 100 ps

FS momentum resolution Δp/p=0.01

$$m = p\sqrt{\frac{t^2}{t_c^2} - 1}\,, \qquad t_c = L_{track}/c$$

$$\frac{\delta m}{m} = \sqrt{\left(\frac{\delta p}{p}\right)^2 + \gamma^4\left(\frac{\sigma_{TOF}}{t}\right)^2}$$



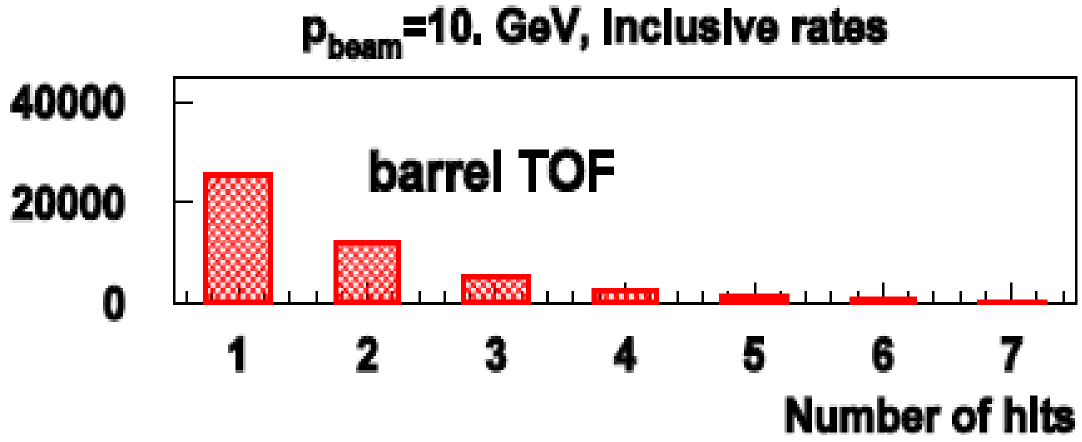


Track multiplicity/event in TOF detectors at 10 GeV

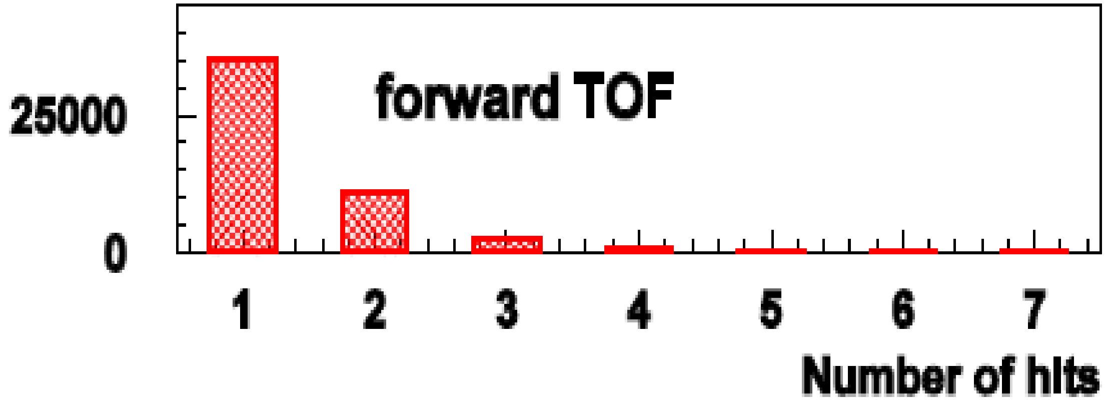
No dedicated start counter

coincidence efficiency

SciTil ≈ 50%



FTOF wall ≈ 31%

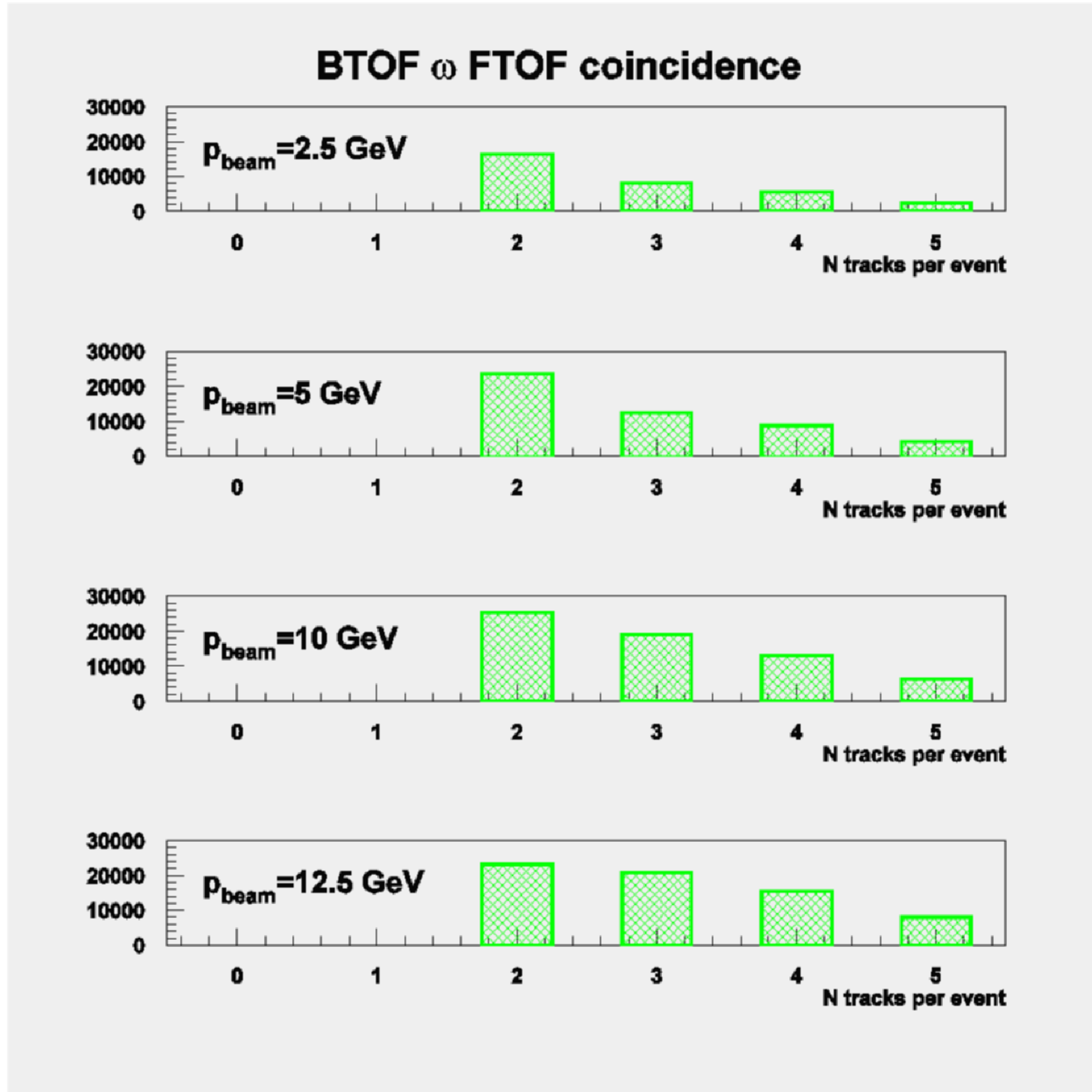


FTOF wall and barrel TOF interplay

No dedicated start counter

FTOF•BTOF coincidence probabilities

2.5 GeV	23.6%
5.GeV	35.1%
10.GeV	45.4%
12.5GeV	48.3%



Count rates of FTOF wall and $e^+ e^-$ background at 10 GeV (3.5 MHz)

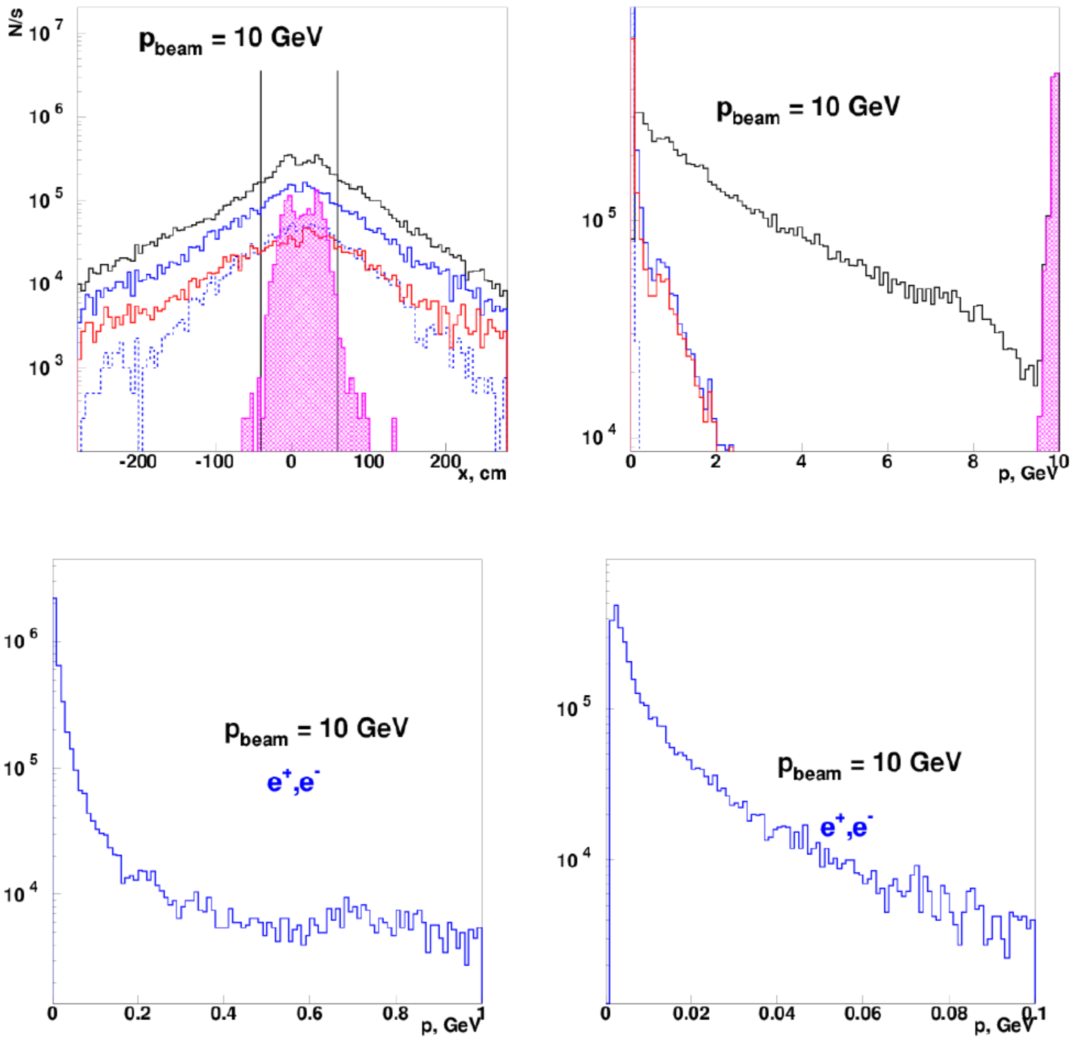
All

Pbar forward peak

$e^+ e^-$ all

$e^+ e^-$ produced in vacuum pipe

$e^+ e^-$ backward scattering from EMC (dashed)



Detection Efficiency of FTOF wall

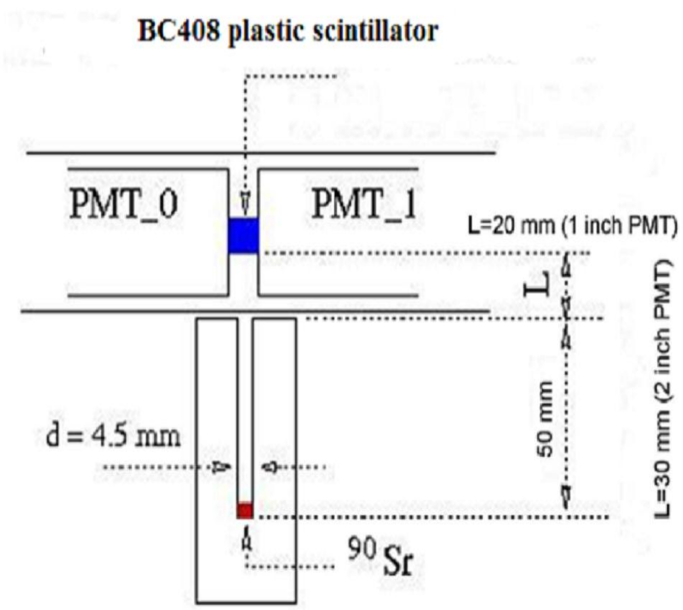
$0.72\times10^6\ \bar{p}p$ interactions @10 GeV, $\frac{\sigma(p)}{p}=0.01,\ \sigma(TOF)=50\,ps$

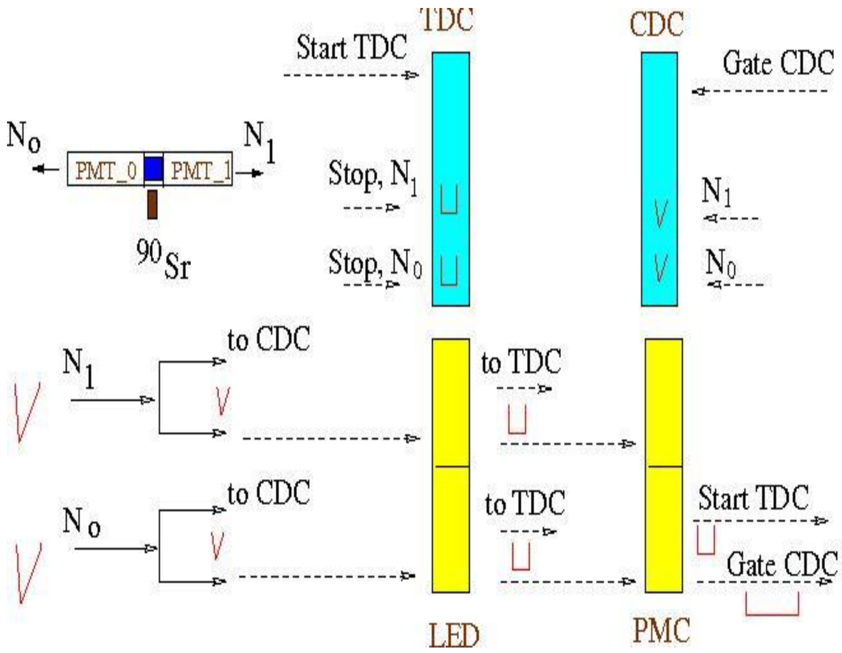
acceptance of FS ±10 deg. hor. ±5 deg. ver. $\rightarrow\ \Omega_{FS}=0.09\,sr$

	Generated by DPM	Detected by FTOF wall	detection efficiency
π^-	880346	172188	0.195
π^+	877255	150440	0,171
K^-	30179	5820	0.192
K^+	26811	2863	0.107
$\bar{p}$	453293	202174	0.446
p	398323	51241	0.129
$\bar{\Lambda}\rightarrow\bar{p}+\pi^+$	19874	3840	0.193
$\Lambda\rightarrow p+\pi^-$	19518	≈100	$\approx5\cdot10^{-3}$

Both proton and pion detected with FTOF

Prototyping. Test stand layout and electronics



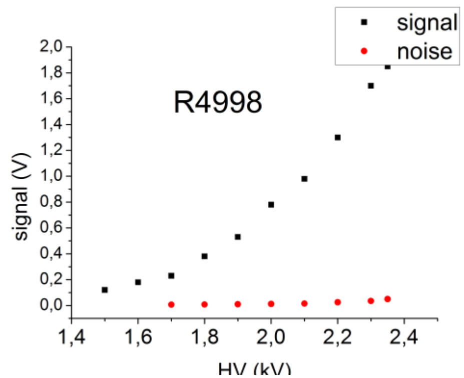


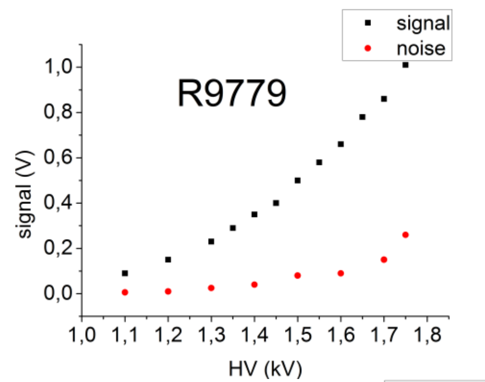
Measured are TDC_1, TDC_0, QDC_1, QDC_0

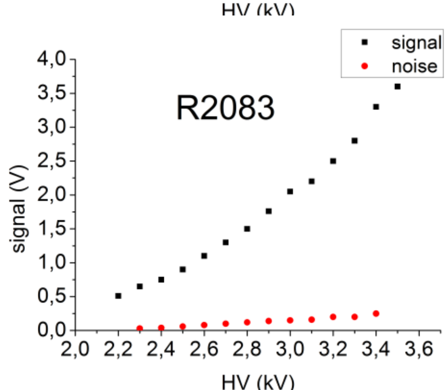
2 MeV energy deposition, 2x10^4 photons
Track walk in scintillator $\sigma_{tr.w.}$ = 15 ps
Electronics contribution σ_{el} = 30 ps

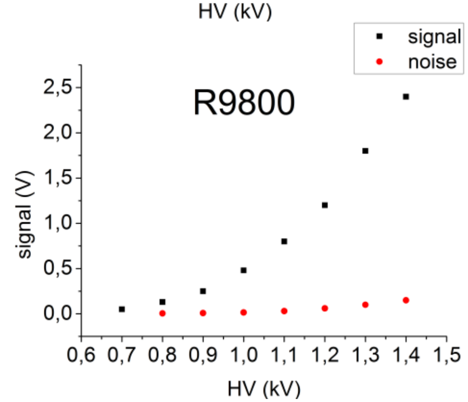
PMT characteristics

PMT	Photocathode diameter (mm)	Anode pulse rise time (ns)	Electron transition time (ns)	Transition time spread (ps)	Gain / 10^6	Typical voltage (V)
R4998	25 (1 inch)	0.7	10	160	5.7	2250
R9800	25 (1 inch)	1.	11	270	1.1	1300
R2083	51 (2 inch)	0.7	16	370	2.5	3000
R9779	51 (2 inch)	1.8	20	250	0.5	1500
XP2020	51 (2 inch)	1.6	28	??	30	2000



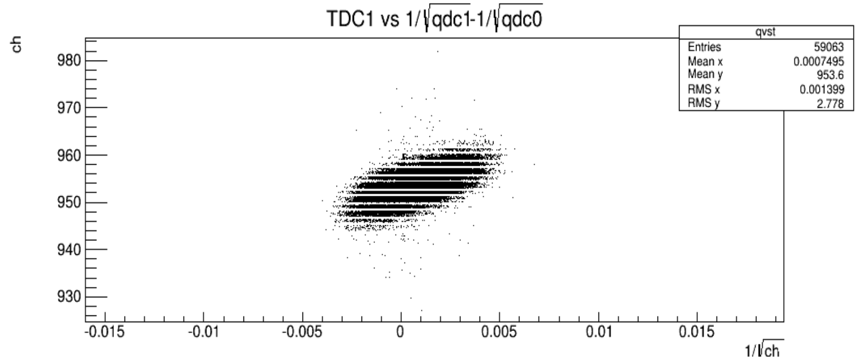






Test station results

After offline amplitude corrections

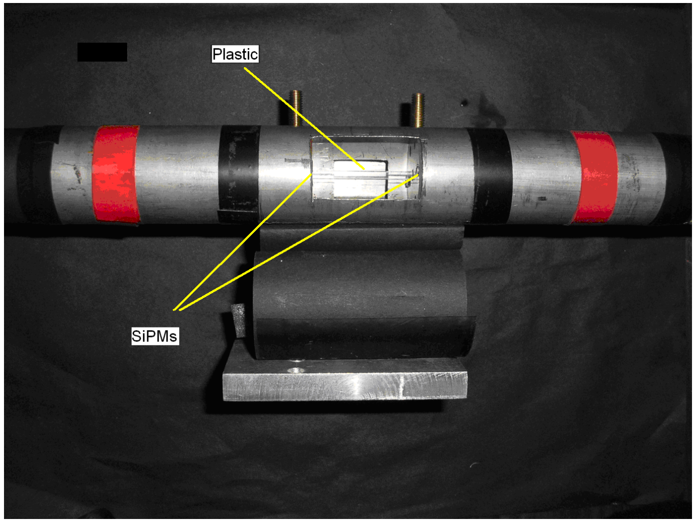


$$\frac{1}{\sqrt{Q_i}} - \frac{1}{\sqrt{Q_k}}$$

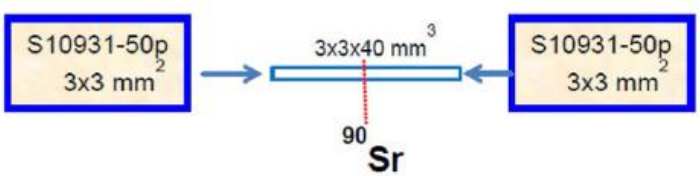
PMT_1	σ_{TDC_1} (ps)	σ_{PMT} (ps)
R4998 (4998/4998)	72.	44.4
R9800 (4998/9800)	86.	64.6
R2083 (2083/2083)	72.6	44.9
R9779 (2083/9779)	64	56.5
XP2020 (2.5, 2.36kV)	82	52,3

After corrections for electronics and track walk

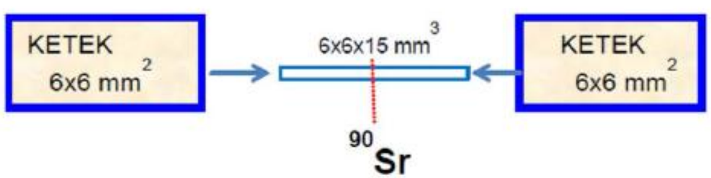
SiPM timing tests



Variant A



Variant B mm



Amplitude correction $$\Delta t = \Delta t_0 - a\left(\frac{1}{\sqrt{q_1}} - \frac{1}{\sqrt{q_2}}\right) - b$$

variant A S10931

after corrections **σ =103 ps**

variant B KETEK 6660

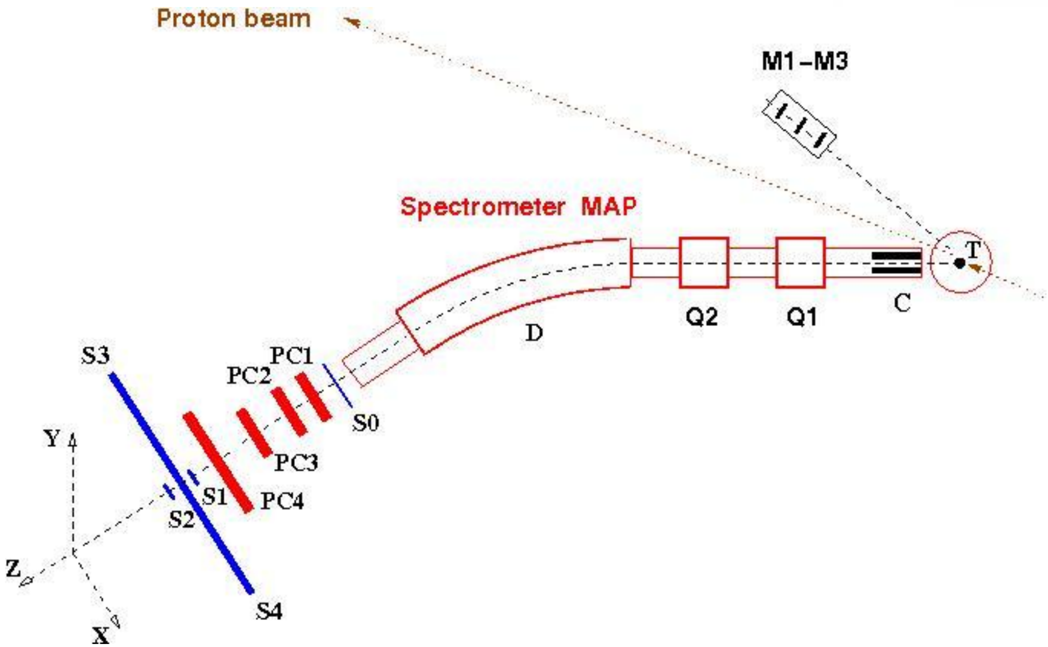
after corrections **σ =65 ps**

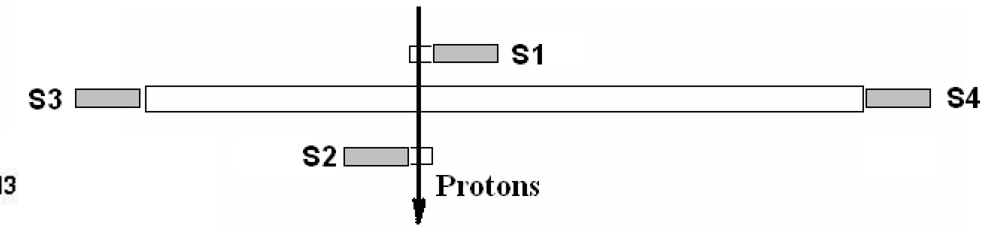
Table 4. Main parameters and time resolution of KETEK 6660.

Supply voltage (V)	Signal amplitude (mV)	Noise amplitude (mV)	Current without ^{90}Sr (mkA)	Current with ^{90}Sr (mkA)	σ_{TDC_1} (ps)	$\frac{\sigma_{TDC\_1}}{\sqrt{2}}$ (ps)	σ_{KETEK} (ps)
26.35	20÷30	~ 0.3	7.5	9	120	84.8	81.1
26.85	70÷90	~ 0.5	11	13	100	70.7	66.1

Beam tests at 1 GeV PNPI SC

1 GeV proton beam





S_3S_4 scintillation slabs B408:
length 100, 140cm
width 2.5, 5,10cm
thickness 1.5, 2.5cm
S_1S_2 1x1x1cm
R4998, R2083, Electron187

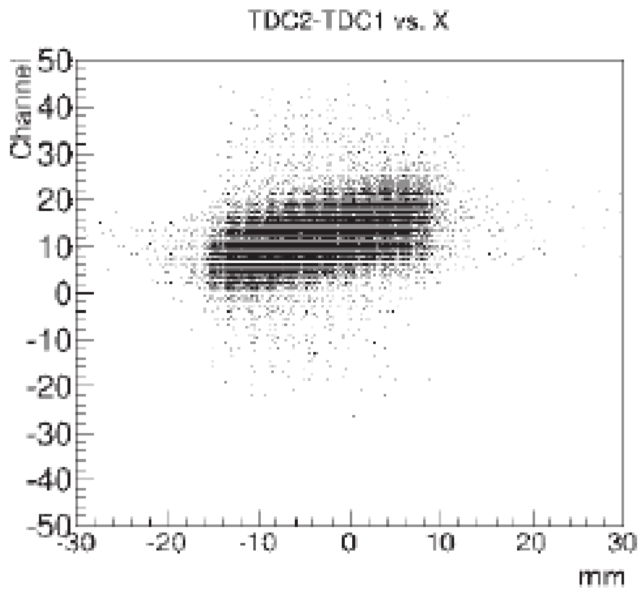
Scattered protons up to 10^6 / cm^2

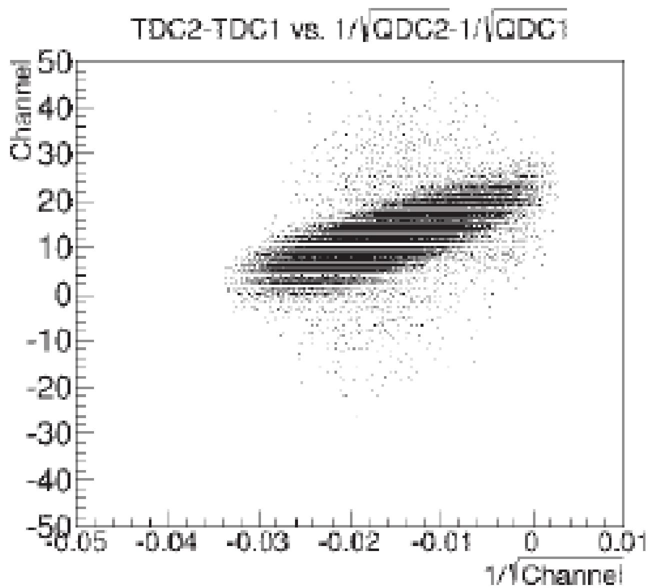
Proton energy E_p=740 and 920MeV, $\sigma(E_p)$ about 0.5%

B408 thickness 2.5cm
Energy deposition ≈ 5MeV

Scintillation Efficiency several 10^4 photons/MeV

Off-line time resolution





Hit position and pulse amplitude corrections

on event basis calculated are

$$\tau_{13}, \tau_{14}, \tau_{23}, \tau_{24}, \tau_{34}$$

$$\tau_{nk} = t_n - t_k - a\left(\frac{1}{\sqrt{q_n}} - \frac{1}{\sqrt{q_k}}\right) - bx - c,$$

x hit position along the scintillation slab,

t_n, t_k time stamp measured with TDC,

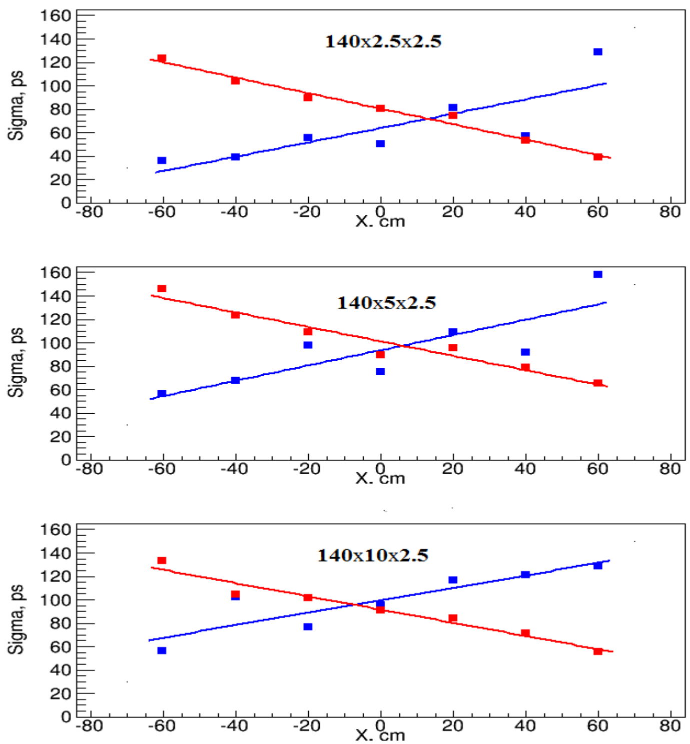
q_n, q_k measured with QDC,

a,b,c free parameters to minimize τ_{nk}

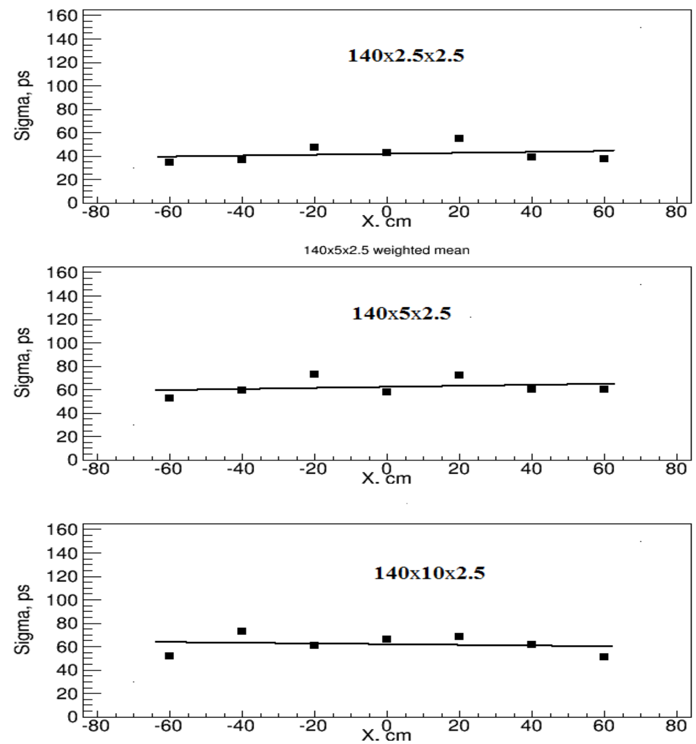
timing resolution is σ of

(corrected) τ_{nk} distribution.

Timing resolution results from 1 GeV PNPI SC



σ_{TOF} vs hit position



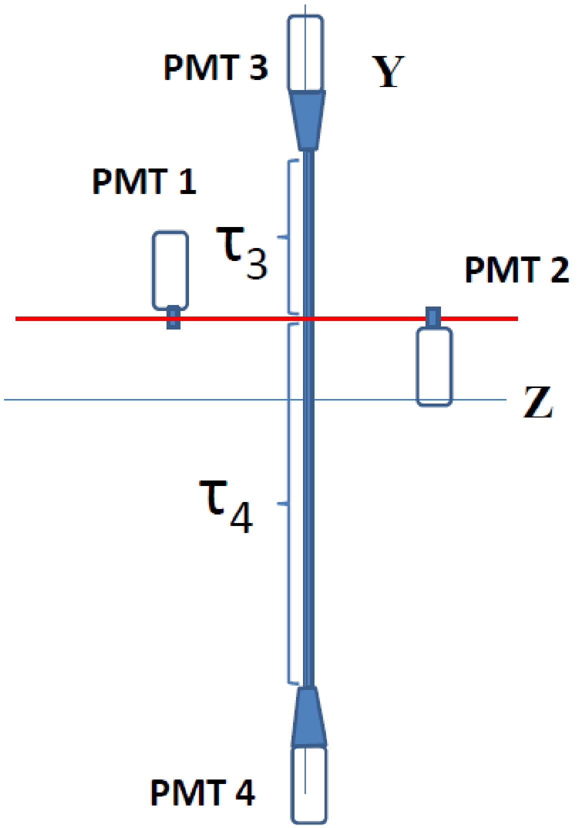
σ_{TOF} weighted means

weighted mean

$$\frac{1}{\sigma^2_{TOF}} = \frac{1}{\sigma^2_{TDC3}} + \frac{1}{\sigma^2_{TDC4}}$$

in the middle of slab $\sigma_{TOF} \approx \frac{\sigma_{TDC3}}{\sqrt{2}} \approx \frac{\sigma_{TDC4}}{\sqrt{2}}$

Time resolution without hit position correction



$\tau_3 + \tau_4 = \tau$ constant

light propagation

time through slab

$$T_3 = T_1 + t + \tau_3 \quad T_4 = T_1 + t + \tau_4$$

$$(T_3 - T_1) + (T_4 - T_1) = T_{31} + T_{41} = 2t + \tau$$

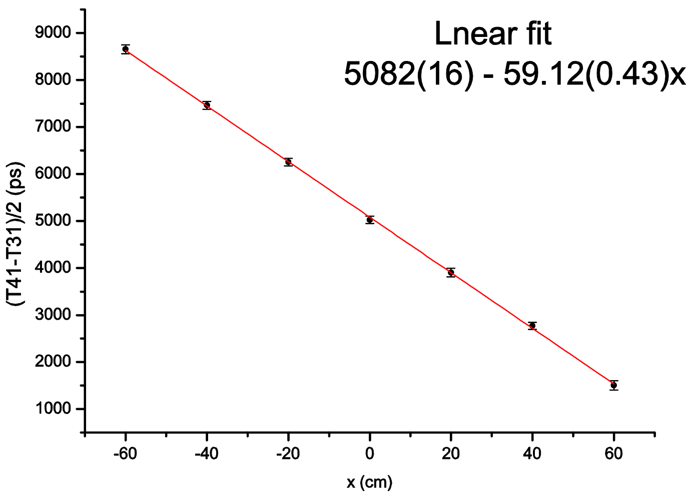
sensitive to measured time, not sensitive to hit position

$$(T_3 - T_1) - (T_4 - T_1) = T_3 - T_4 + \tau - 2\tau_4$$

sensitive to hit position, not sensitive to measured time

Time and hit position measurements using TDC information only

x	$(T_{41}-T_{31})/2$	σ_{431}^-	$(T_{41}+T_{31})/2$	σ_{431}^+	$(T_{42}-T_{32})/2$	σ_{432}^-	$(T_{42}+T_{32})/2$	σ_{432}^+
cm	ps	**ps**	ps	**ps**	ps	**ps**	ps	**ps**
60	1504	**99**	11950	**148,5**	1503,5	**100,5**	11580	**120,5**
40	2770,5	**74**	11865	**138,5**	2770,5	**74,5**	11510	**102**
20	3904	**90,5**	11975	**145,5**	3904	**90,5**	11630	**114**
0	5025	**76**	11920	**136,5**	5025	**75,5**	11580	**103,5**
-20	6255	**81,5**	11940	**150**	6255	**82,5**	11630	**115,5**
-40	7460	**84**	11895	**143,5**	6890	**85**	11560	**112,5**
-60	8655	**93,5**	11945	**148,5**	8655	**93,5**	11600	**121**



$$\tau = 59.12\,\text{ps}/\text{cm} \times 140\,\text{cm} = 8276.8\,\text{ps}$$

v_{BC408} = 1/59.12 = 0.17mm/ps
speed of light in BC408 = 0.19 mm/ps

hit position resolution
80ps x 0.17mm/ps = 13.6 mm

Summary table of beam tests

Off line time resolutions obtained as weighted means with amplitude and hit position correction using 920 MeV protons

scintillation slab dimensions (cm)	PMT	timing resolution σ (ps)	comment
140 × 10 × 2.5	**Hamamatsu R2083 (both ends)**	**63**	**Recommended for a prototype for the FTOF wall.**
140 × 5 × 2.5	**Hamamatsu R4998 (both ends)**	**60**	**Recommended for a prototype for the FTOF wall**
140 × 2.5 × 2.5	Hamamatsu R4998 (both ends)	43	a variant of a prototype with smaller stintillator width
140× 5 × 1.5	Hamamatsu R4998 (both ends)	≈ 88	projected originally for the FTOF wall
140 × 2.5 × 2.5	Electron PMT 187 (both ends)	78	magnetic field protected,
1×1×1	Electron PMT 187, Hamamatsu R4998	49	“net” timing resolution of one PMT

Count rates in frame of DPG

Number of events selected from 100 generated $\bar{p}p$ *collisions chosen arbitrarily, at 10 GeV*

$\bar{p}p \to \bar{p}p$	24	$\bar{p}p \to \bar{p}p\pi^0$	5
$\bar{p}p \to \bar{n}n\pi^0$	3	$\bar{p}p \to \bar{p}n\pi^+$	3
$\bar{p}p \to \bar{p}p\pi^+\pi^-$	2	$\bar{p}p \to \bar{n}p\pi^0\pi^-$	2
$\bar{p}p \to \bar{p}n\pi^+\pi^0$	2	$\bar{p}p \to \bar{p}p\pi^0\pi^+\pi^-$	9
$\bar{p}p \to \bar{n}p\pi^0\pi^+\pi^-\pi^-$	4	$\bar{p}p \to \bar{p}p\pi^0\pi^+\pi^-\pi^+\pi^-$	4
$\bar{p}p \to \bar{\Lambda}n\bar{K}^0\pi^0\pi^+\pi^-$	1		

Hadron count rate by TOF wall at 0.35×10^7/s interactions in target

$\bar{p}$ beam momentum, GeV/*c*	Pion rate, 1/s	Kaon rate, 1/s	Proton rate, 1/s	Antiproton rate, 1/s
2	3.9×10^5	2×10^3	1.2×10^4	1.07×10^6
5	6×10^5	7.8×10^3	3.8×10^4	9.5×10^5
15	9.6×10^5	4.7×10^4	3.2×10^4	8.2×10^5

High rate of π^0

Bgr expected from

$\pi \to 2\gamma$ $\gamma \to e^+ e^-$

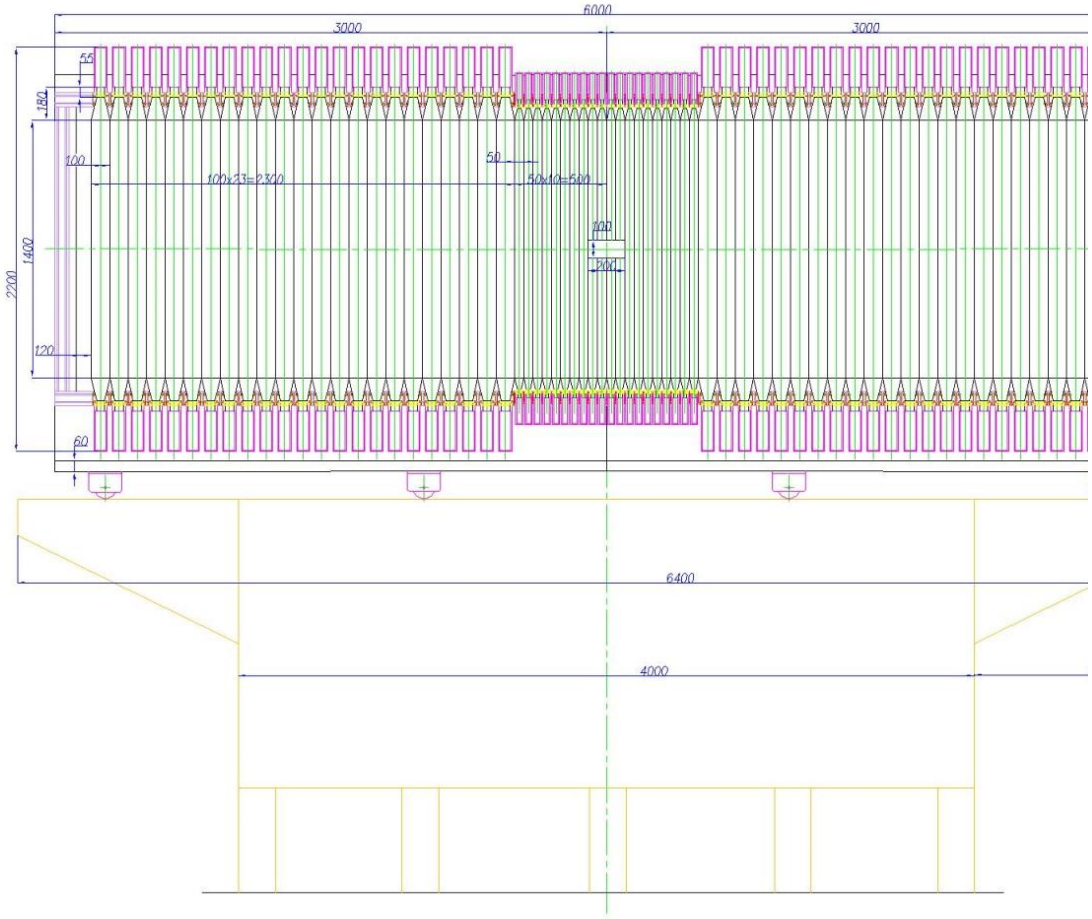
Cost estimation update

FTOF wall

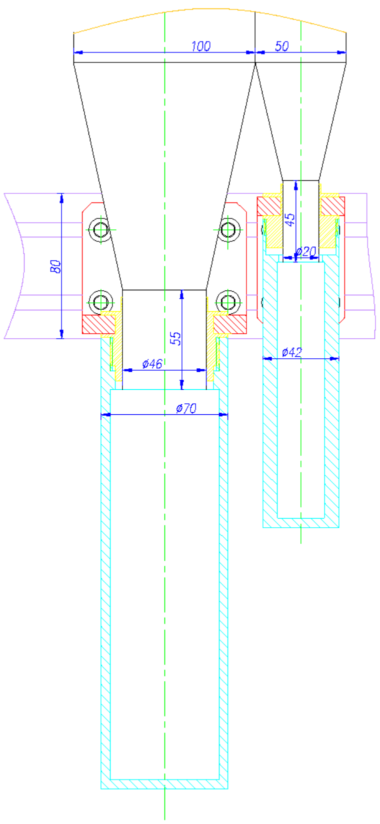
Plastic scintillators	
B408 20u.140x5x2.5cm+46u.140x10x2.5cm	40 k€
PMTs 1” 760 € 40u. +5u.(spare)	42
PMTs, 2” 1270 € 92u.+20u.(spare)	155
FEE+DAQ	35
HV power supply	22
Monitoring/calibration system	25
Supporting structure , mechanical items	75
Test stand for mass production	35
Transportation, custom expenses	42
……………………………………………………………………………	
	471 k€

From RRB February 2014 470 k€

FTOF wall mechanics.



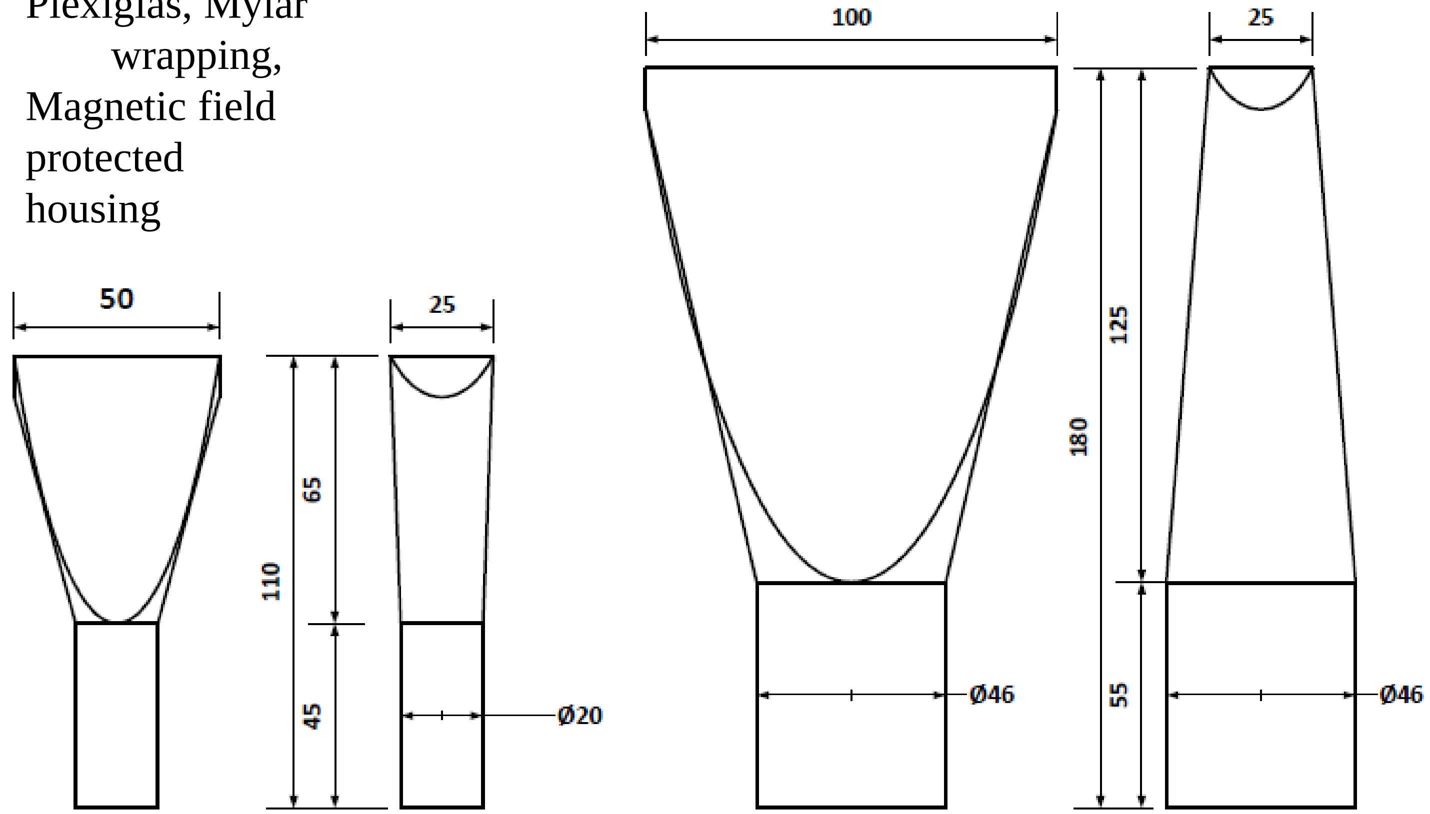
FTOF wall front view



Scintillation counter mechanical components

LIGHT GUIDES FOR 1” AND 2” PMTs

Plexiglas, Mylar wrapping,
Magnetic field protected housing

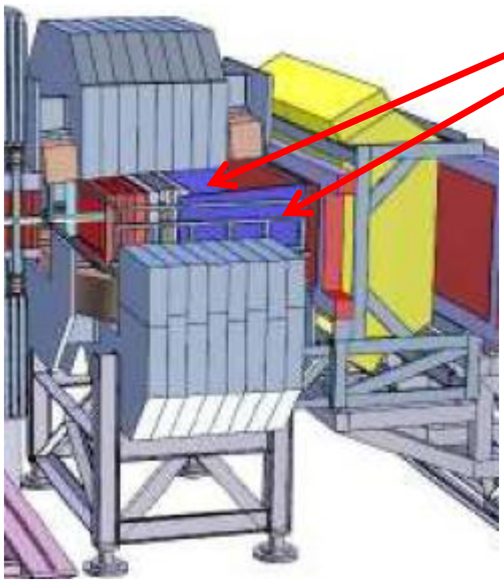


FSTT impact on FTOF

Tracking station	$z_{min} - z_{max}$ [mm]	Active area w [mm]	h [mm]	Number of modules	Number of straw tubes
1	2954-3104	1338	640	4x10=40	4x288=1152
2	3274-3424	1338	640	4x10=40	4x288=1152
3	3945-4245	1782	690	4x12=48	4x384=1536
4	4385-4685	2105	767	4x14=56	4x448=1792
5	6075-6225	3923	1200	4x27=108	4x824=3296
6	6395-6545	3923	1200	4x27=108	4x824=3296

Table 1.1: Positions, width and height of active area, number of modules and number of straw tubes in the Forward Tracker stations. In the second column z-coordinate of the first and forth double layers are given. The indicated width and height of active area corresponds to dimensions of the first double layer with vertical straws in individual tracking stations.

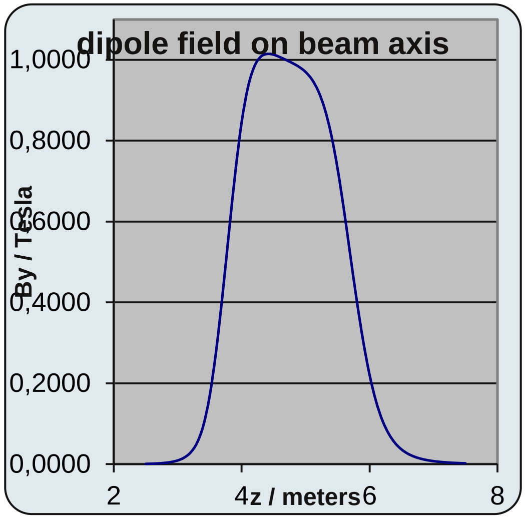
Dipole TOF positioned inside the dipole magnet gap as planned for TDR



Projected 2x10 scintillation slabs 80÷100x10x2.5cm readout from each end with Electron PMT 187

Diameter	30mm
Photocathode	20mm
Anode pulse rise time	1.4ns
TTS	≈500ps
Gain	$5x10^5$
W.m. emission	380nm
	(80% at 420nm)
HV	1800v

tested in magnetic field up to 0.5T



Alternative solution SiPMs provided timing resolution better than 100ps

radiation hardness??

Not sensitive to mag. F.(!)

SiPMs*(hamamatsu)*

S10931-50p, S10931-100p

active area	3x3mm
Pixels	3600
Gain	$7.5x10^5 – 2.4x10^6$
W.m. emission	440nm
TTS	0.5-0.6ns(FWHM)

TDR TABLE OF CONTENT