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 80ps resolution
- FTOF TDR
- Preassembly at COSY
- PNPI involvement in PANDA

С. Белостоцкий Сессия УС ОФВЭ 2014

PANDA Physics

$\bar{P}P \to \bar{C}C$

<u>Charmonium Spectroscopy.</u>

Measurement of masses and width of charmonium states with unprecedented precision of 100kV

$\bar{P}P \to \bar{C}Cg$ (hybrids)

<u>Search for Gluonic Excitations.</u>

objects with exotic quantum numbers J^{PC}

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

$\bar{P}P \to e^- e^+$

<u>Electromagnetic Processes</u>.

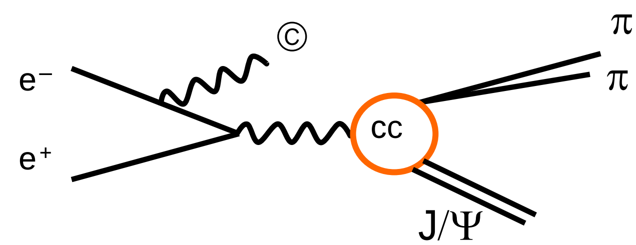
proton form factors in the time-like region up to $S=14\ (GeV/c)^2$

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

<u>Hyperon biner reactions.</u> Production cross section and mechanism, polarization

<u>Hypernuclei</u> with more than one strange hadrons.

e^+e^- colliders



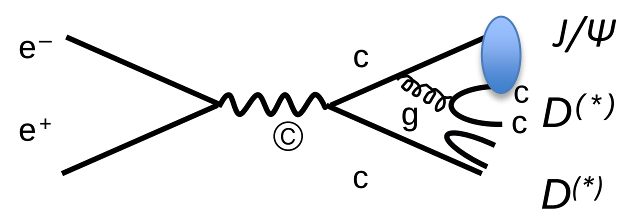
1^{--} states only !!

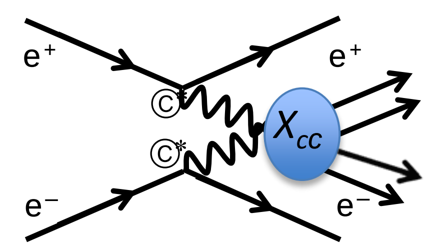
X(4008)? Belle

Y(4260) BaBar, Belle, Cleo

Y(4350) BaBar, Belle

Y(4660) Belle





Accelerator facilities and experiemnts @GSI

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

HESR

ANTI PROTONS

Momentum range

1.5 -8.9 Gev

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

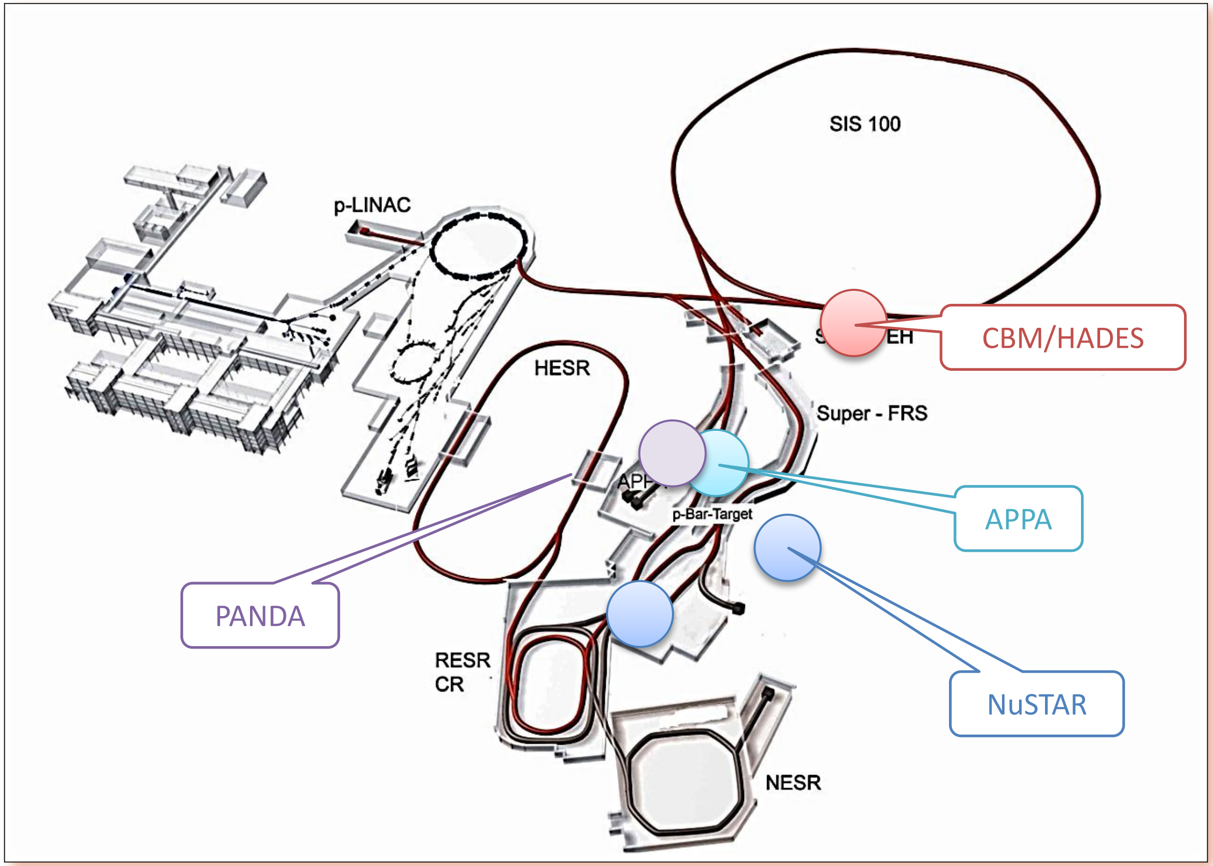
Δp/p=$5x10^{-5}$!!!

Momentum range

1.5 -15 GeV

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

Δp/p=$5x10^{-4}$



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

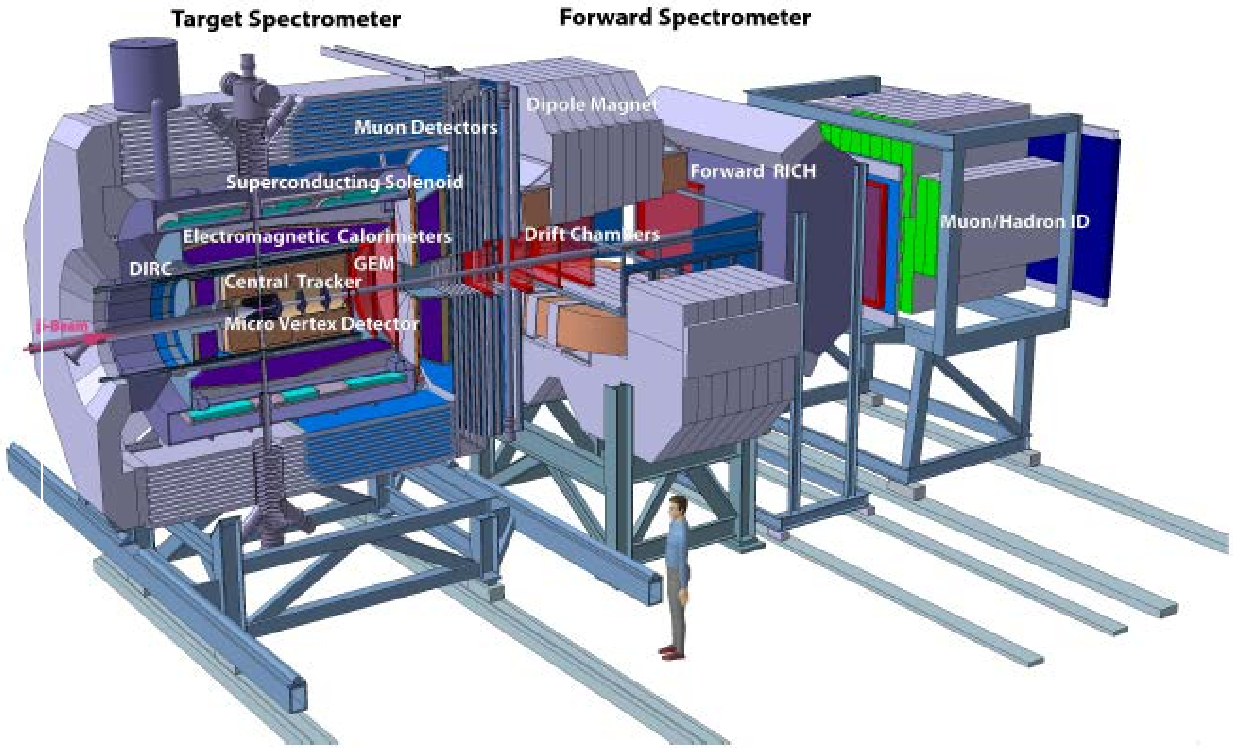


Figure 2.1: Artistic view of the $\overline{\text{P}}$ANDA Detector

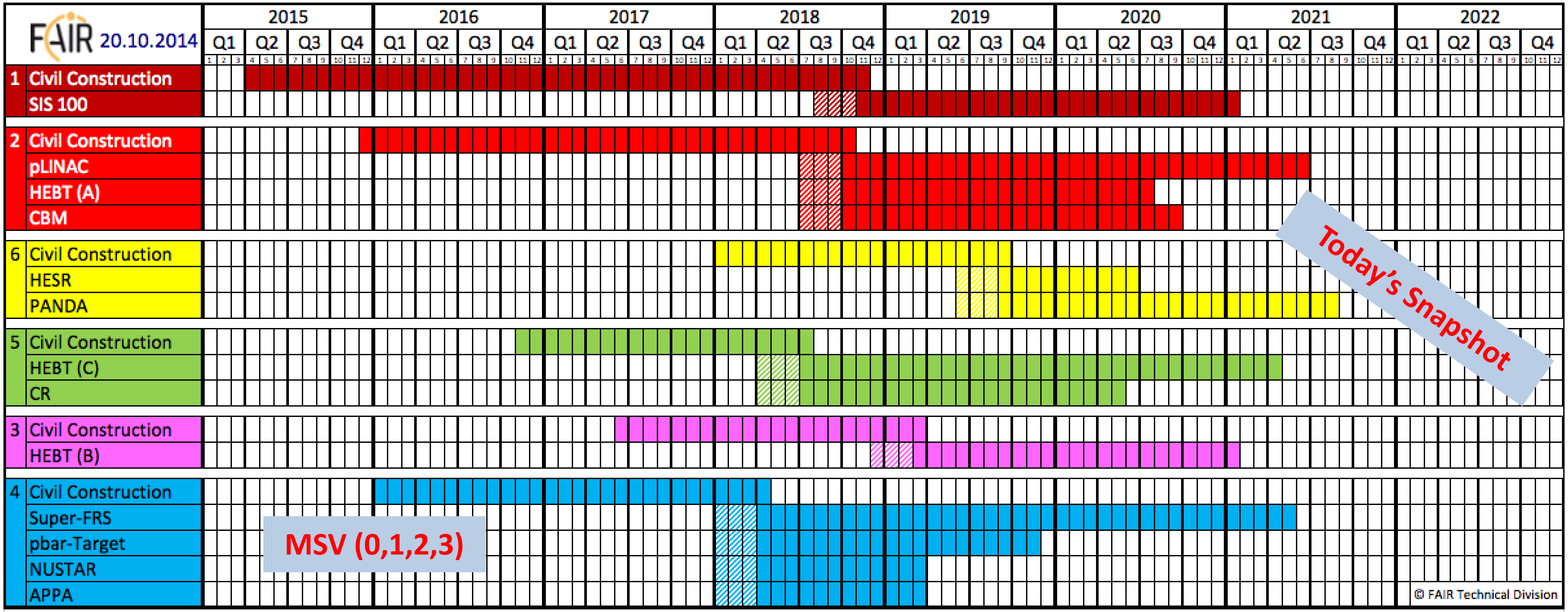
Targets: pellet H(D) target

frozen drops of 25-40μm, controlled position;
Target station for hyper-nucleus physics;
Wire targets for pbar-A interaction
He3 polarized target (under design)

Total integrated luminosity about 1.5 fb-1/year

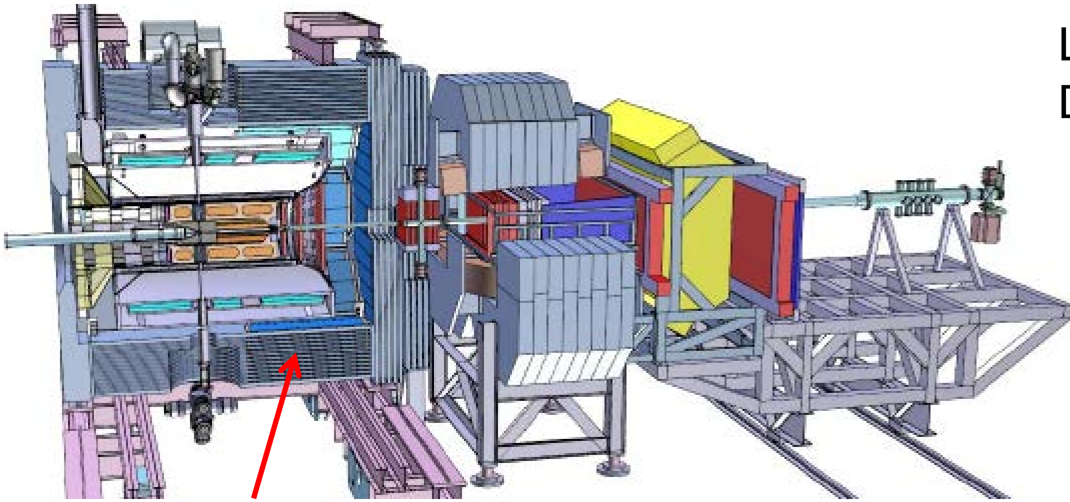
FAIR Combined Schedule (EM 20.10.2014)

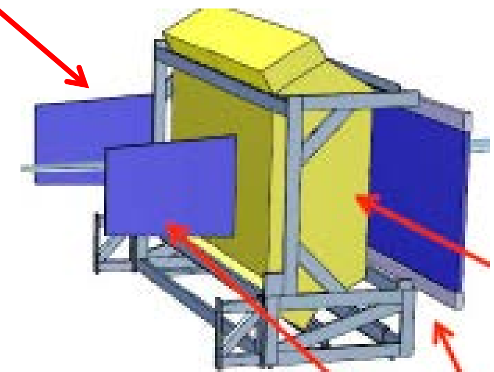
Combined Schedule (Civil Construction Variant 1-2-4-5-3-6)

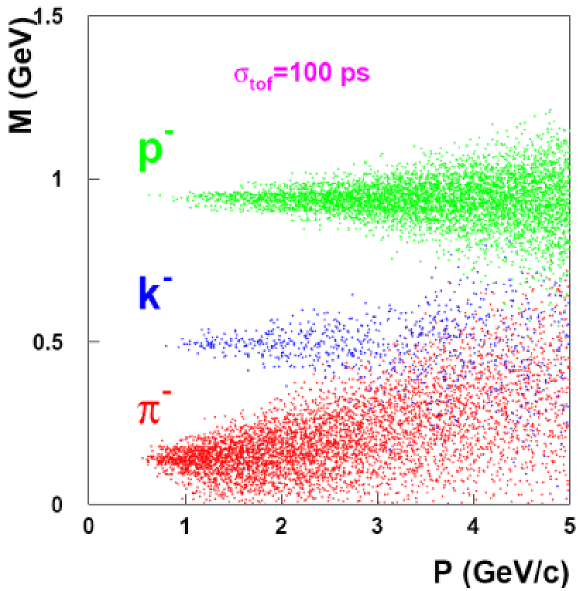


End of Civil Construction	**Q3 2019**
PANDA start installation	**Q4 2019**
PANDA beam tests	**Q3 2020**

Forward Time-Of-Flight PNPI Commitment





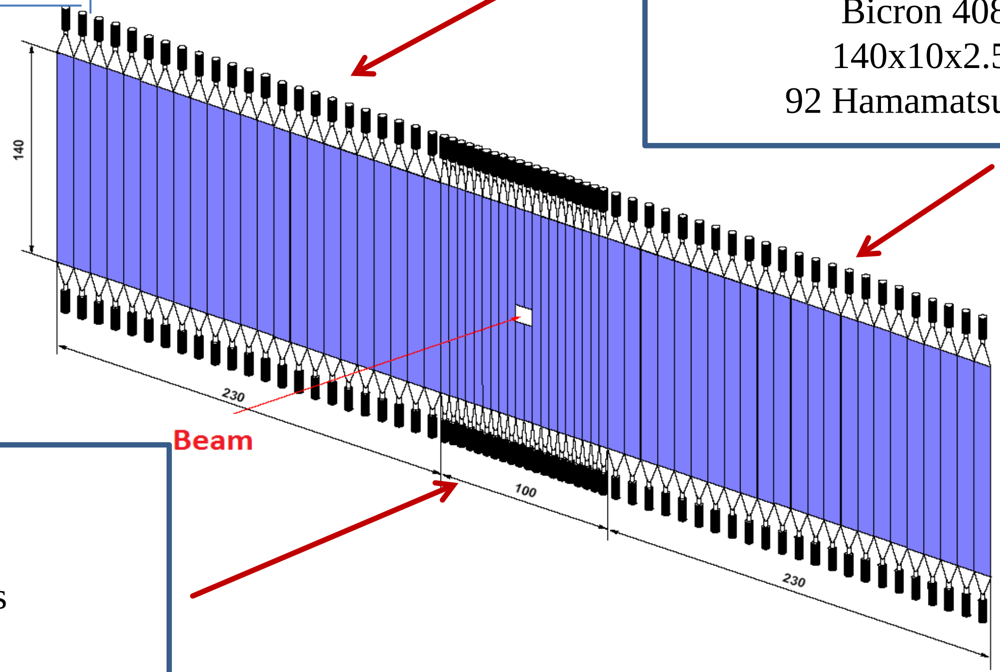


Motivations for FTOF

- PID of forward emitted particles up to 4 GeV @ 80ps timing resolution
- Event start time stamp reference
- A good strangeness (offline) trigger

FTOF wall

positioned at 7.5 m from the IP



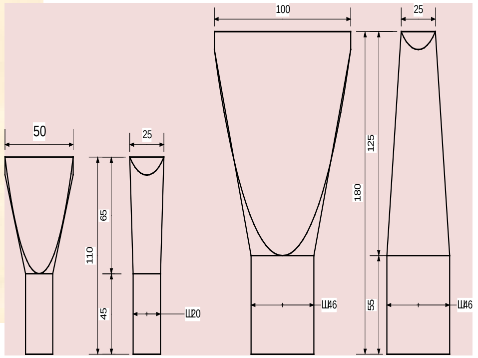
Side parts
2x23 counters
46 plastic scintillators
Bicron 408
140x10x2.5 cm
92 Hamamatsu R2083 (2”)

light guides

Plexiglas, Mylar wrapping

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

Light guides



Bicron 408
(recommended for large TOF counters)

Rise time	0.9 ns
Decay time	2.1 ns
1/e light attenuation length	210cm
Wavelength of max emission	425nm

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

Anode pulse rise time	0.7-1.8ns
TTS	250-370ps (FWHM)
Gain	1.1-5.7x10^6
W.m. emission	420nm
HV	1500-3500v

Monte Carlo Study with PANDAROOT

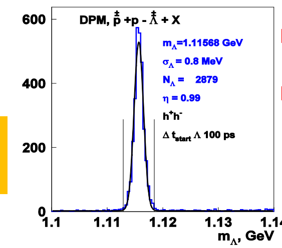
FRAMEWORK

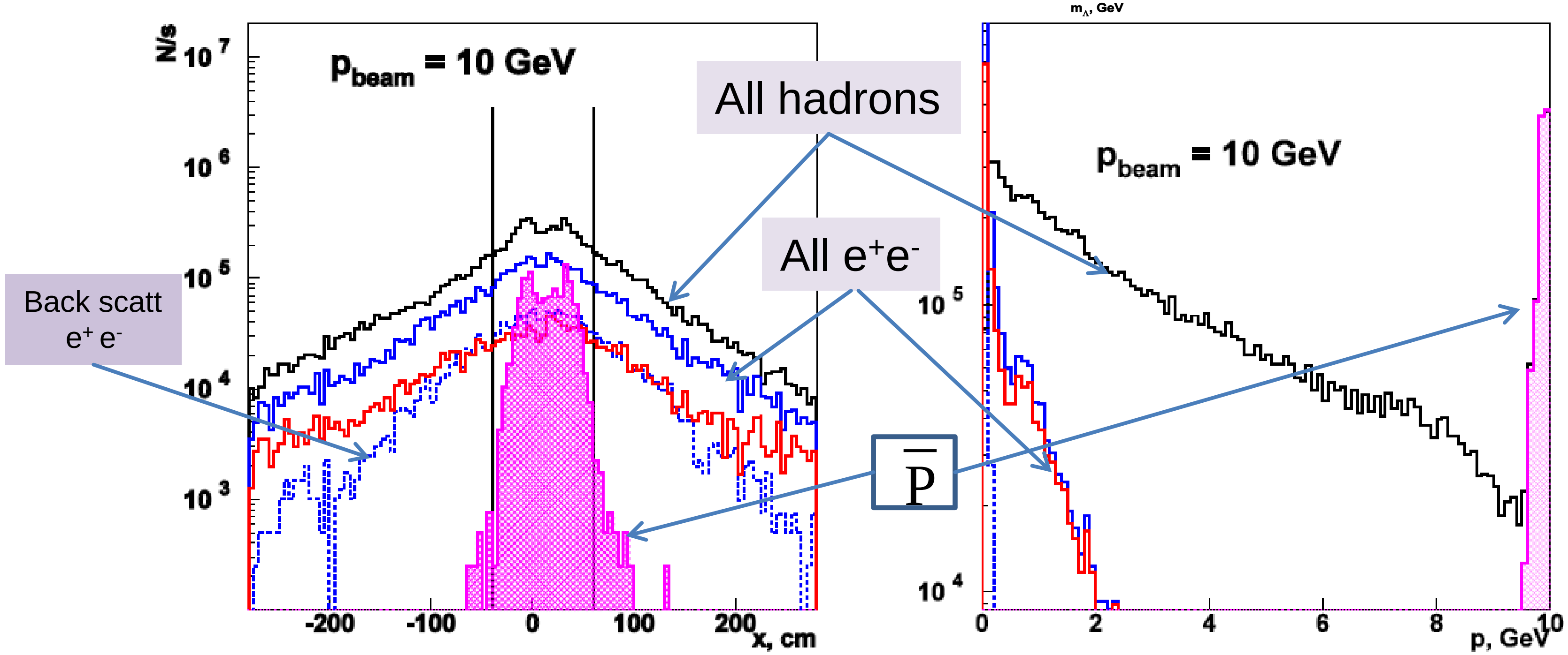
- Dual Parton Model /Pyphia 6 generator
- Geometry and materials of detector components
- Tracking in magnetic field on GEANT4 level
- Event reconstruction in a simplified way

MISSING

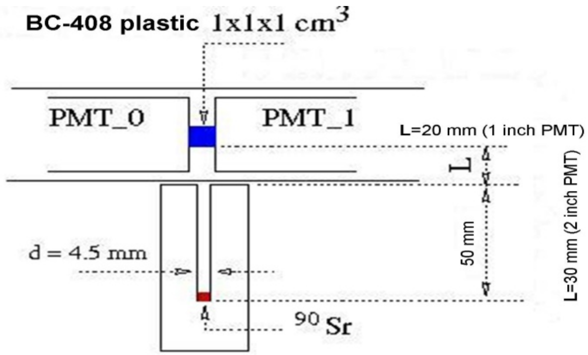
- Full digitization
- Calibration concept Λbar
- Startles TOF algorithm
- Time based reconstruction
- Benchmark reactions
  e,g Lambda_C production

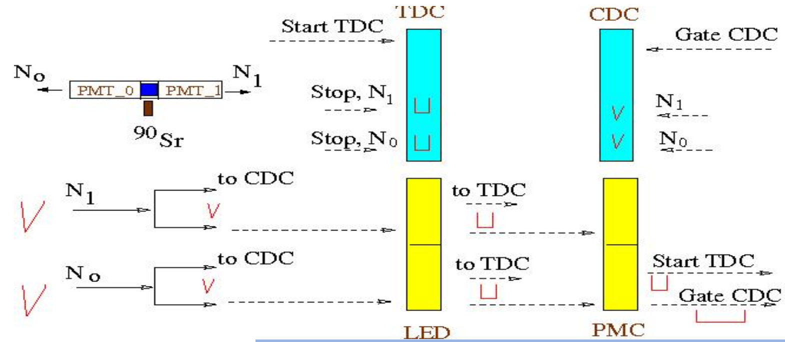
Finding: 20% detection efficiency of $\overline{\Lambda}$





PMT timing resolution at PNPI test station





Hamamatsu PMT	Rise time, ps	TTS sigma, ps	Gain 10^6	Appl. Voltage kV
R4998(1”)	0.7	160	5,7	2.25
R9800(1”)	1.	270	1.	1.3
R2083(2”)	0.7	370	2.5	3.
R9779(2”)	1.8	250	0.5	1.5

Results of measurements TDC spectrum amplitude corrected

R4998-R4998 σ= 72 ps
R2083-R2083 σ= 70 ps
R4998-R9800 σ= 86 ps
R2083-R9779 σ= 64 ps

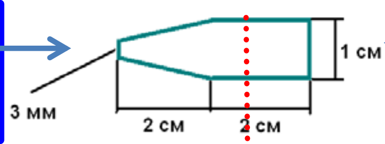
R4998 σ= 48 ps
R9800 σ= 67 ps
R2083 σ= 43 ps
R9779 σ= 40 ps

$\sigma_{electronics}$= 25-30 ps
$\sigma_{geometry}$= 10-12 ps

SiPM timing resolution at PNPI test station

Variant A

S10931-50p
3x3mm

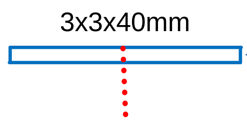


R4998 1”

^{90}**Sr**

Variant B

S10931-50p
3x3mm

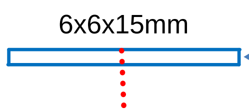


S10931-50p
3x3mm

^{90}**Sr**

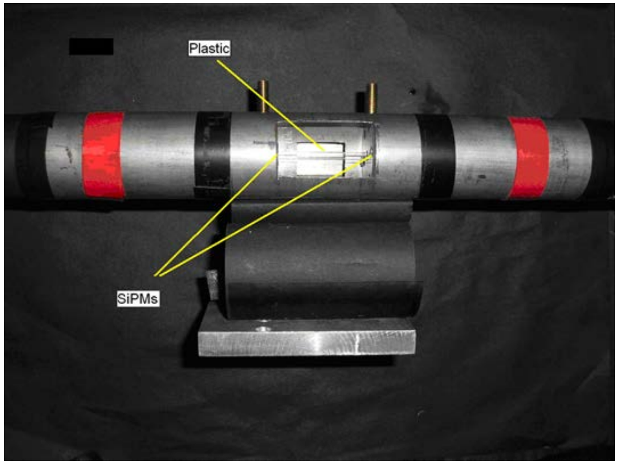
Variant C

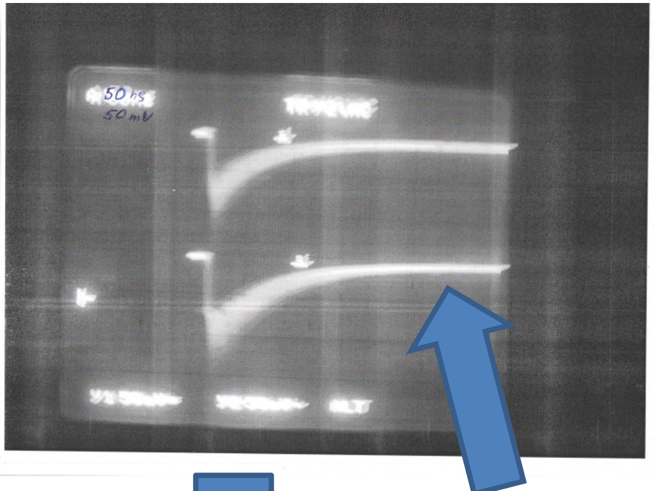
KETEK
6x6mm



KETEK
6x6mm

^{90}**Sr**





50 mV

50 ns

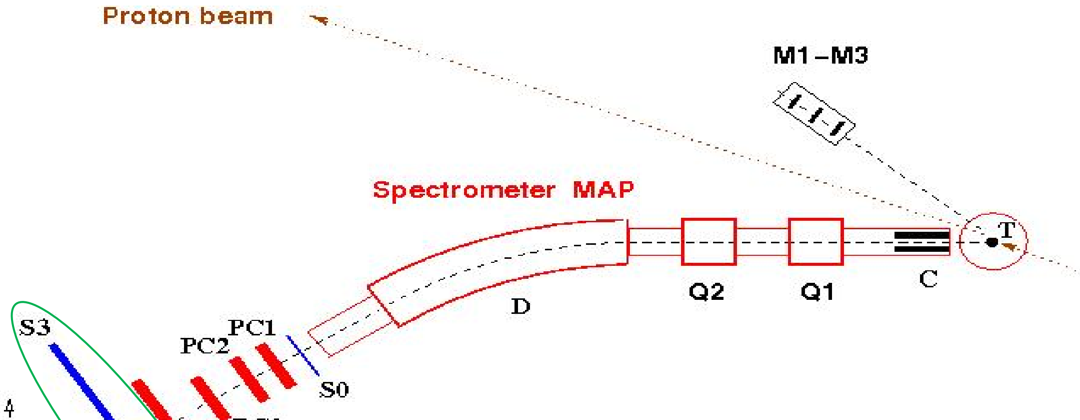
RC=1kΩx500pF

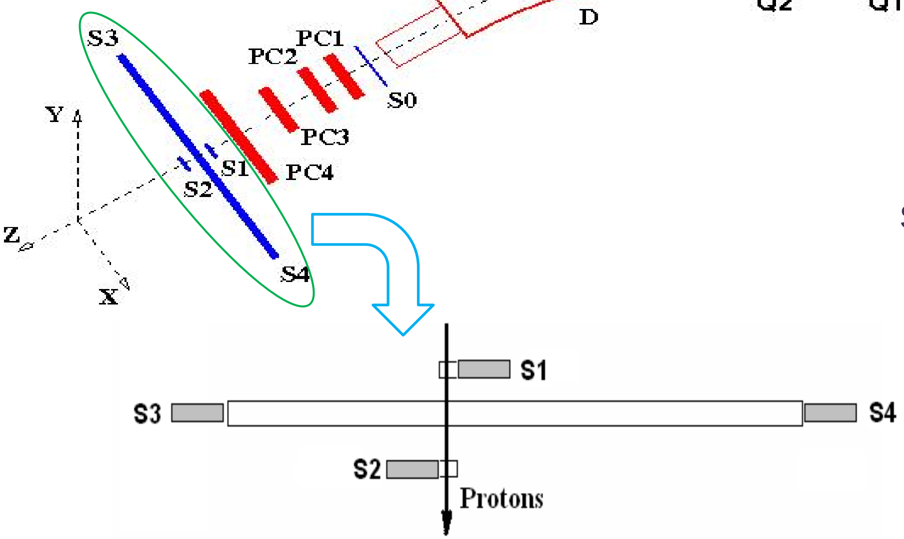
Measurement results

S10931-50p (3x3 mm³) σ=150 ps
KETEK (6x6 mm³) σ=100 ps

Radiation hardness ?? Maximum rate below 10^6

Prototyping using PNPI and COSY proton beams





1 GeV extracted proton beam

pp elastic scattering:

E_p=730 MeV at Θ_p=26.0 deg.

E_p=920 MeV at Θ_p=13.5 deg.

2 GeV COSY test beam

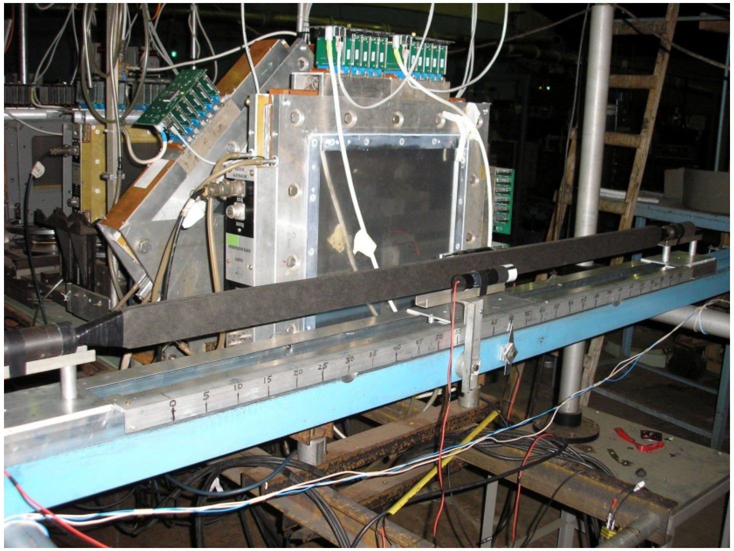
scattered proton energy uncertainty **σ(Ep)=5 MeV**

hit position uncertainty **σ(x)=1mm -> 5 ps**

S1 S2 S3 S4 coincidences

Small counters: S1, S2

BC-408 2x2x2 cm^3



Summary for prototyping from tests using proton beam

Scintillation slab dimensions	Photo multiplier tube	Comments
140 cm × 10 cm × 2.5 cm	Hamamatsu R 2083	**75ps Accepted as a prototype for the FTOF wall**
140 cm × 5 cm × 2.5 cm	Hamamatsu R 4998	**70ps Accepted as a prototype for the FTOF wall**
140 cm × 2.5 cm × 2.5 cm	Hamamatsu R 4998	60ps Variant of a prototype with smaller slab width
140 cm × 10 cm × 1.5 cm	Hamamatsu R2083	150ps Projected originally for the FTOF wall
140 cm × 5 cm × 1.5 cm	Hamamatsu R4998	120ps Projected originally for the FTOF wall
140 cm × 2.5 cm × 2.5 cm	Electron PMT 187	**80ps Magnetic field protected, tentatively projected for the dipole TOF**
100 cm × 10 cm × 2.5 cm	Electron PMT 187	150ps Magnetic field protected, tentatively projected for the dipole TOF

Weighted means of σ(TDC3-TDC1) and σ(TDC3-TDC1):

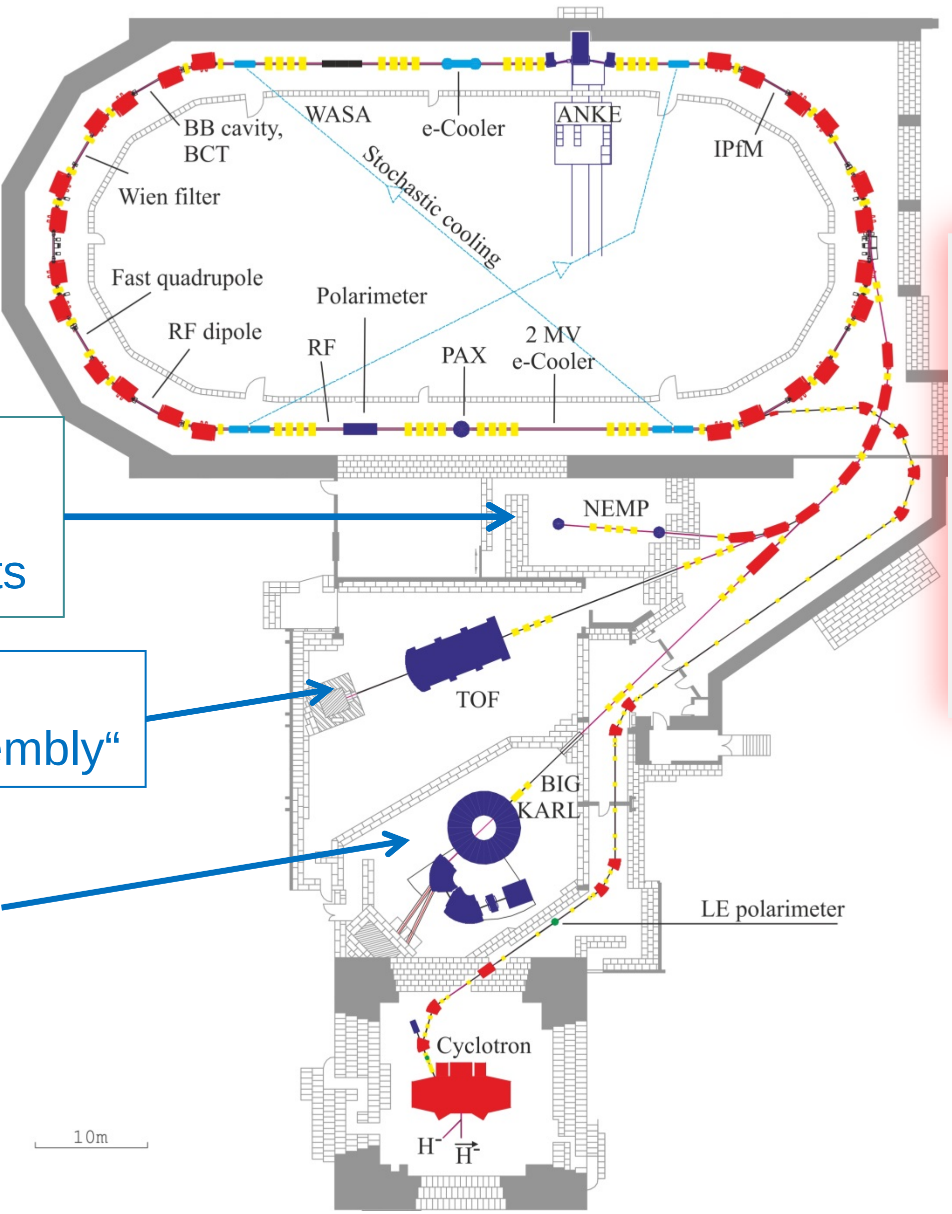
.

$$1/\sigma^2 = 1/\sigma_3^2 + 1/\sigma_4^2$$

TDC spectra corrected for pulse amplitude spread and hit position.

Test facility for FAIR

COoler SYnchrotron



JESSICA area:
CBM-tests
PANDA-MVD tests

TOF area:
„PANDA pre-assembly“

BIG Karl area:
PANDA STT

PNPI participates in PANDA pre-assembly starting from 2015. Corresponding MoU between PNPI and IKP in progress

ПИЯФ в эксперименте ПАНДА

Состав группы

С.Белостоцкий
Д.Веретенников
А.Жданов
А. Изотов
О. Миклухо
Ю.Нарышкин
А.Прокофьев
С.Манаенков
Г. Гаврилов

FTE ~ 0.6

Frontend readout/DAQ эксперт ?

Инженер- конструктор ?

Студенты/аспиранты/ молодые специалисты ?

Supporting slides

Forward Time-Of-Flight wall
FTOF wall

Technical Design Report (TDR)

Petersburg Nuclear Physics Institute

Table of content

1. **EXECUTIVE SUMMARY** 100%
2. **PHYSICS CASE OF FTOF, MC STUDY** 90%
3. **TECHNICAL DESIGN CONSIDERATIONS OF FTOF** 50%
4. **EXPERIMENTAL STUDY OF PROTOTYPES** 100%
5. **MECHANICS, CABLING AND INTEGRATION** 30%
6. **PROJECT MANAGEMENT** 50%
7. **CONCLUSION** 50%

Timing resolution using proton beams

PNPI synchrocyclotron, 740 and 920 MeV
April 2009. Nov. 2012 June 2013 Dec. 2013

COSY test beam in Juelich, 2 GeV
Dec. 2012

Tasks: optimization of slab thickness and width; time resolution versus hit position; count rate scan; tests with TRB-2, TRB-3 readout;

Table 1. Prototypes of scintillation counters tested at proton beams

Scintillator dimensions: thickness x width x length, cm^3 BC408	Photomultiplier
1.5 x 5 x 140	Hamamatsu PMT R4998 (both ends)
1.5 x 10 x 140	Hamamatsu PMT R2083 (both ends)
2.5 x 2.5 x 140	Hamamatsu PMT R4998 (both ends)
2.5 x .5 x 140	Hamamatsu PMT R4998 (both ends)
2.5 x 10 x 140	Hamamatsu PMT R2083 (both ends)
2.5 x 2.5 x 140	Electron PMT 187 (both ends)
2.5 x 5 x 140	Electron PMT 187 and Hamamatsu R4998
2.5 x 5 x 140	Electron PMT 187 (both ends)
2.5 x 10 x 100	Electron PMT 187 (both ends)
2.5 x 10 x 100	Electron PMT 187 and Hamamatsu R4998

Global plan for FTOF / DTOF design, fabrication and installation 2014-2018

1. TDR approval, funding, tender, agreement, manufacturing concept. from 01.01.2014 to 31.05.2015 17 months

2. Material procurement, manufacturing and final prototype tests, manufacturing all components, detector pre-assembly. from 01.06.2015 to 31.03.2017 22 months

3. Shipment to FAIR: good inspection , test inspection, approval for installation, shipment from 01.04.2017 to 31.12.2017 9 months

4. Installation at HESR from 01.01.2018 to 30.09.2018 9 months

5. Commisioning from 01.10.2018 to 31.12.2018 3 months

M3 9/2014	M8 04/2016	M10 06/2017	M11 10/2018
Approval of TDR	Prototype tested pre-series accepted	Approval for installation	Ready for beam

Cost estimation update

FTOF wall

Plastic scintillators	
B408 20u.140x5x2.5cm+46u.140x10x2.5cm	60 k€
PMTs 1” 600€ 40u. +5u.(spare)	27
PMTs, 2” 900€ 92u.+10u.(spare)	92
FEE+DAQ	30
HV power supply	22
Gain monitoring system	9
Supporting structure (design, fabrication)	40
Test stand for mass production	35
Transportation, custom expenses	25
…………………………………………………………………	
	340 k€

Infrastructure

- PNPI test beam
- PNPI design department (mechanical components drawings)
- PNPY electronic department (expertise, HV)
- PNPI Workshop (fabrication of mechanical components)
- Test station/preassembly in Juelich

Dipole TOF

Plastic scintillators B408 20u.	15
PMTs Electr.187 1.5” 1400€ 40u. +5u.(spare)	63
FEE +DAQ	5
HV power supply	9
Gain monitoring system	5
Supporting structure (design, fabrication)	35 ??
…………………………………………………………………	
	132 k€

From RRB February 2014 471 k€

Efficiencies and count rates of charged hadrons

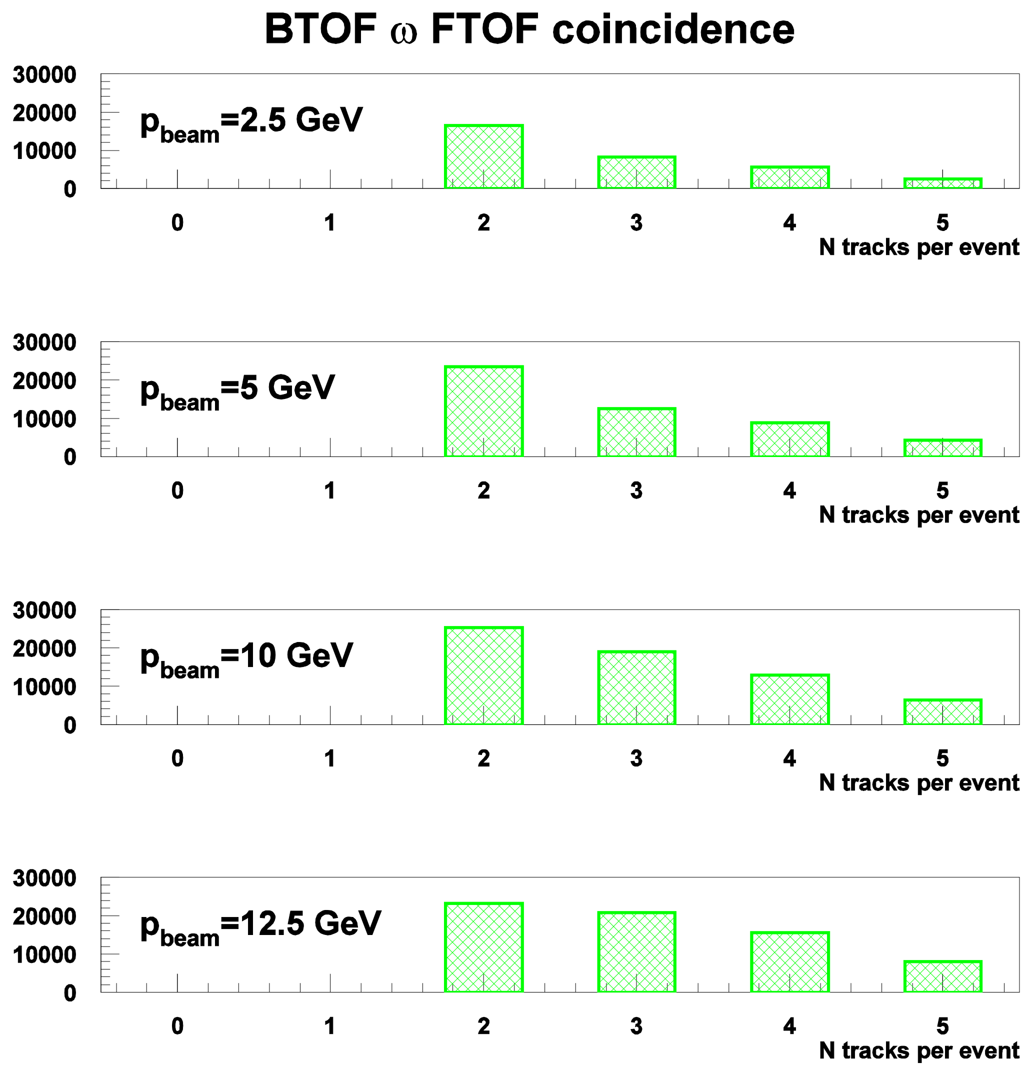
	Generated by DPM	Detected by BTOF (eff / N per sec)	Detected by DTOF (eff / N per sec)	Detected by FTOF (eff / N per sec)
π^-	90693	$0.36 / 4.08 \cdot 10^6$	$0.01 / 0.14 \cdot 10^6$	$0.23 / 2.59 \cdot 10^6$
π^+	90725	$0.44 / 5.03 \cdot 10^6$	$0.002 / 0.03 \cdot 10^6$	$0.18 / 2.07 \cdot 10^6$
K^-	3022	$0.09 / 0.03 \cdot 10^6$	$0.001 / 0.0004 \cdot 10^6$	$0.26 / 0.1 \cdot 10^6$
K^+	3082	$0.25 / 0.09 \cdot 10^6$	$0.003 / 0.001 \cdot 10^6$	$0.12 / 0.046 \cdot 10^6$
p-bar	42095	$0.007 / 0.04 \cdot 10^6$	$0.0002 / 0.001 \cdot 10^6$	$0.62 / 3.24 \cdot 10^6$
p	42003	$0.61 / 3.19 \cdot 10^6$	$0.002 / 0.012 \cdot 10^6$	$0.07 / 0.35 \cdot 10^6$

Tracks multiplicity distributions in coincidences

FTOF/BTOF coincidence probabilities

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

FTOF/DTOF, BTOF/DTOF a few %



Lambdabar and Lambda Hyperon Event Selection

$$\bar{p} + p \rightarrow \bar{\Lambda} + X$$

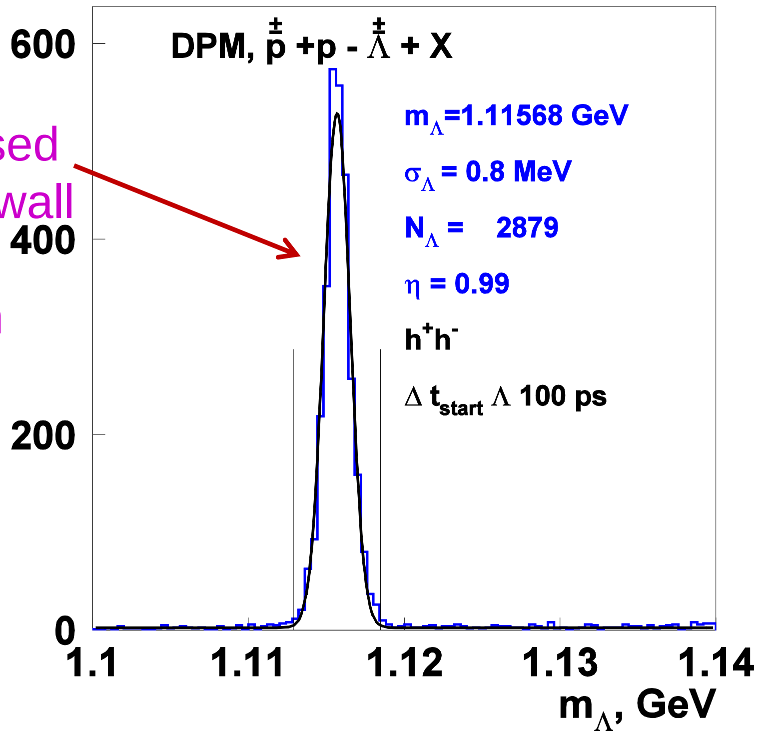
$$\bar{p} + p \rightarrow \Lambda + X$$

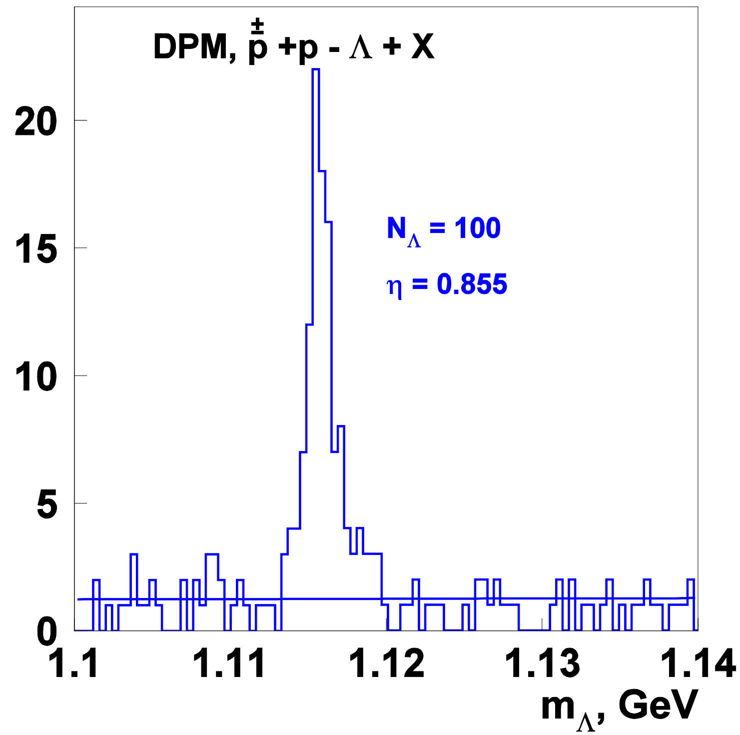
Event selection criteria

$$m(h^-) = m_p \quad m(h^+) = m_\pi \text{ and } \Delta t_{start}^{\bar{p}\pi^+} > 100ps$$

$$m(h^+) = m_p \quad m(h^-) = m_\pi \text{ and } \Delta t_{start}^{p\pi^-} > 100ps \text{ and } z2 > 6mm$$

May be used for FTOF wall timing calibration



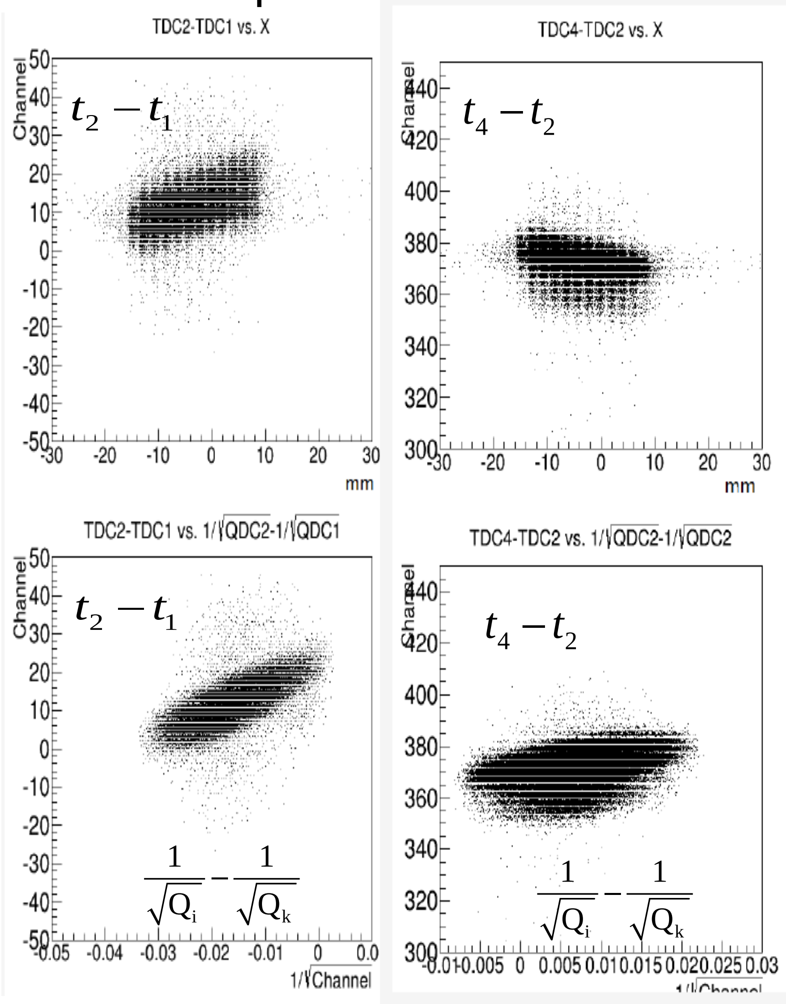


$\bar{\Lambda}$ detected with high efficiency (20%) at weak selection criteria

$N_\Lambda / N_{\bar{\Lambda}} \simeq 1/40$ Λ events also well detected

Amplitude and hit position corrections

Corrections are based on strong dependence of time difference on pulse amplitude and hit position in the scintillator.



<u>*Correction function*</u>

$$t_{ik} = t_{ik}^{raw} - f^{corr} = t_{ik}^{raw} - Ax - B\left(\frac{1}{\sqrt{Q_i}} - \frac{1}{\sqrt{Q_k}}\right) - C,$$

A,B,C found by minimizing functional

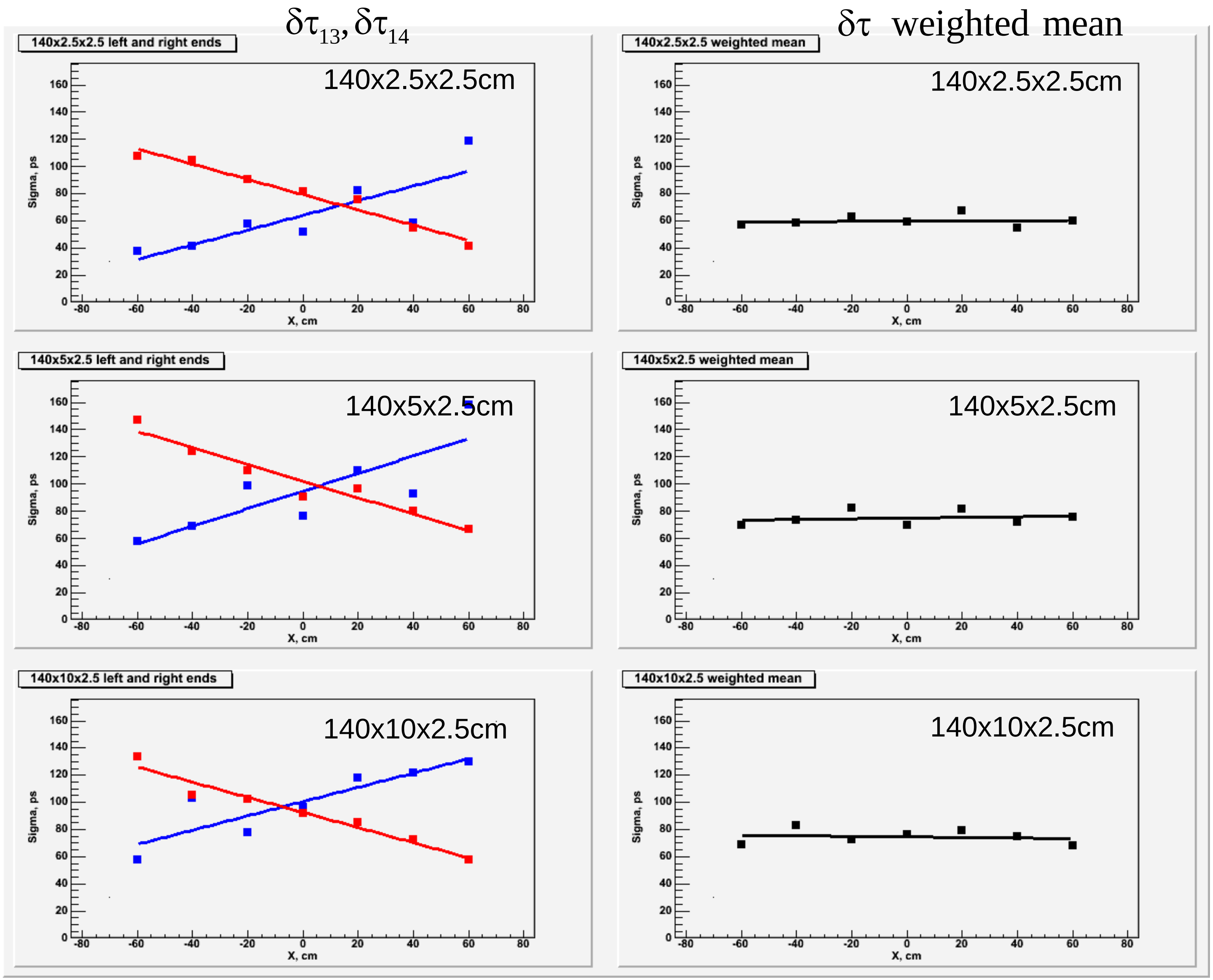
$$\sum_{n=1}^{N} \left[t_{ik}\right]_n^2 = \sum_{n=1}^{N} \left[t_{ik}^{raw} - f^{corr}\left(A,B,C,x,Q_iQ_k\right)\right]_n^2,$$

<u>Example at 920 MeV</u>

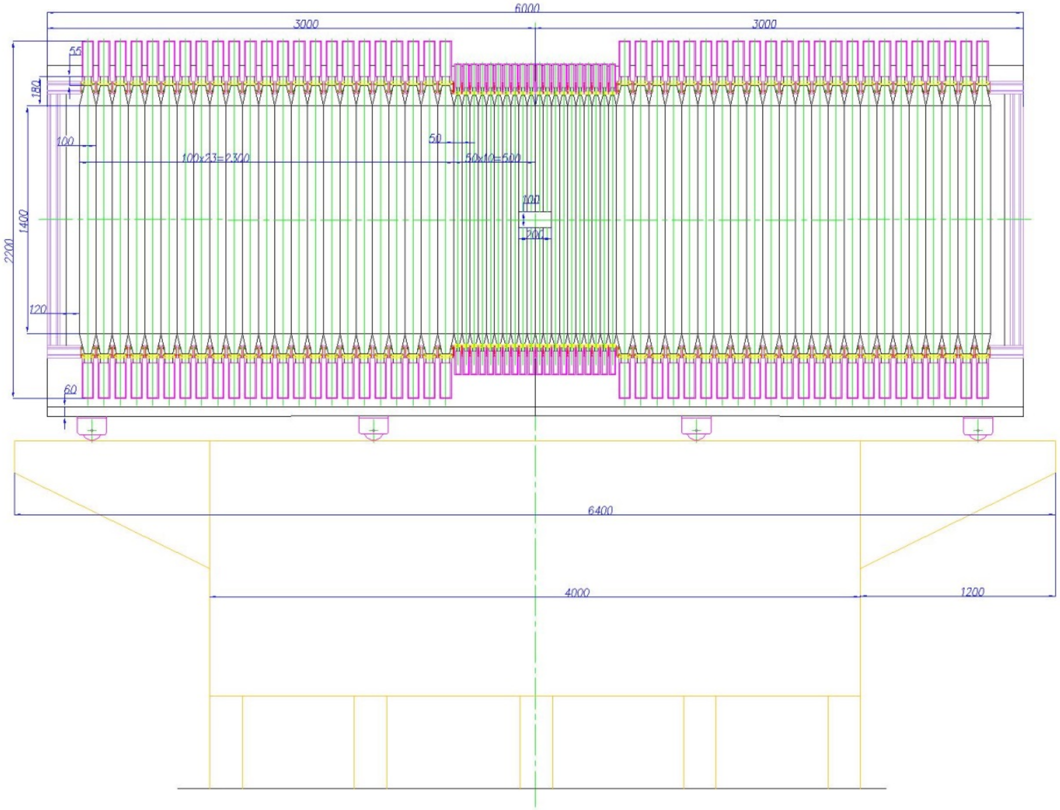
Slab 2,5x5x140 PMT R4998

- No corrections, Δx=15 mm **σ= 126 ps**
- Only amplitude correction **σ= 106 ps**
- Both hit position (σ_X= 1mm) and amplitude corrections **σ= 88 ps**

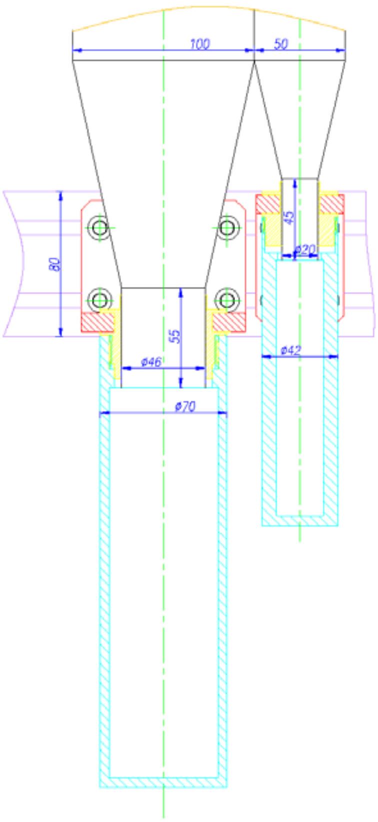
Timing resolution vs hit position



FTOF wall mechanics.



FTOF wall front view



Scintillation counter mechanical components

Summary on work package 2014

- TDR — **in progress (2015)**

R&D

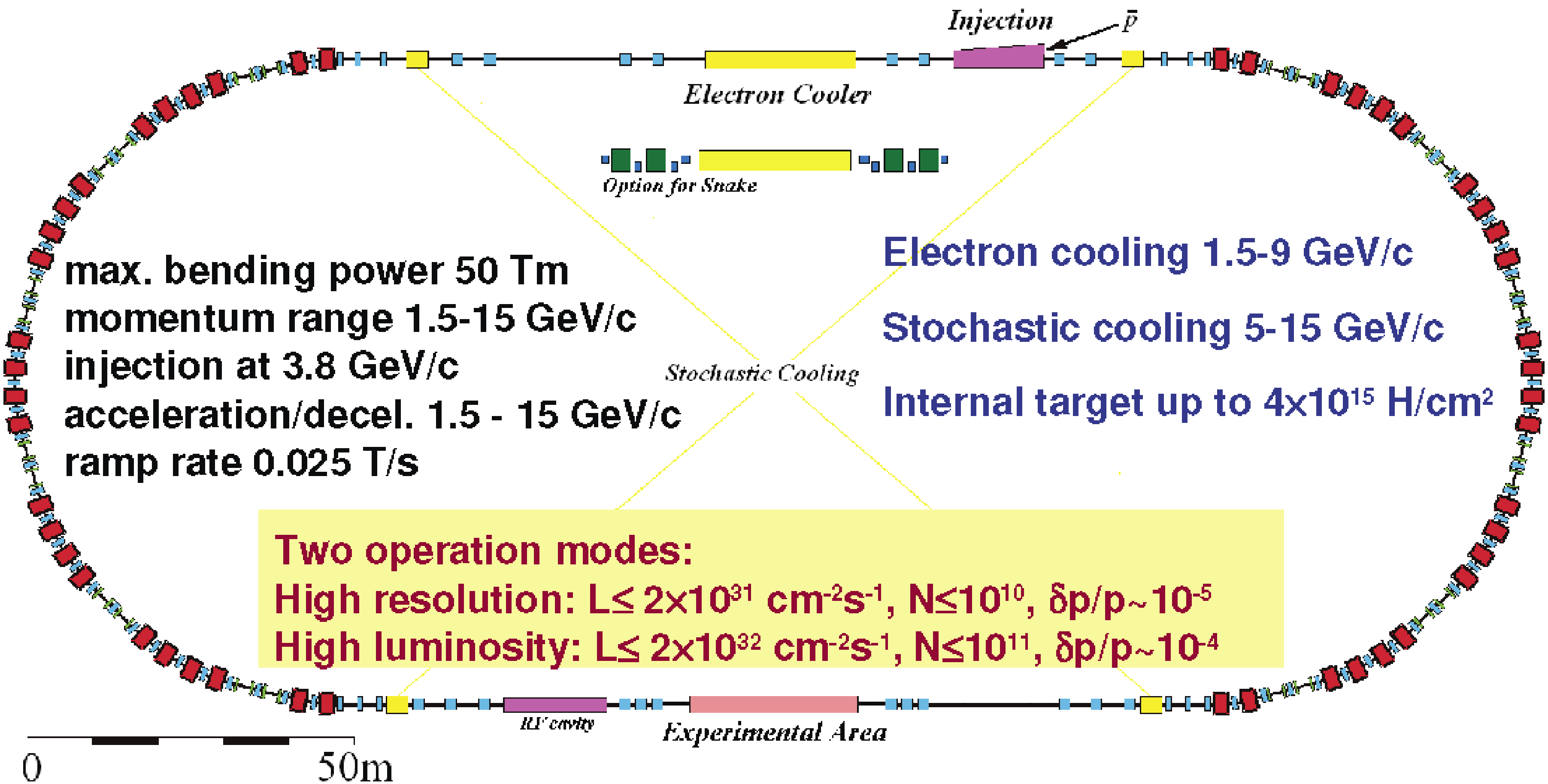
- Complete on-beam tests with TRB-3 readout — **one module & qualified help needed (2015)**
- 90Sr tests of Hamamtsu R9800, R9779 PMTs — **done**
- Determine finally type of divider(active/passive) — **done**
- Complete study of PM-187 in strong magnetic field — **done**
- drawings of mechanical items — **done**
- work out cable routing scheme — **in progress (2014)**
- first test of KETEK SiPM — **first results obtained (2015)**

Monte Carlo simulation
In PANDAROOT Framework

- Startless TOF algorithm — **postponed (2015)**
- Enhance study of count hadron rates and background — **done**
- Coincidence FTOF wall, BTOF and DTOF — **done**
- Study of inclusive $\bar{p}+p\rightarrow\bar{\Lambda}+X,\ \bar{p}+p\rightarrow\Lambda+X$ reactions — **done**
- Study of Λ_C production — **not done (2015**)
- Light propagation in slab, PMT, full digitization — **started (2015**)

The High Energy Storage Ring HESR

designed by a consortium between FZ Jülich, TSL Uppsala, GSI



max. bending power 50 Tm
momentum range 1.5-15 GeV/c
injection at 3.8 GeV/c
acceleration/decel. 1.5 - 15 GeV/c
ramp rate 0.025 T/s

Electron cooling 1.5-9 GeV/c

Stochastic cooling 5-15 GeV/c

Internal target up to 4×10^{15} H/cm^2

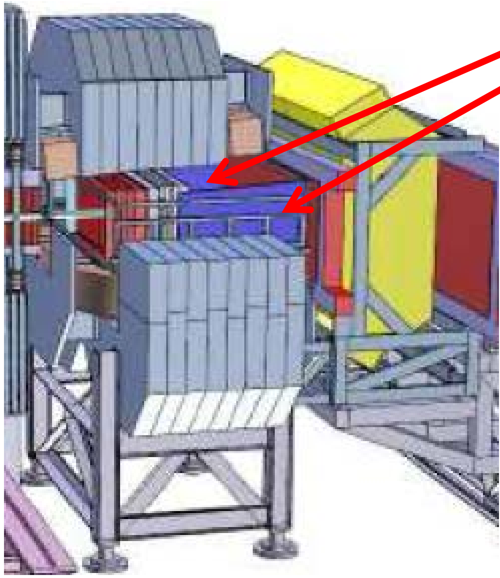
Two operation modes:

High resolution: $L \leq 2\times10^{31}$ cm^{-2}s^{-1}, $N \leq 10^{10}$, $\delta p/p \sim 10^{-5}$

High luminosity: $L \leq 2\times10^{32}$ cm^{-2}s^{-1}, $N \leq 10^{11}$, $\delta p/p \sim 10^{-4}$

straight sections of 132 m length
ring circumference 574 m.

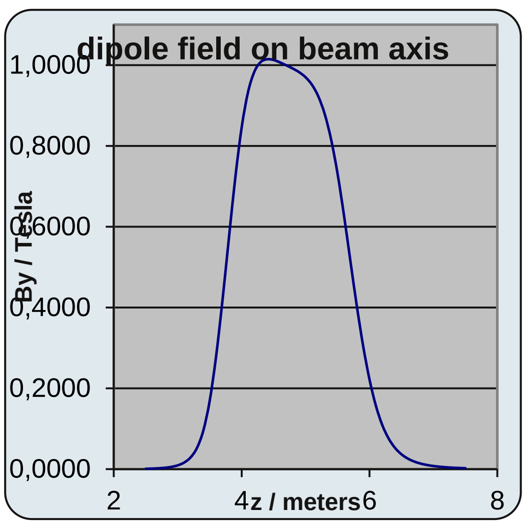
Dipole TOF positioned inside the dipole magnet gap as planned for TDR



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

Not sensitive to mag. F.(!)

SiPMs*(hamamatsu)*

S10931-50p, S10931-100p

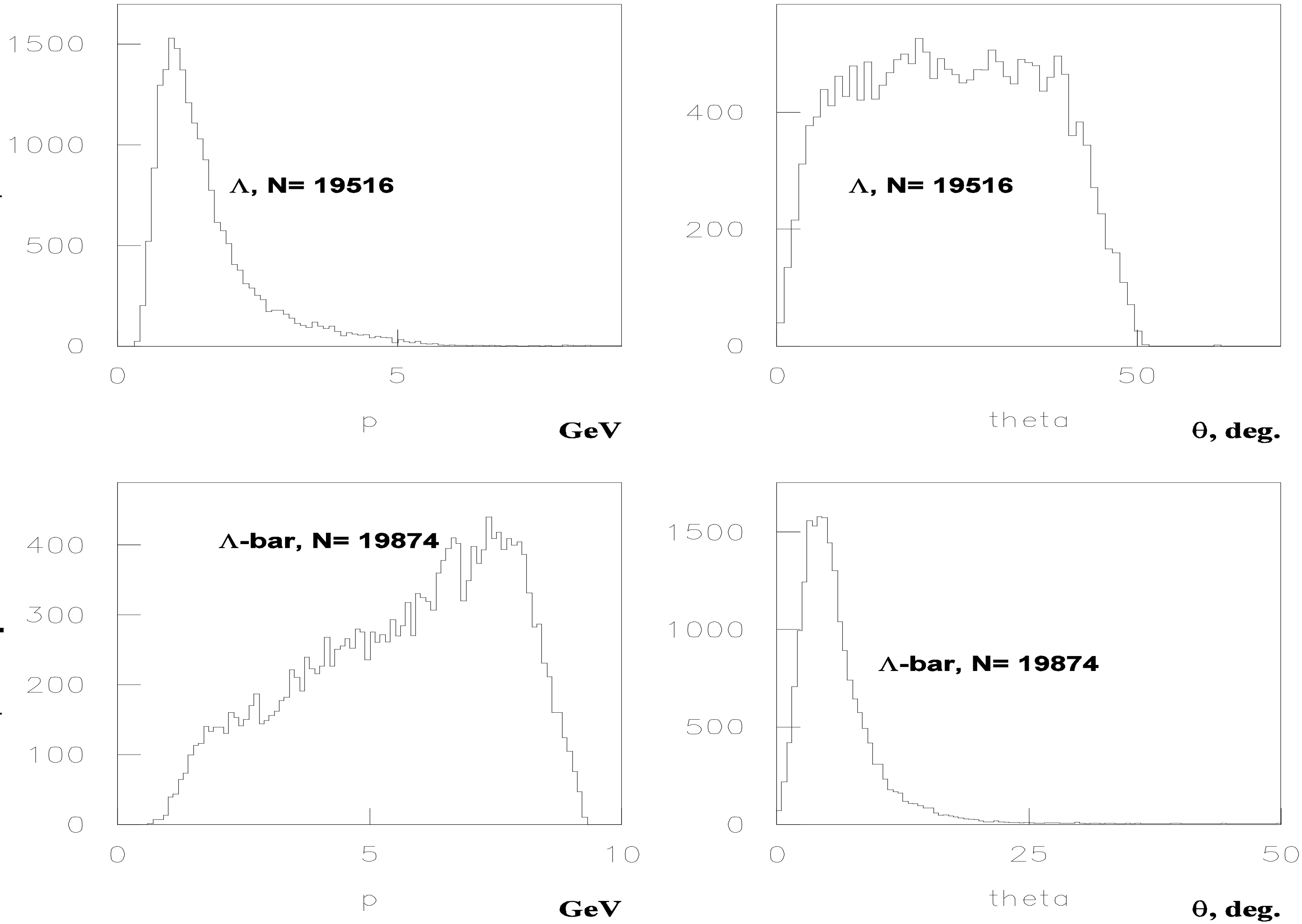
active area	3x3mm
Pixels	3600
Gain	$7.5x10^5 – 2.4x10^6$
W.m. emission	440nm
TTS	0.5-0.6ns(FWHM)

radiation hardness??

Generated Lambda hyperons

Λ

$\bar{\Lambda}$



SiPM Radiation Hardness Test @ 1GeV PNPI Proton Beam.

- The absolute beam intensity was determined in a standard way by measuring induced radioactivity of irradiated aluminum foils.
- The beam intensity during the tests was varied in the range 1.3 - 2.1x10^8 $cm^{-2}s^{-1}$.
- The SiPM sample was not powered!
- Radiation was exposed in 10 successive periods about 10 minutes each. The integrated number of protons passing through the sensitive surface of the SiPM sample with the cross-section of 3x3 mm^2 was 0.9*10^{11}SiPM parameters (dark noise, amplitude and time characteristics for different values of high voltage) were measured before and after the radiation test using test station with ^{90}Sr electron source.

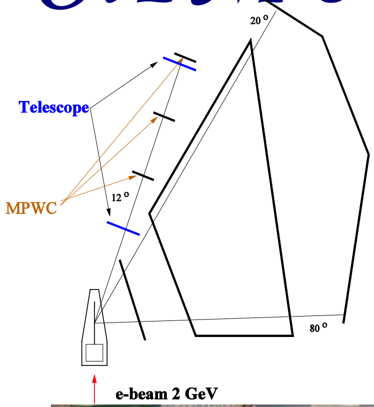
U,V	I, μA	A, mV	Noise	Noise+^{90}Sr
72.06	0.15	40	1550	8700
72.53	0.30	80	4230	18500
72.06	81.0	4	2800	6200
72.53	113.0	6	99000	102000

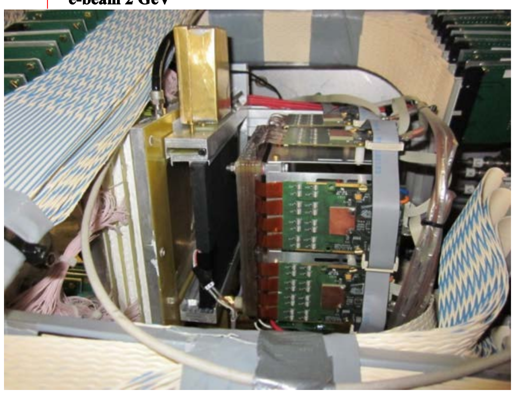
As it is seen from the table the SiPM was practically killed by this dose the value of which can be taken as upper limit,

- Yet it is important to find out at which dose the sample start malfunctioning,
- It is also important to compare irradiation effect on unpowered and powered samples,
- All this will constitute our experimental program with SiPM samples.

$\Delta T = 0.056\ C^o$ *this is not heat!*

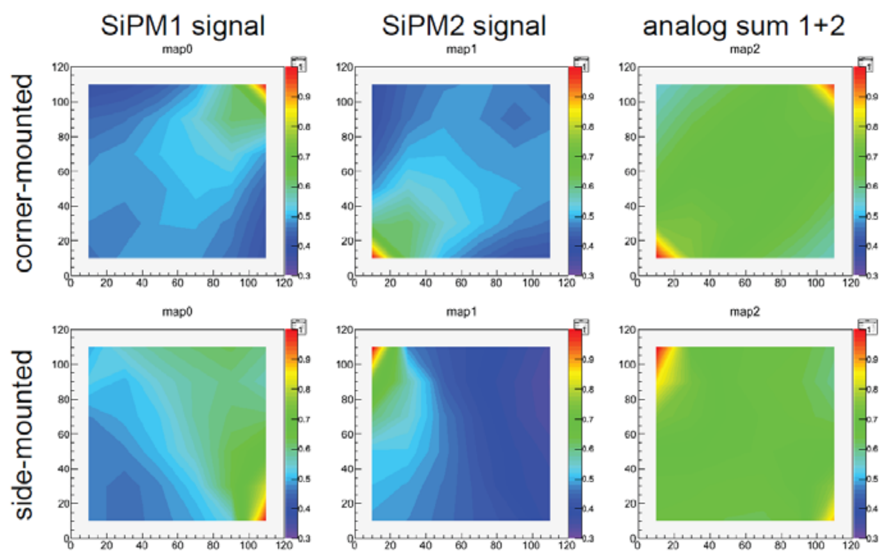
SiPM's @ OLYMPUS. DESY TB22.





Counters:8mm/2SiPM's, 4mm/2SiPM's (corners), 4mm/2SiPM's (sides),
Readout: 25x preamp (electronics workshop, KPH Mainz)

- *QDC spectra to see light yield,*
- *QDC spectra with prescaled baseline triger mixed into determine gain for each spectrum,*
- *Triple coincidence from beam trigger finger conciliators (2 with PMT's, 1 with SiPM)*
- *Quadruple coincidence (3 PMT's, 1 SiPM and single SiPM*
  - *efficiency scan,*
  - *maximum efficiency reachable with single SiPM*

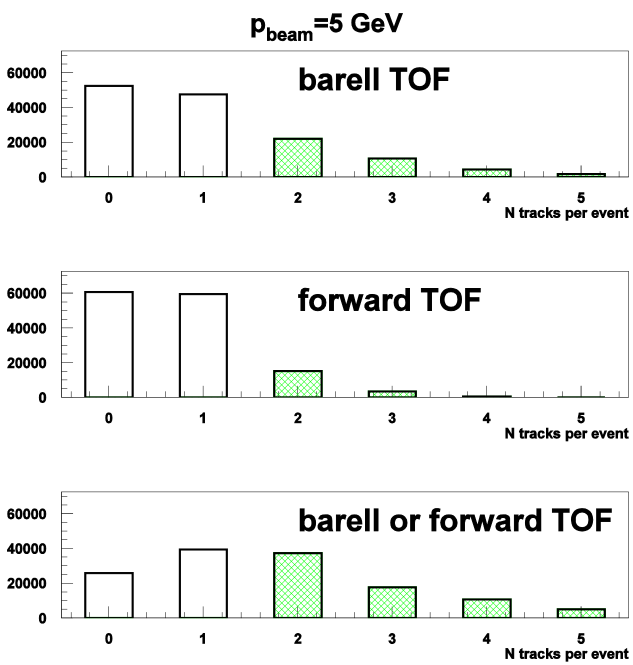


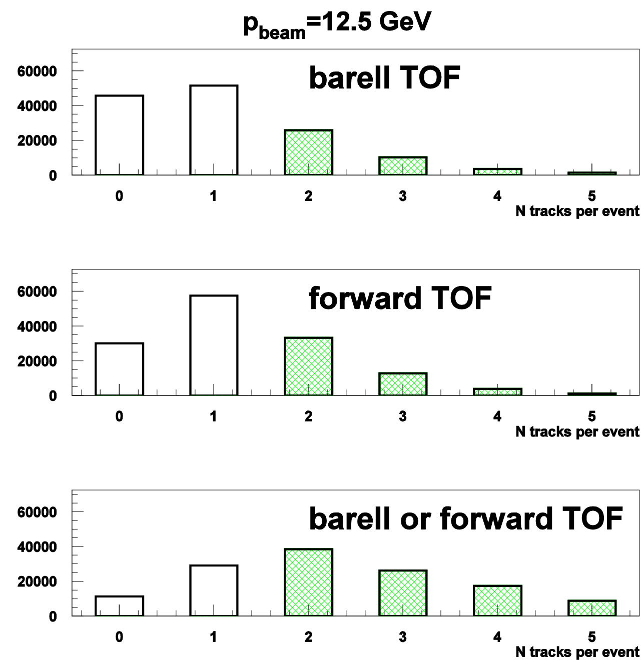
- *Both side-mounting and corner-mounting, counters have similar yields,*
- *Blind spots exist in both configurations,*
- *Side-mounting is easier,*
- *Trigger scan shows, that even one SiPM is enough with proper threshold*

FTOF wall and barrel TOF multiplicities

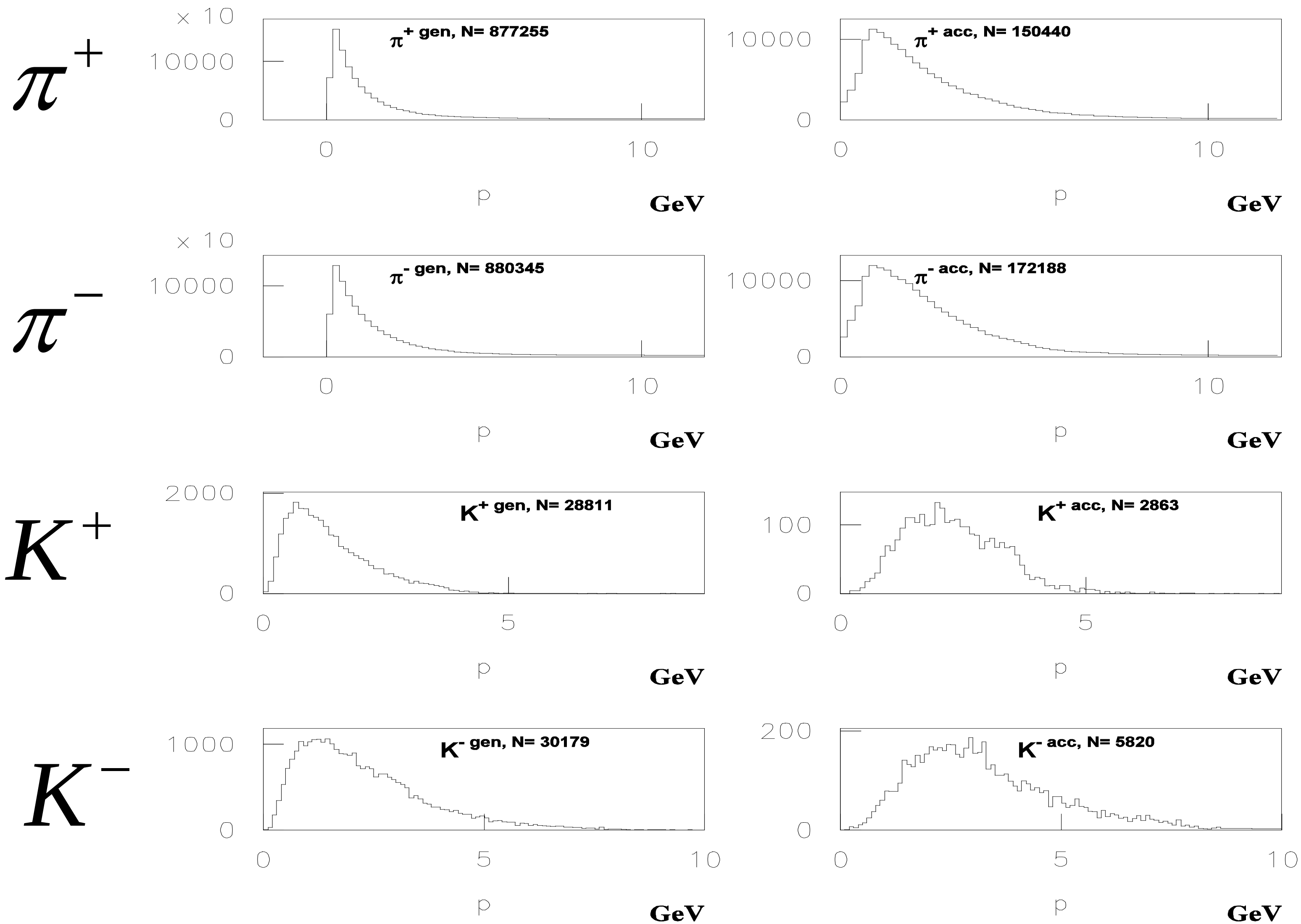
$0.14\times10^{6}\ \bar{p}p$ interactions generated

No dedicated start counter !





Generated/detected with FTOF wall



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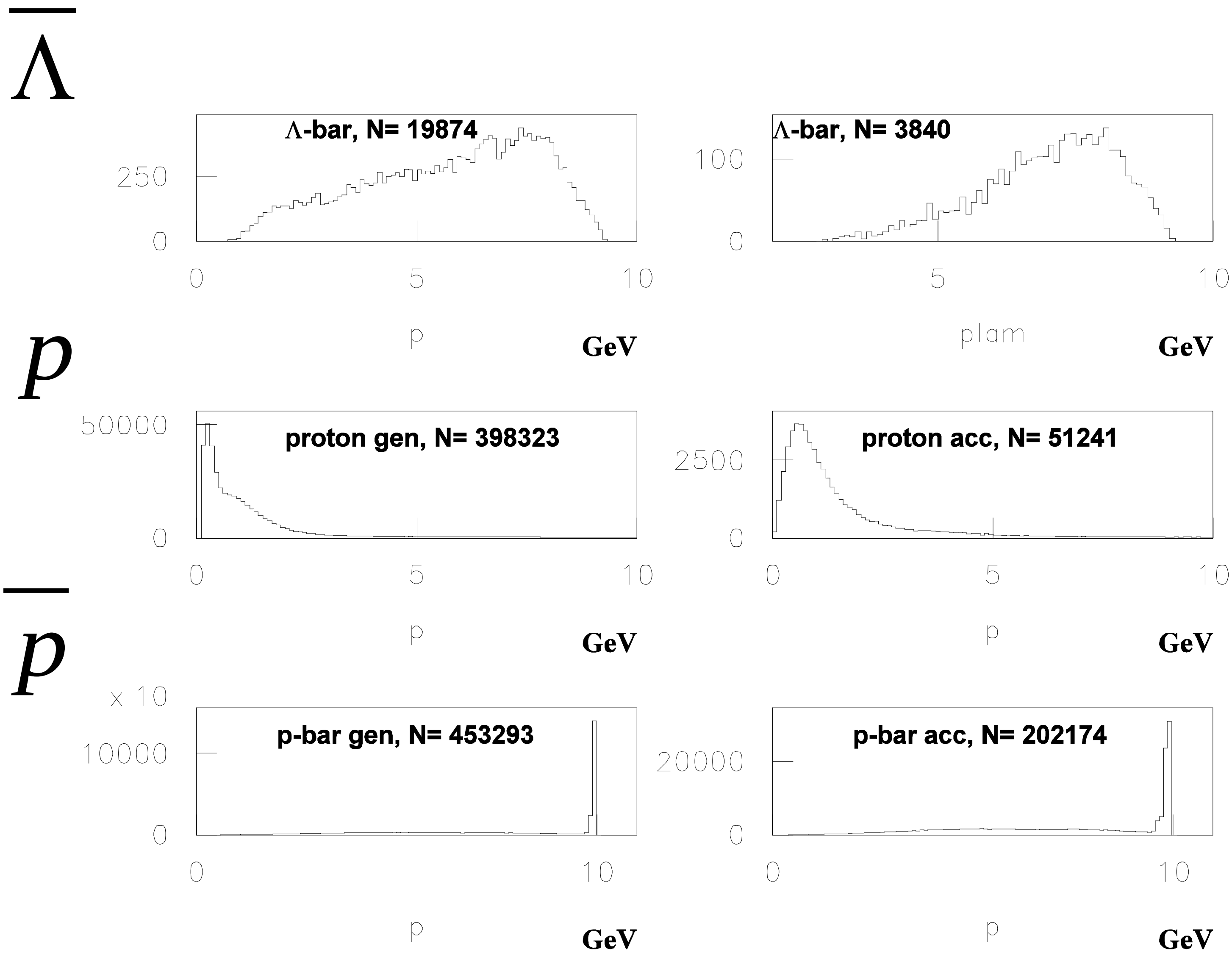
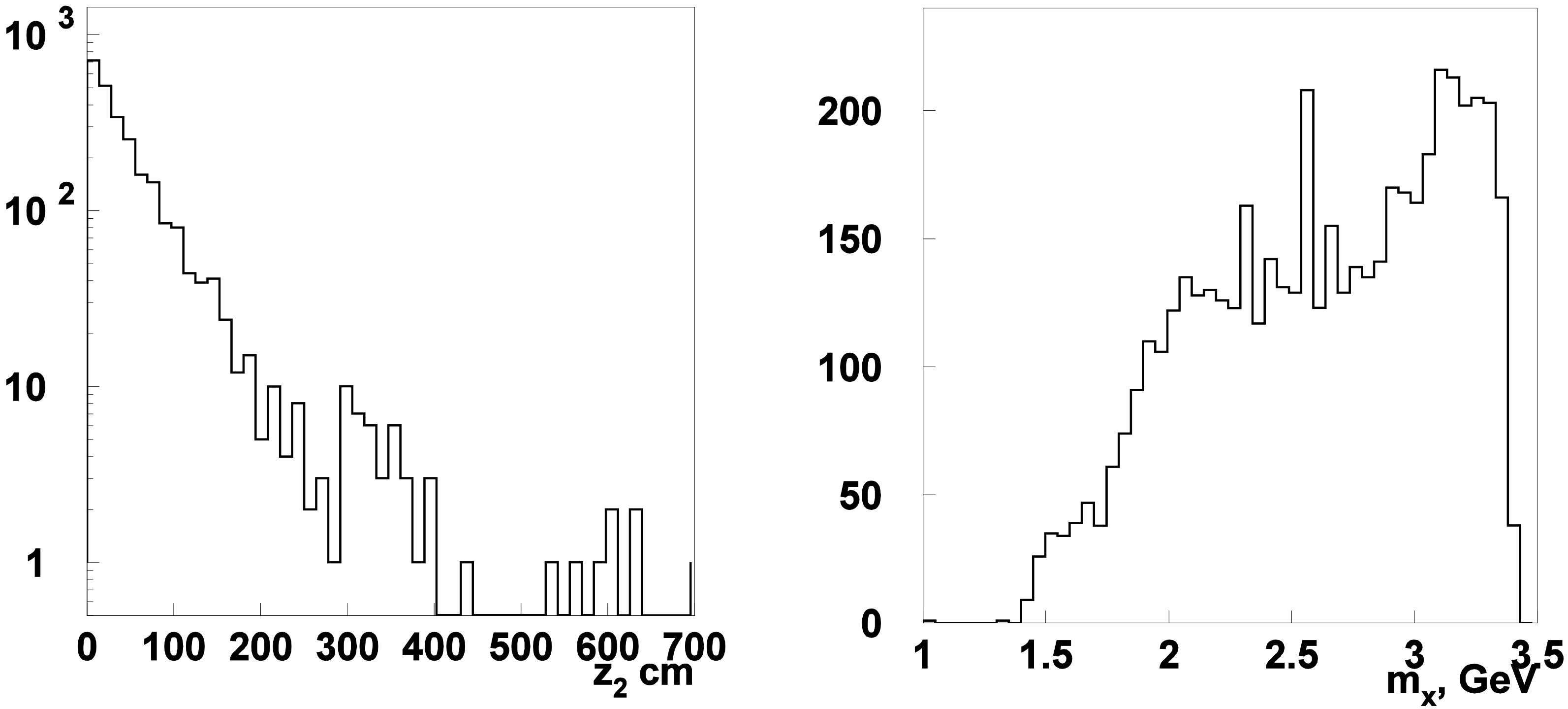


Decay length and m_X for Lambda-bar

$$\bar{p} + p \rightarrow \bar{\Lambda} + X$$



Selection of inclusive Λ and anti Λ

$$\overline{p} + p \rightarrow \overline{\Lambda} + X \qquad\qquad \overline{p} + p \rightarrow \Lambda + X$$

$$\overline{\Lambda} \rightarrow \overline{p} + \pi^{+} \qquad\qquad \Lambda \rightarrow p + \pi^{-}$$

<u>Selection criteria</u>

- pair of hadrons detected with the FTOF wall
- hadrons in a pair are of opposite charge: $H^{+}H^{-}$
- invariant mass calculated under assumption

$$m(H^{-}) = m_p \quad m(H^{+}) = m_\pi \quad for \quad \overline{\Lambda} \qquad m(H^{-}) = m_\pi \quad m(H^{+}) = m_p \quad for \quad \Lambda$$

- time-of-flight from decay vertex to FTOF calculated

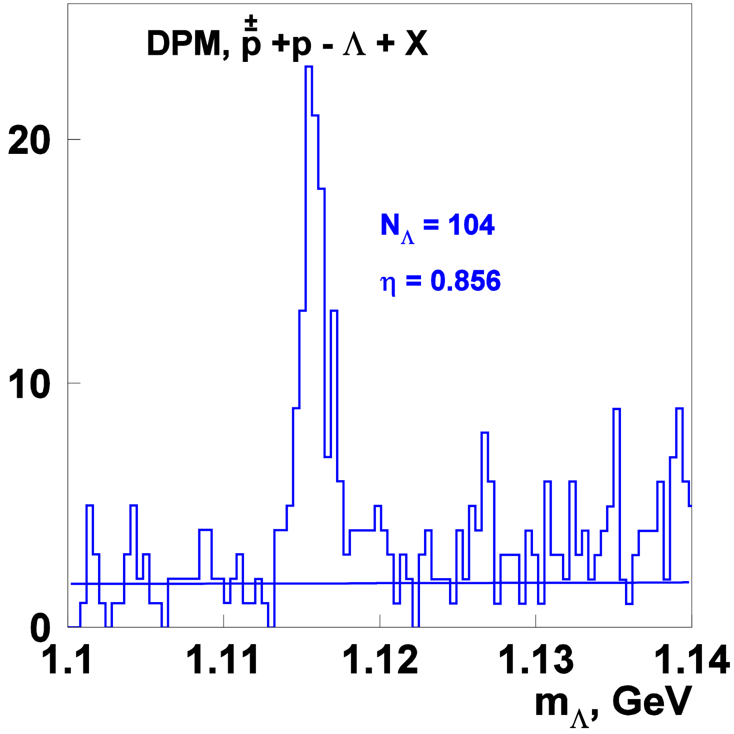
$$t = t_c \sqrt{\frac{m^2}{p^2} + 1} \quad t_c = \frac{L}{c} \qquad \left| t(H^{+}) - t(H^{-}) \right| < 100\, ps$$

- Kinematic criterion

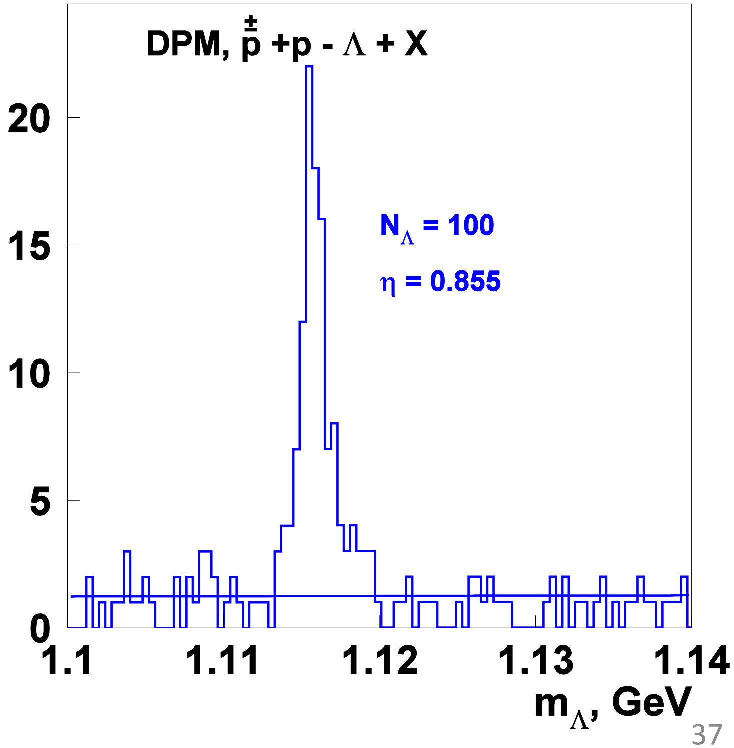
$$p(H^{-}) > p(H^{+}) \quad for \quad \overline{\Lambda} \qquad p(H^{-}) < p(H^{+}) \quad for \quad \Lambda$$

$$\overline{p} + p \rightarrow \Lambda + X$$

Pairs of hadrons with opposite charge and calculated Δt start <100 ps

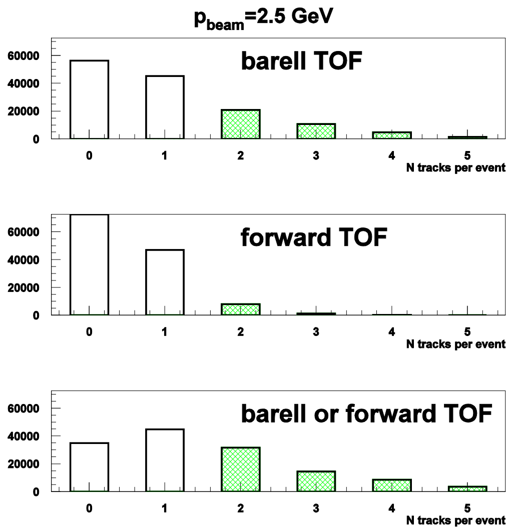


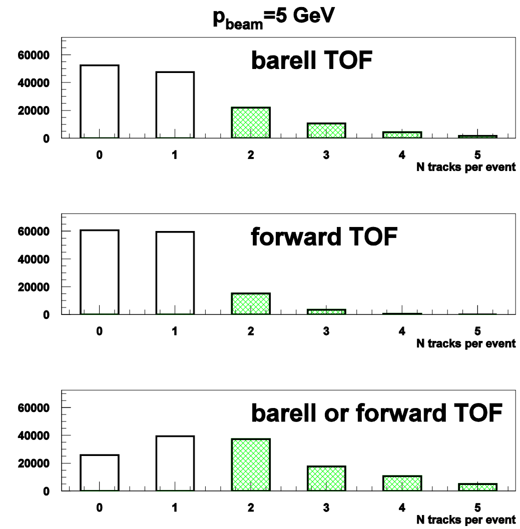
Pairs of hadrons with opposite charge and calculated Δt_{start} <100 ps and z_2>0.066 cm

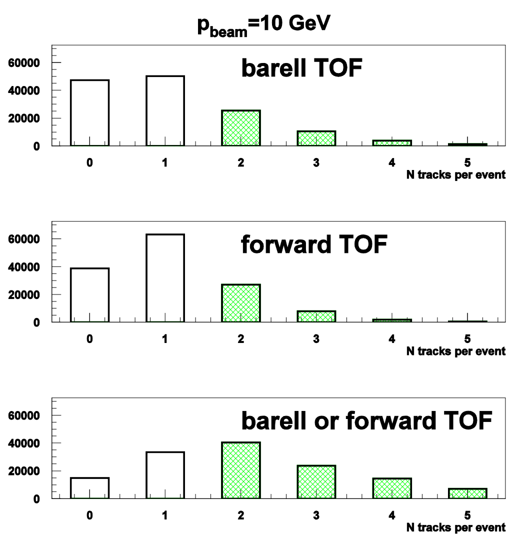


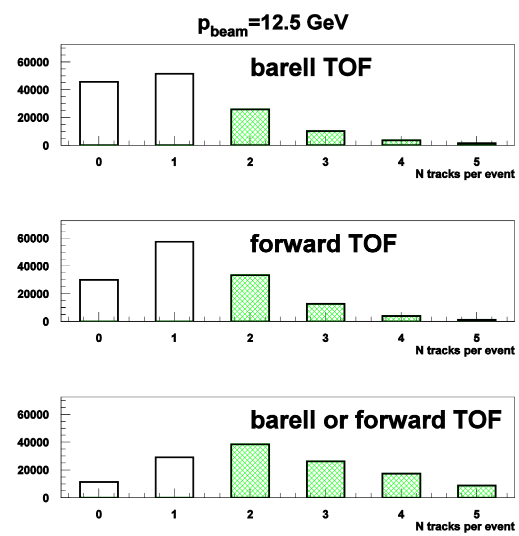
FTOF wall and barrel TOF multiplicities

$0.14\times10^{6}\ \bar{p}p$ interactions generated







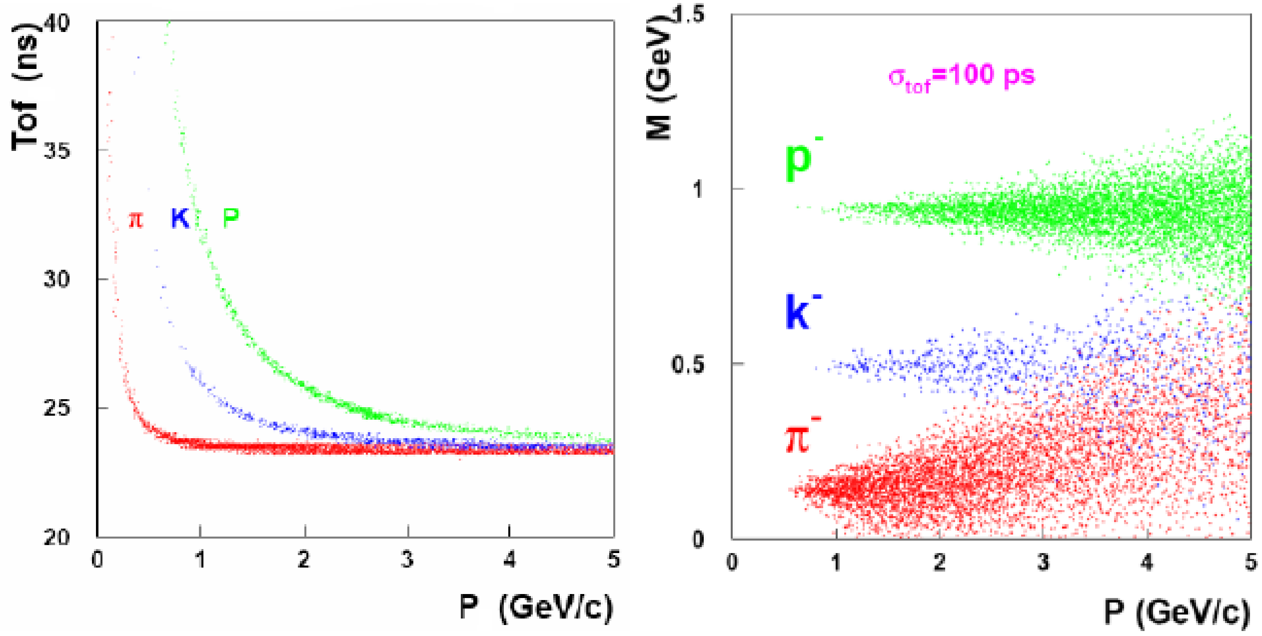


Time-of-flight PID with tracking and momentum analysis

$$m = p\sqrt{\frac{t^2}{t_c^2} - 1}$$

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

$t_c = L_{track} / c$ $L_{track} \simeq 7.5m$ (TOF wall position) $\sigma(TOF) = 50 - 100ps$



- **Good separation of hadrons up to 3-5 GeV**
- **Good event start reference in combination with FRICH at higher momenta**

Detection Efficiency of FTOF

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

acceptance of FS $\pm10\,\mathrm{deg.\ hor.}\ \pm5\,\mathrm{deg.\ ver.}\ \rightarrow\ \Omega_{FS}=0.09\,sr$

	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

Funding Modules 0-3

Contracting Party	Contribution (in 2005 M€)
Finland	5.00
France	27.00
Germany	705.00
India	36.00
Poland	23.74
Romania	11.87
Russia	178.05
Slovenia	12.00
Sweden	10.00
Total	**1.008,66**

- **International endeavour**
- **All numbers in 2005 €**
  escalation until 2018 ca. +50%
  i.e. about € 1.6 billion
- Most contributions in-kind

Binary reactions

$$\bar{p} + p \rightarrow \bar{h} + h$$

$$h = \text{hyperons} : \mathbf{\Lambda, \Sigma, ...\Omega_C}$$

$$h = \text{mesons} : \mathbf{...D...}$$