Детектор для Супер Ц-Тау фабрики

А.Ю. Барняков

ИЯФ СО РАН им. Г.И. Будкера,
г. Новосибирск

13 декабря 2019

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СЦТФ (Новосибирск) и HIEPA (Hefei)

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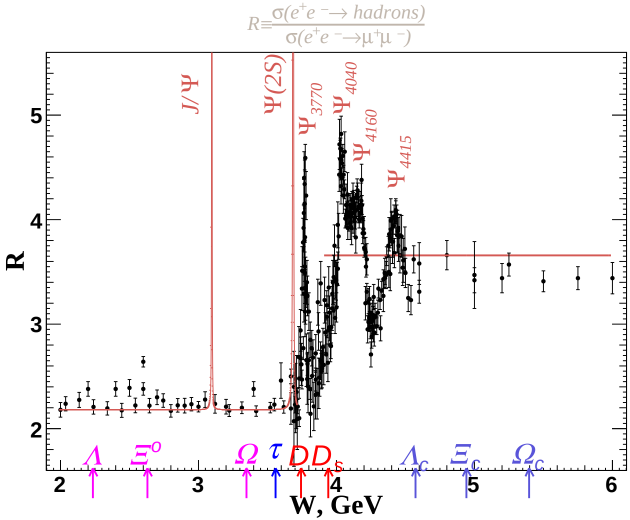
Перспективные детекторные технологии

Диапазон рабочих энергий СЦТФ



Зависимость R от энергии в области W=2÷6 ГэВ.

Ожидаемые обьемы данных

Ожидаемый $\int L dt \approx 1000\ fb^{-1}$/год

Energy, GeV	L, fb^{-1}	
3.096	300	J/ψ rare decays light hadr. spectroscopy
3.554	50	$e^+e^- \to \tau^+\tau^-$ (threshold)
3.686	150	$\psi(2S)$ J/ψ-spectroscopy light hadr. spectroscopy
3.770	300	$\psi(3770)$ (D-meson study)
4.170	100	$\psi(4160)$ (D_s-meson study)
4.650	100	$e^+e^- \to \Lambda_c\bar{\Lambda}_c$ (maximum)

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HIEPA: $\int Ldt \approx 10^{35}cm^{-2}s^{-1} \times 86400s \times 180days \times 90\% = 1.4ab^-1/year$

	CLEO-c		BES-III/year **$10^{33}cm^{-2}s^{-1}$ ($10fb^{-1}$)**	HIEPA/year **$10^{35}cm^{-2}s^{-1}$ ($1ab^{-1}$)**	Belle-II/year **$10^{36}cm^{-2}s^{-1}$ ($10ab^{-1}$)**
J/ψ	–	–	$10{\cdot}10^9$	$10{\cdot}10^{11}$	–
$\psi(2S)$	54 pb^{-1}	$27{\cdot}10^6$	$3{\cdot}10^9$	$3{\cdot}10^{11}$	–
$\psi(3770)$	818 pb^{-1}	$5{\cdot}10^6\ D\bar{D}$	$4{\cdot}10^7$	$4{\cdot}10^9$	$\geqslant \times 3$
4.17 GeV	586 pb^{-1}	$7{\cdot}10^5\ D_s\bar{D}_s$	$1{\cdot}10^6$	$1{\cdot}10^8$	$\geqslant \times 10$
$\tau^+\tau^-$		$4{\cdot}10^6$	$3{\cdot}10^7$	$3{\cdot}10^9$	$1{\cdot}10^{10}$

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4.650	100	$e^+e^- \to \Lambda_c\bar{\Lambda}_c$ (maximum)

- Физическая программа эксперимента предполагает регулярные перестройки по энергии в широком диапазоне.
- Под какие физические процессы оптимизировать детектор?
- Для поиска "Новой физики" нужен безкомпромисно-хороший детектор.

HIEPA: $\int Ldt \approx 10^{35} cm^{-2}s^{-1} \times 86400s \times 180days \times 90\% = 1.4ab^{-}1/year$

	CLEO-c		BES-III/year $10^{33}cm^{-2}s^{-1}$ ($10fb^{-1}$)	HIEPA/year $10^{35}cm^{-2}s^{-1}$ ($1ab^{-1}$)	Belle-II/year $10^{36}cm^{-2}s^{-1}$ ($10ab^{-1}$)
J/ψ	–	–	$10 \cdot 10^9$	$10 \cdot 10^{11}$	–
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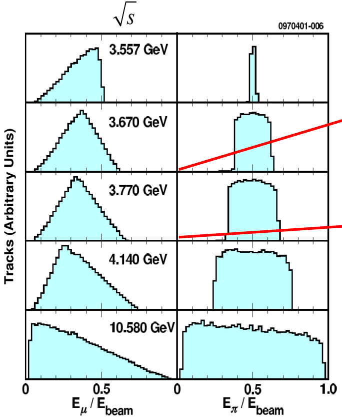
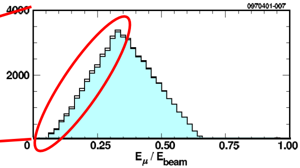
$\psi(3770)$	818 pb^{-1}	$5 \cdot 10^6$ $D\bar{D}$	$4 \cdot 10^7$	$4 \cdot 10^9$	$\geqslant \times 3$
4.17 GeV	586 pb^{-1}	$7 \cdot 10^5$ $D_s\bar{D}_s$	$1 \cdot 10^6$	$1 \cdot 10^8$	$\geqslant \times 10$
$\tau^+\tau^-$		$4 \cdot 10^6$	$3 \cdot 10^7$	$3 \cdot 10^9$	$1 \cdot 10^{10}$

τ decay two and three body momentum spectra



$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$ $\tau^- \to \pi^- \nu_\tau$

Michel parameter η

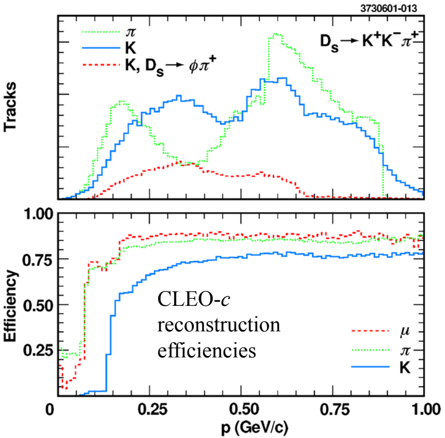


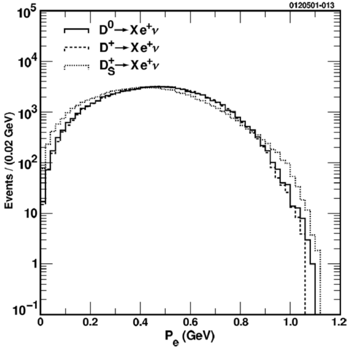
$\eta = 0$

$\eta = 0.2$

$\sqrt{s} = 3.77$

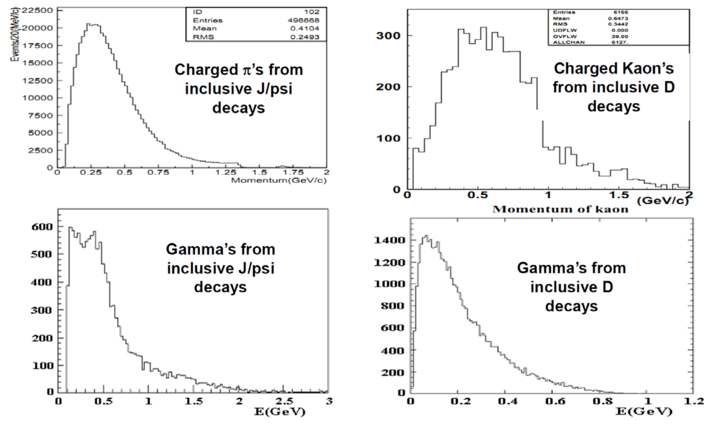
D_s^+ decays – typical momentum spectra





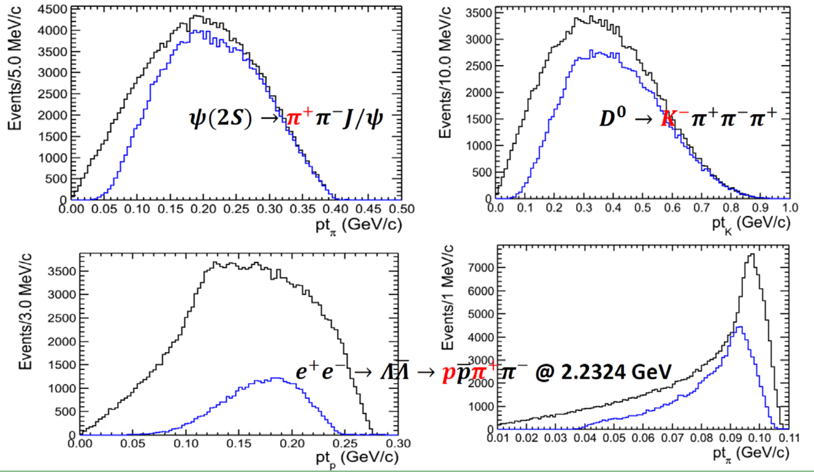
semileptonic D decay: electron momentum spectra

Inclusive spectra



Low momenta matter

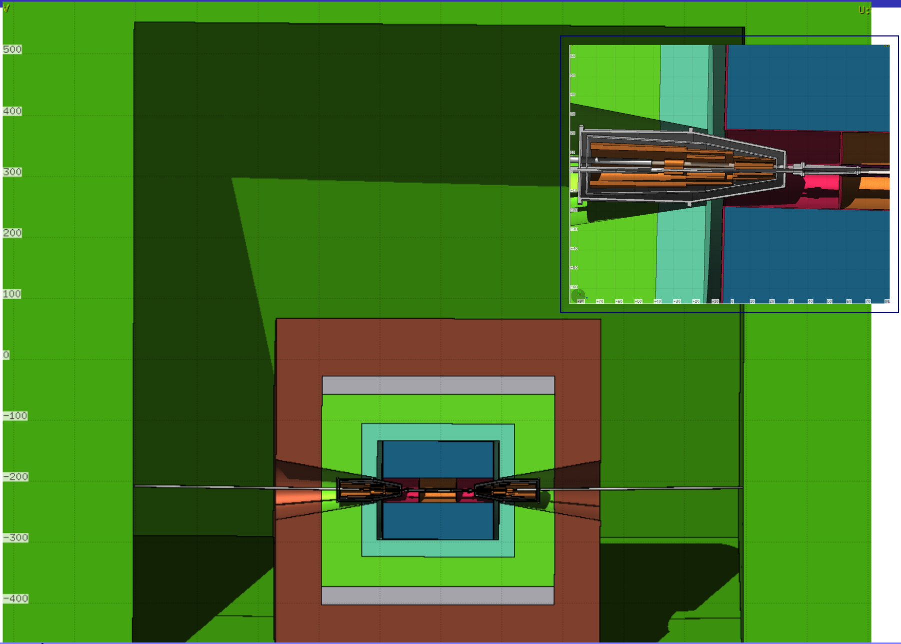
- Low momentum tracking efficiency and momentum are important



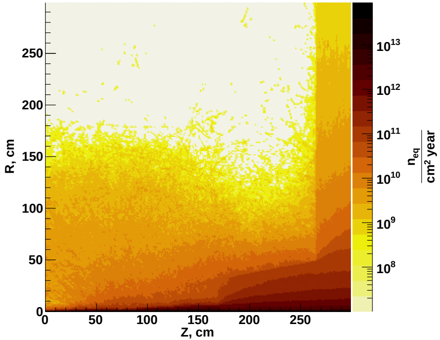
Should the particle ID system be able to tell a p from a K or π?

Caltech David Hitlin Tau/charm Workshop Orsay December 7, 2018 8

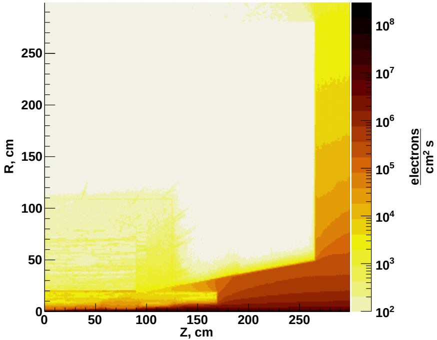
Моделирование фонов в детекторе



Физический фон в детекторе



1 MeV equivalent neutron dose for silicon



Electrons flux per second

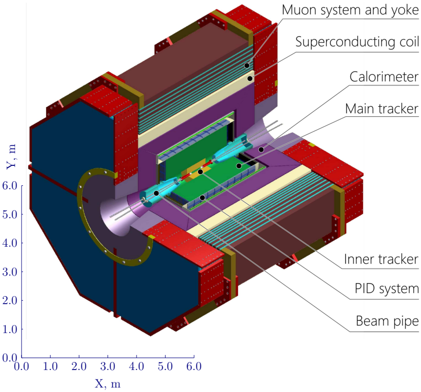
Два основных процесса рассмотренно:

- BhaBha рассеяние ($\sigma \approx 1.7$ mb for 2E = 7 GeV and $\Theta \geqslant 5^\circ$);
- $e^+e^- \to \gamma^*\gamma^* \to e^+e^-e^+e^-$ ($\sigma \approx 6.0$ mb for 2E = 7 GeV).

Основные выводы:

- Доза нейтронов $\leqslant 10^{11} n_{eq} cm^{-2}$/год
- При частоте столкновений $2 \cdot 10^8 c^{-1}$ в каждом событии может быть 4 фоновых трека
- С учетом толщины ЦВК и магнитного поля (1.5 Тл) в области внутреннего трекера загрузка составляет $10^4 \div 10^5 \frac{\text{электрон}}{\text{см} \cdot \text{с}}$

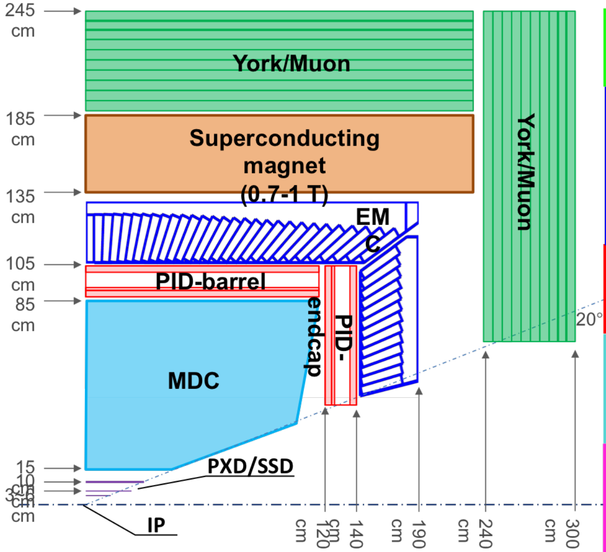
Концепция детектора СЦТФ.



Physics requirements:

- Good $\frac{\sigma_P}{P}$ for charged particles.
- Good symmetry and hermeticity;
- Soft track detection;
  - Inner tracker to work with rate of charged tracks $\geqslant 10^4 \frac{\textbf{tracks}}{cm^2 \cdot s}$;
- Good $\mu/\pi/K$-sep. up to 1.5 GeV/c;
  - Good $\frac{dE}{dx}$ resolution;
  - Specialized PID system for μ/π and π/K-separation;
- Good π^0/γ-separation and γ detection with E_γ=10÷3000 MeV;
  - EM calorimeter with σ_E as close as possible to physics limit;
  - Fast calorimeter ($\sigma_t \leqslant$1 ns and small shaping time) to suppress beam background and pileup noise;
- DAQ rate ~ 300 kHz at J/ψ-peak.

HIEPA detector concept



MUD

μ/π suppression power >10

EMC

Energy range: 0.02-2GeV

At 1 GeV	σ_E (%)
Barrel(Cs(I):	2
Endcap (Cs):	4

PID

π/K (and K/p) 3-4σ separation up to 2GeV/c

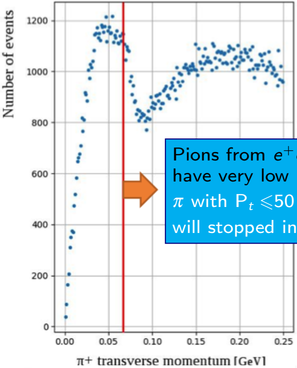
MDC

- σ_{xy}=130 μm
- dE/dx<7%, σ_p/p =0.5% at 1 GeV

PXD

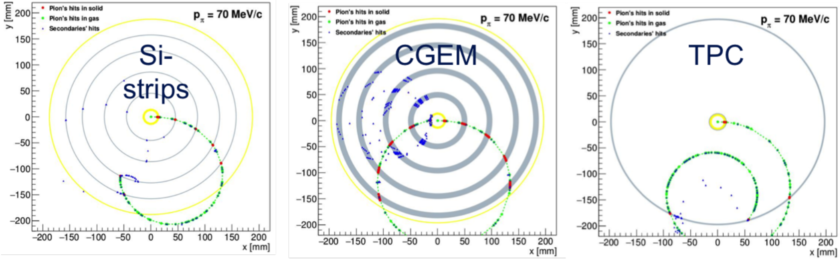
- Material budget ~0.15%X_0 / layer
- σ_{xy}=50 μm

Внутренний трекер



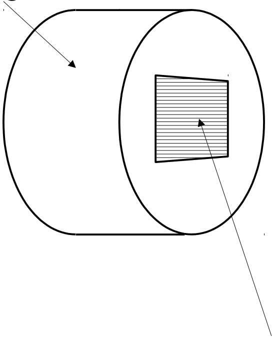
Pions from $e^+e^- \to DD^*$ have very low momenta;
π with $P_t \leqslant 50$ MeV/c will stopped in beam-pipe;

- The TPC is more attractive option:
  - More hits per track,
  - more reliable dE/dx – measurements.
- TPC capability to reconstruct the tracks in expected experimental conditions will be checked with full simulation soon.



Прототипирование опции ВПК (TPC)

Prototype construction



Main goals:

1) Check IBF;
2) Test the field cage design;
3) Compare readout options;
4) Verify the gas mixture properties;
5) Data rate estimation.

Conclusions

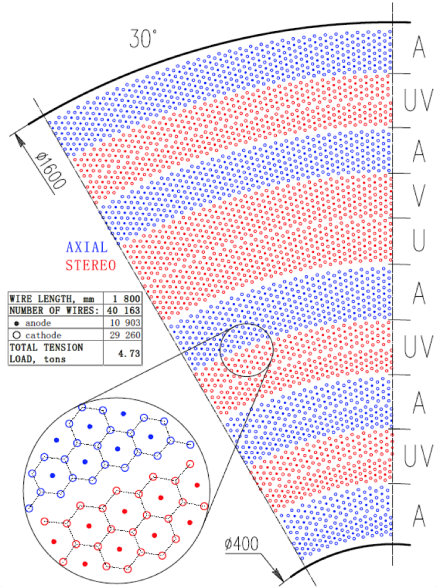
- Three options of Inner Tracker are considered
  - Si-strips — reconstruction for $p_\pi > 65$ MeV/c
  - CMPGD — reconstruction for $p_\pi > 60$ MeV/c
  - TPC
    - Standard wall — reconstruction for $p_\pi > 60$ MeV/c
    - Thin wall — reconstruction for $p_\pi > 55$ MeV/c
- The TPC options is the favorite at the moment.
- The simulations shows the small distortions level from the ion backflow for Ne and Ar based gas mixtures.
- The reconstruction software is developing.
- The prototype of TPC is designed and will be build in the near future.

Drift Chamber

Traditional DC optimization:

- Hexagonal cell, size $\sim$0.8÷1.2 cm.
- 41 layers: 5 stereo and 5 axial super-layers.
- 10903 – anode wires.
- He/C_3H_8(60%/40%).
- ⋆ $\sigma_x \leqslant 90\ \mu$m.
- ⋆ $\frac{\sigma_P}{P_t}$(1GeV/c) $\sim$0.38%.
- ⋆ $\frac{\sigma_{dE/dx}}{\left\langle \frac{dE}{dx} \right\rangle} \leqslant$7%.

Prototyping is going.



WIRE LENGTH, mm	1 800
NUMBER OF WIRES:	40 163
● anode	10 903
○ cathode	29 260
TOTAL TENSION LOAD, tons	4.73

Опция ультра-легкой ДК from INFN-Lecce

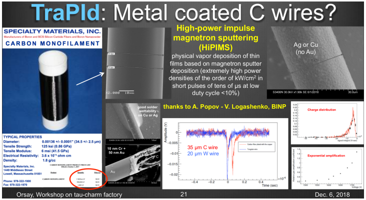
TraPId: A proposal for SCTF

$R_{in} – R_{out}$ [mm]		200 – 800
active L – service area [mm]		1800 – 200
inner cylindrical wall		
C-fiber/C-foam sandwich	2×80 µm / 5 mm	0.036 g/cm² – 8×10^{-4} X/X_0
outer cylindrical wall		
C-fiber/C-foam sandwich	2×5 mm / 10 mm	0.512 g/cm² – 1.2×10^{-2} X/X_0
end plate		
gas envelope	160 µm C-fiber	0.021 g/cm² – 6×10^{-4} X/X_0
instrumented wire cage	wire PCB, spacers, HV distr. and cables, limiting R, decoupling C and signal cables	0.833 g/cm² – 3.0×10^{-2} X/X_0

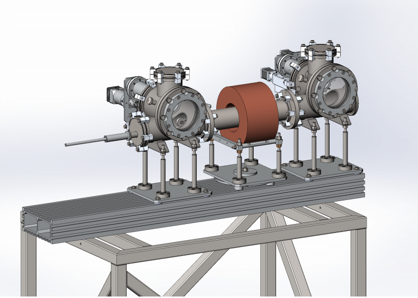
cell	
shape	square
size [mm]	7.265 – 9.135
layer	
8 super-layers	8 layer each
64 layer total	
stereo angles	66 – 220 mrad
n. sense wires [20µm W]	23,040
n. field wires [40/50µm Al]	116,640
n. total (incl. guard)	141,120
gas + wires [600 mm]	
90%He – 10%iC_4H_{10}	4.6×10^{-4}
W + 5 Al ➔ Ti + 5 C	(13.1 ➔ 2.5)$\times10^{-4}$

Orsay, Workshop on tau-charm factory 22 Dec. 6, 2018

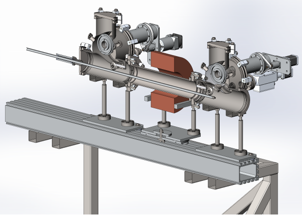
Cylindrical magnetron sputtering apparatus



Orsay, 2018. F.Grancagnolo



Project of cylindrical magnetron sputtering apparatus.



Sectional view.

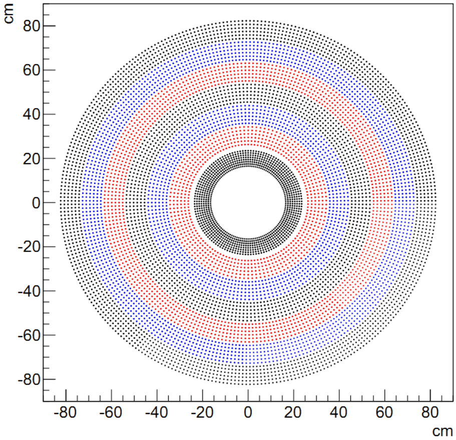
- Project is ready.
- Cylindrical magnetron is made. Stable discharge is obtained.
- The system of wire moving is in production process.

Статус R&D ДК в ИЯФ

- Выполнен расчет и оптимизация дрейфовой ячейки, газовой смеси и предложен проект ДК для СЦТФ
- Сделан предварительный расчет конструкции ДК в ANSYS
- Ведутся исследование качества проволоки
- Идет подготовка и запуск стендов для изучения старения проволочек и оптимизации газовых смесей
- Ведется поиск вариантов покрытия проволоки золотом как в ИЯФ, так и среди промышленных партнеров
- Изучаются возможности использования современных композитных материалов в конструкции ДК

HIEPA DC concept

Outer Tracker: A Drift Chamber



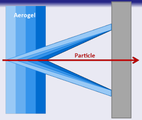
- Rin = 18 cm, Rout = 85 cm, L = 2.4 m
- Helium-based gas: He/C_2H_6 (60/40)
- Small square cells:
  1.0 cm (chamber inner, high rate)
  1.6 cm (chamber outer, low rate)
- Sense wire: 20 um W
  Field wire: 110 um Al
- 44 layers
- Sharing field wire layers at the axial-stereo boundaries.
- Carbon fiber for both inner and outer walls
- Expected spatial resolution: <130µm
- Expected dE/dx resolution: <7%

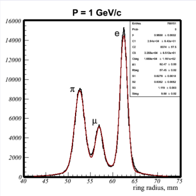
PID system: FARICH

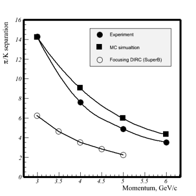
FARICH method

- Increase N_{pe} w/o σ_{Θ_c} increase;
- μ/π-sep.$\sim 5\sigma$ at 1 GeV/c

was obtained in beam tests;



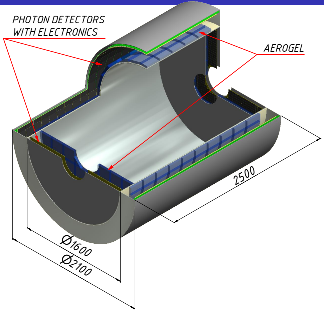




Status & perspectives:

No any showstopers have been found yet, but there are several challenges:

- ! Mass-production of the multilayer focusing aerogel.
- ! 1.5 million of SiPMs and their radiation hardness.
- ! Big data flow in DAQ system.

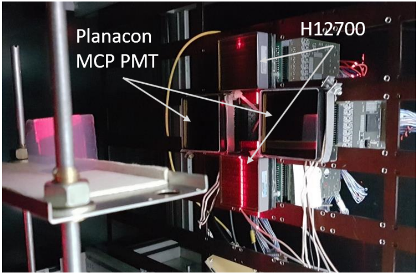


FARICH system parameters:

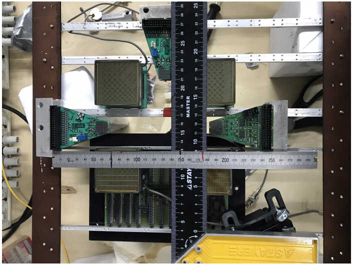
- Focusing aerogel with n_{max}=1.05(1.07?), 4 layers, total thickness 35 mm
- Aerogel area: 14 m^2
- Photon detectors (3×3 mm^2):
  - Barrel – SiPMs (16 m^2)
  - Endcap – MCP PMT (5 m^2) LAPPD?
- $1\div2\cdot10^6$ channels (it depends on pitch)
- Load 0.5÷1.0 MHz/channel
- Cooling system ($\leqslant$-30°C) is needed
- R&D for read out electronics is required.

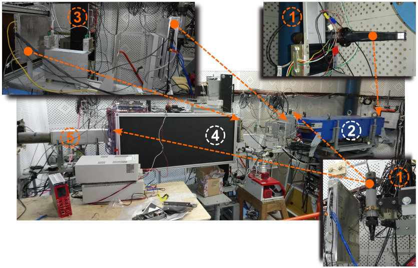
2018: 3^{rd} prototype generation

- Determine critical moments in focusing aerogel production;
- Define optimal photon detector type and producer for SCTF;
- Find solution for readout electronics.



Photon detectors plane





MaPMTs 8×8 pixels □6 mm

SiPM arrays 4×4 pixels □3 mm;

Tracker based on GEMs $\sigma_x \sim 70\mu$m;

Readout electronics based on PaDiWa (discriminator) and TRB3 (TDC) from GSI.

- e^- with E=3 GeV;
- Only central tracks are selected (20x16 mm area);
- Time window $\sim$ 25 ns;
- Cut on energy deposited in NaI is aplied;

Alternative PID options

Why we need to find alternatives to FARICH

- μ/π-separation below 400 MeV/c;
- The aerogel RICH with largest radiator area. $\rightarrow$ Multilayer aerogel production is very challenge issue!
- 16 m^2 of SiPMs with 10^6 pixels:
  - Radiation hardness and cooling system which lead to increase material budget before EMC is a complex engineering task;
  - Such amount of the SiPMs with appropriate parameters is a rather large batch for one manufacturer (Hamamatsu, FBK, KETEK, SensL?!).
- 5 m^2 of MCP-PMTs. The very good approach is to use LAPPD with 20$\times$20 cm^2 size, but readout system should be optimized for our task to obtain the spatial resolution $\leqslant$1 mm in both directions.
- The total estimated coast of the FARICH system $\approx$ EMC of the detector.

ASHIPH with SiPM

MCP PMT → SiPM

Pros:

	MCP PMT	SiPM
PDE=QE*CE	25*0.6≈15%	30-45%
Magnetic field imm.	Axial	Any direction
Power supply	2÷4 kV	<100V

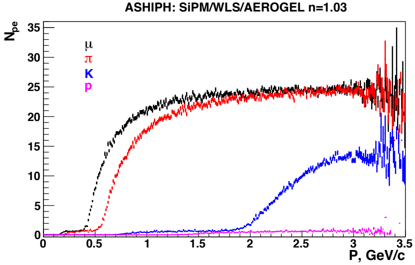
Cons:

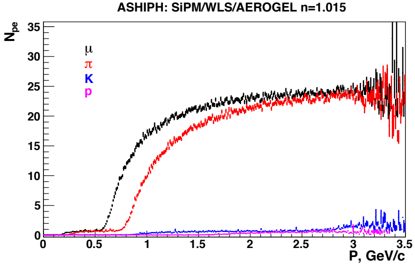
- High level of noise → New specific FEE → Cooling system
- Radiation tolerance is still low.

It is possible to upgrade KEDR and SND ASHIPH systems right now.

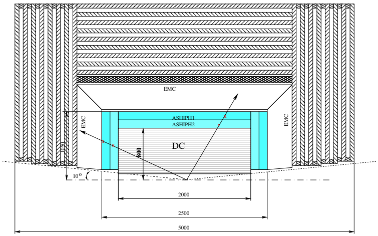
For Super Cτ (B)- Factories SiPM radiation tolerance study is needed.

ASHIPH with SiPM for μ/π-separation





Number of photoelectrons vs P MeV/c



ASHIPH with SiPM

- π/K-separation from 500 to 2000 MeV/c
- μ/π-separation from 400 to 900 MeV/c
- Preliminary design:
  - 6000 l of aerogel in three layers: n=1.03 (8 cm) and n=1.015 (8+8 cm)
  - 1400 counter with sizes $\sim$ $18 \times 30 \times 8$ cm
  - n=1.03 (8 см) и n=1.015 (16 см)
  - Amount of material $\sim 15\% X_0$
  - Light collection – WLS(BBQ) and 28000 SiPMs 3×3 mm^2

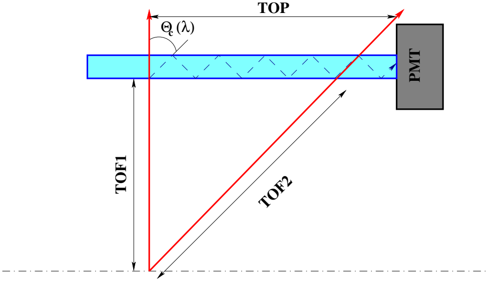
ToF + ToP

- The record time resolution (~5 ps) was obtained with quartz radiator coupled to MCP PMT.
- The best accuracy of TOF measurement achieved in currently operating colliding beam experiment is about 80 ps (BESIII).
- The time resolution of about 30 ps is considered for future upgrade of the CMS detector.
- The time resolution of about 15 ps is the aim of TORCH project — a time-of-flight detector.
- Recent progress in time-of-flight technique allows us to consider the TOF system with intrinsic time resolution better than 30 ps.

Time resolution mainly is determined by:

- refractive index dispersion
- time of light collection
- photon detector & electronics jitter

It is possible to use TOP information in addition to TOF.



TOF & TOP

For perpendicular tracks with $\beta \geqslant \frac{1}{\sqrt{n(\lambda)^2-1}}$

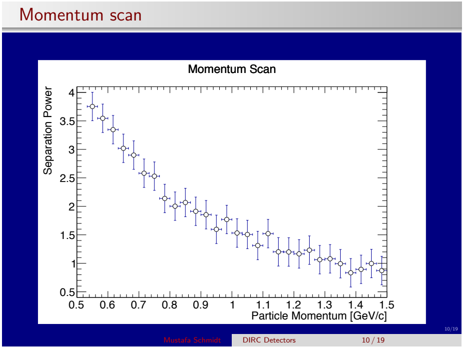
$$\mathrm{TOP} \sim \frac{L}{c/n(\lambda)} \cdot \frac{\beta \cdot n(\lambda)}{\sqrt{n(\lambda)^2\beta^2-1}} = \frac{L}{c} \cdot \frac{n(\lambda)^2\beta}{\sqrt{n(\lambda)^2\beta^2-1}}$$

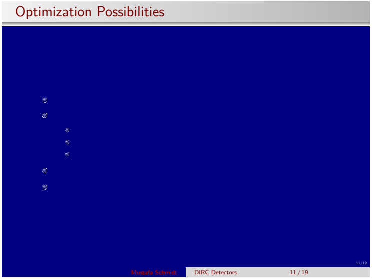
Time of Propagation (ToP) can improve the Time of Flight (ToF).

FDIRC опция from Giessen Univ.

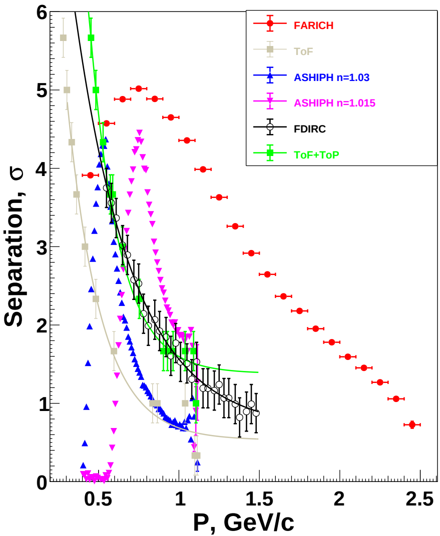
Few comments to DIRC option

- Sufficient change of yoke geometry and calorimeter is needed.
- DIRC is very compact system in barrel part, therefore it is possible to increase DC or decrease the EMC volume.
- Good enough μ/π-separation is provided up to 700 MeV/c $\rightarrow$ further improvement or use additional PID technique is needed to separate μ and π up to 1.2 GeV/c.





Сравнение опций системы идентификации

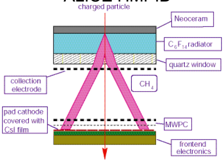


μ/π-разделение разных PID опций в параметрическом моделировании

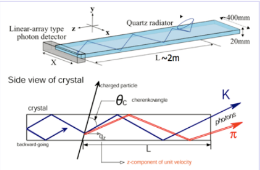
Detector Options

- RICH
  - Very powerful over a wide range of momentum
  - Reconstruction straightforward
  - Additional space for Cherenkov cone expansion: less compact
  - A large number of readout channels : cost, cooling …
- DIRC-like: iTOP, FTOF, DIRC …
  - Very compact, operation convenient
  - Reconstruction complicated
  - Quartz manufacturing and processing very challenging

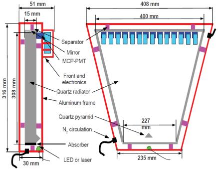
ALICE HMPID



iTOP for BELLE2

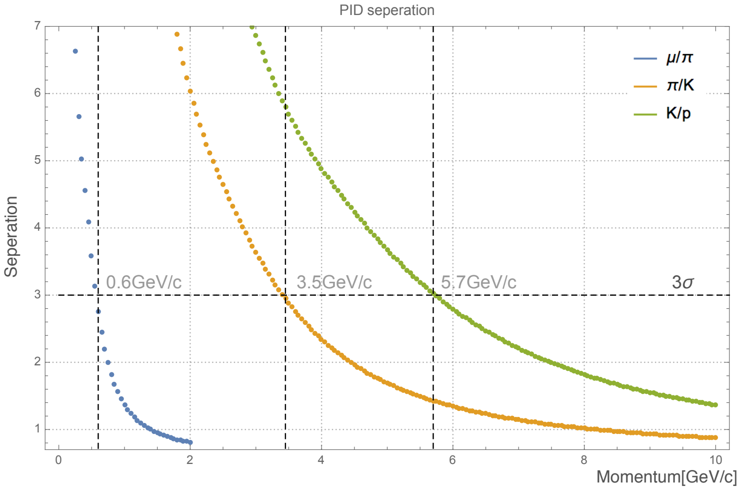


FTOF for superB



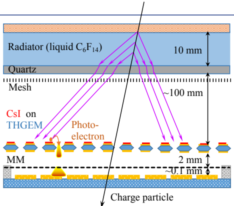
HIEPA: PID capability simulation

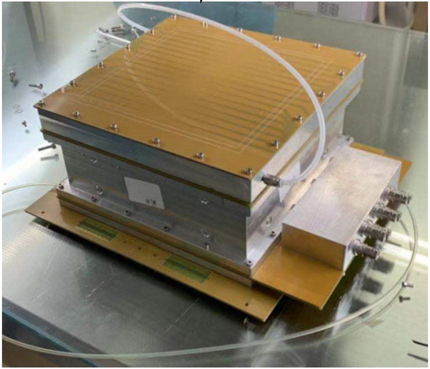
PID separation for vertical incidence



HIEPA RICH prototype

RICH Prototype development





- Effective area: 16X16 cm^2
- Quartz/MgF_2 as radiator (10mm) will be replaced by C6F14
- Drift region 94mm
- THGEM+CsI (700nm)
- MicroMegas
- Anode pad(5mm^2)
- AGET FEE: 1024 channels

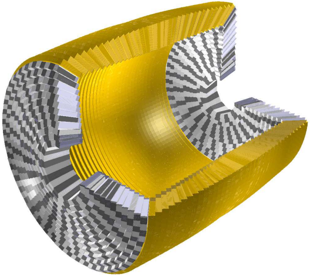
10

EMCalorimeter based on pure CsI

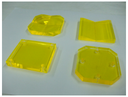
CsI(pure):

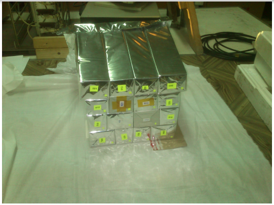
- $\tau \approx 30$ ns.
- Using of WLS(NOL-9) coupled with CsI(pure) crystal($6\times6\times30$ cm^3) and 4 APDs (Hamamatsu S8664-55) increase LO in 6 times.
- Prototype consisting of 16 crystals, 64 APDs and all necessary readout electronics are ready for beam tests at BINP in 2019.
- ENE=330±30 keV is obtained with cosmic muons.

Calorimeter geometry



Described in DD4HEP





BINP has a team experienced in constructuion and operation of crystal based calorimeters: SND (NaI), CMD-3 (CsI(Tl) and BGO), KEDR (CsI(Tl)) and Belle-II (CsI(Tl)).

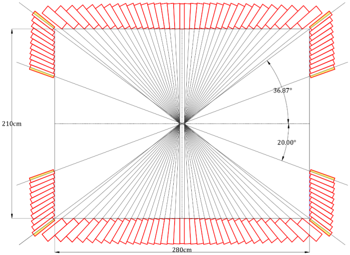
CsI(pure) calorimeter for SCTF:

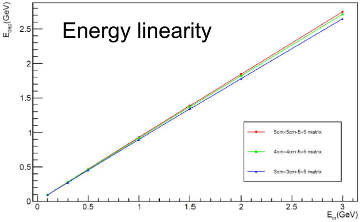
- Thickness $16/18X_0$ – 30/34 cm.
- 7424 crystal, total weight: 36/43 tons.
- 29696 APDs + 7424 WLSs or 7424 Photopentodes.

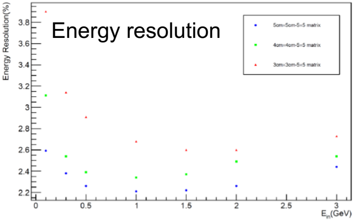
HIEPA ECAL concept

ECAL Design

- Barrel has 4200 crystals arranged in 35 circles with 120 bars.
- Each endcap has 1256 crystals
- Total radiation length : 15 X_0





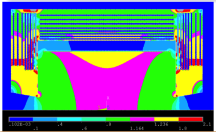


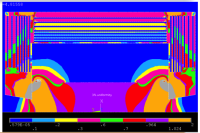
Muon system & Magnet system

Magnet system

Base option:

- B=1÷1.5 T;
- Volume with field ~30 m^3;
- W~28 MJ;
- Access to the detector systems ~12÷24 h.





Thin solenoid option:

- ⋆ B=1÷1.5 T;
- ⋆ Thick ~ 0.1 X_0;
- ⋆ Volume with field ~8 m^3;
- ⋆ W~7.5 MJ;
- ! Impact to σ_E is going to be considered with full detector simulation.

Muon system

Belle-II KLM system as a base option:

There are 9 and 8 gapes in the barrel and end-cap parts of the yoke correspondingly;

Active elements are scintillator strips which readout with help of WLS fibres coupled with SiPM (as Belle-II KLM system);

R&D and Belle-II experience adaptation is carrying out in LPI (Moscow).

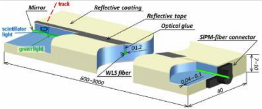


Fig. 1. Schematic view of the scintillator strip. Dimensions are in mm.

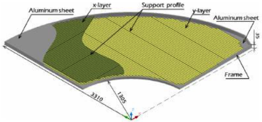
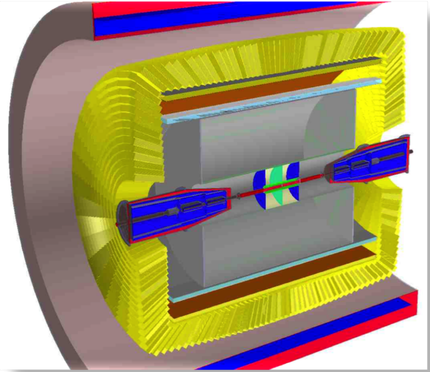


Fig. 2. Schematic view of one superlayer formed by scintillator strips. Sizes are given in mm.

Active element for Belle-II KLM system

Detector software & simulation: status



Detector geometry in DD4HEP

- Parametric simulation is ready to use;
- DD4HEP package is used for detector geometry description;
- Aurora framework is under active developing now. It is based on:
  - Gaudi and FCCSW;
  - build & config system inspired by ATLAS Athena;

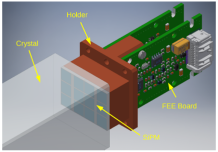
MU2E calorimeter based on pCsI and SiPMs

The Mu2e Calorimeter

The two Calorimeter annuli contain 674 34x34x200 mm^3 un doped CsI crystals each

- → R_{inner} = 374 mm, R_{outer}=660 mm, depth = 10 X_0 (200 mm)
- → Disks separated by 75 cm, half helix length

- → Each crystal is readout by two array UV extended SIPM's (14x20 mm^2) maximizing light collection.
  PDE=30% @ CsI emission peak =315 nm.
  GAIN ~10^6



- → TYVEK + tedlar wrapping
- → Analog FEE is onboard to the SiPM (amplification and shaping) and digital electronics located in electronics crates (200 MhZ sampling)
- → Cooling system – SiPM cooling, Electronic dissipation

- → Radioactive source and laser system provide absolute calibration and monitoring capability

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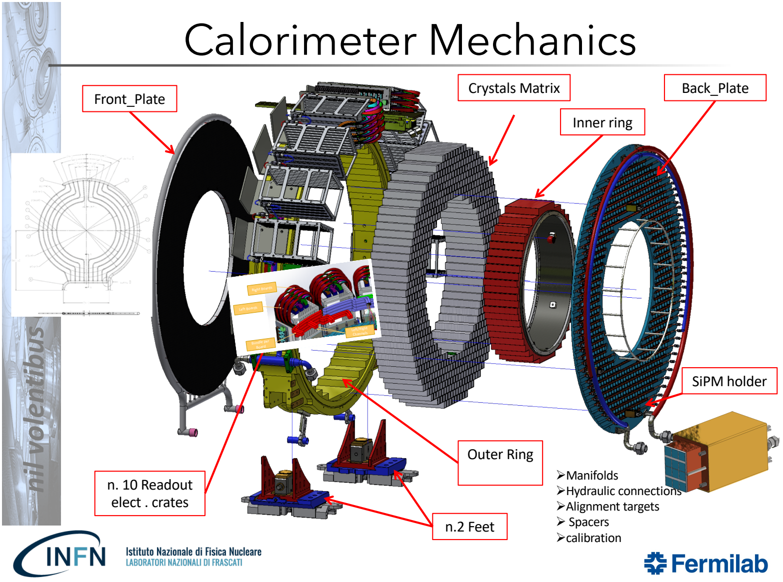
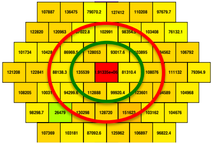
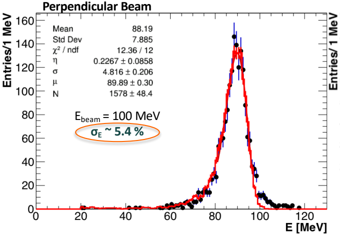
MU2E calorimeter: mechanics

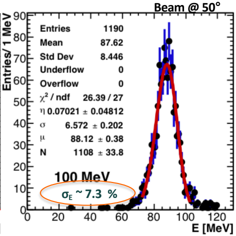


MU2E calorimeter: beam test results

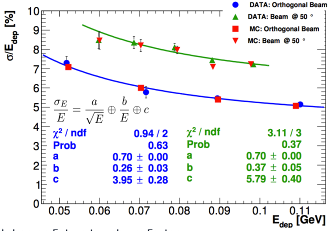
Module 0 - Energy resolution







- Single particle selection
- Equalization and E-scale
  - MIPs
  - 100 MeV e⁻ beam, up to ring **2**
- Threshold applied @ 3 σ (Noise)
- LY/SiPM = 30 pe/MeV
- **Great Data-MC agreement**



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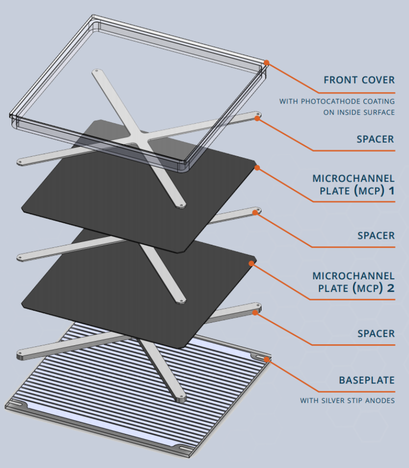
LAPPD: схема

LAPPD Structure

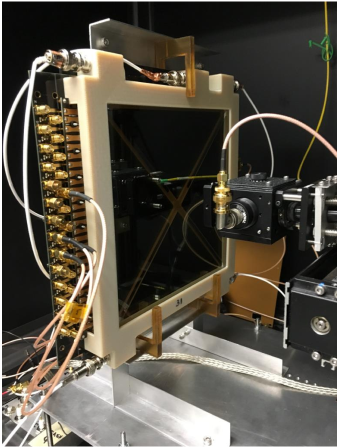
- Manufacured & sold by Incom, Inc.
- A 20 x 20 cm^2 MCP-PMT!
  - 350 cm^2 active area.

INCOM
BRIGHT IDEAS



*images from http://incomusa.com

LAPPD Anode Structure

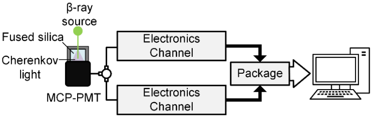


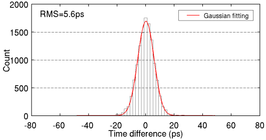
A. Lyashenko, VCI2019 Proceedings

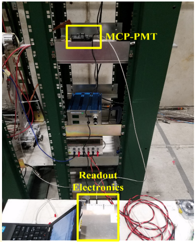
- "Generation I" LAPPDs have 28 anode strips.
- Total 28 strips.
- If we take rough spatial resolutions as 1x3 mm^2, this would correspond to order 10k pixels.
  - Equivalent 8x8 (32x32) Planacon photocathode area would require ~800 (12k) pixels.
- As long as occupancies are low, we can read out the entire tile with 56 electronics channels!
- At some performance cost, can also do single ended readout, 28 channels!

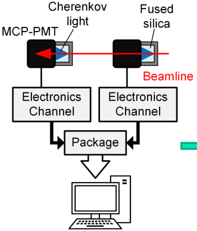
Пикосекундные детекторы на основе FPGA

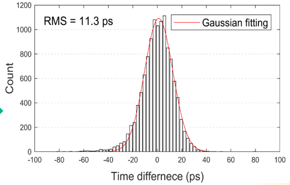
Test Results











Заключение

- В ИЯФ ведется разработка детектора для Супер Ц-Тау фабрики:
  - Внутренний детектор опция TPC и CMPGD
  - ДК с малой гексогональной ячейкой для ультра-легкой ДК разрабатывается установка магнетронного напыления металлов на углеродное волокно
  - Система идентификации: разработка технологии производства фокусирующих аэрогелей совместно с ИК и тестирование прототипов на пучке электронов
  - Прототип калориметра на основе 16 кристаллов чистого CsI подготавливается для испытаний на пучке
  - Прототипом магнитной системы детектора СЦТФ можно считать мганит детектора PANDA, который сейчас активно изготавливается командой ИЯФ
  - Разработка среды для моделирования детектора и физических процессов поддержана грантом РНФ в 2019г.
- В проекте HIEPA наиболее заметен прогресс в разработке
  - PID системы: RICH на основе жидкого радиатора и микроструктурного газового фотонного детектораб а так же DIRC-like-TOF для торцевой части
  - Ведется выбор кристаллов и схемы электроники для э/м калориметра
- С 2020 года работы в нескольких европейских институтах по разработке дететкора для СЦТФ будут поддержаны грантом в рамках проекта CREMLIN+
- Для того чтобы перейти к фазе строительсьства детектора через 4 года необходимо в ближайшем будущем увеличить активность работ по разработке и, соответственно, финансирование примерно в 10 раз.

Публикации 2018-2019гг.

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