Status of Super charm-tau factory project

LOGASHENKO IVAN (BINP, NOVOSIBIRSK)

13TH INTERNATIONAL WORKSHOP ON E+E- COLLISIONS FROM PHI TO PSI

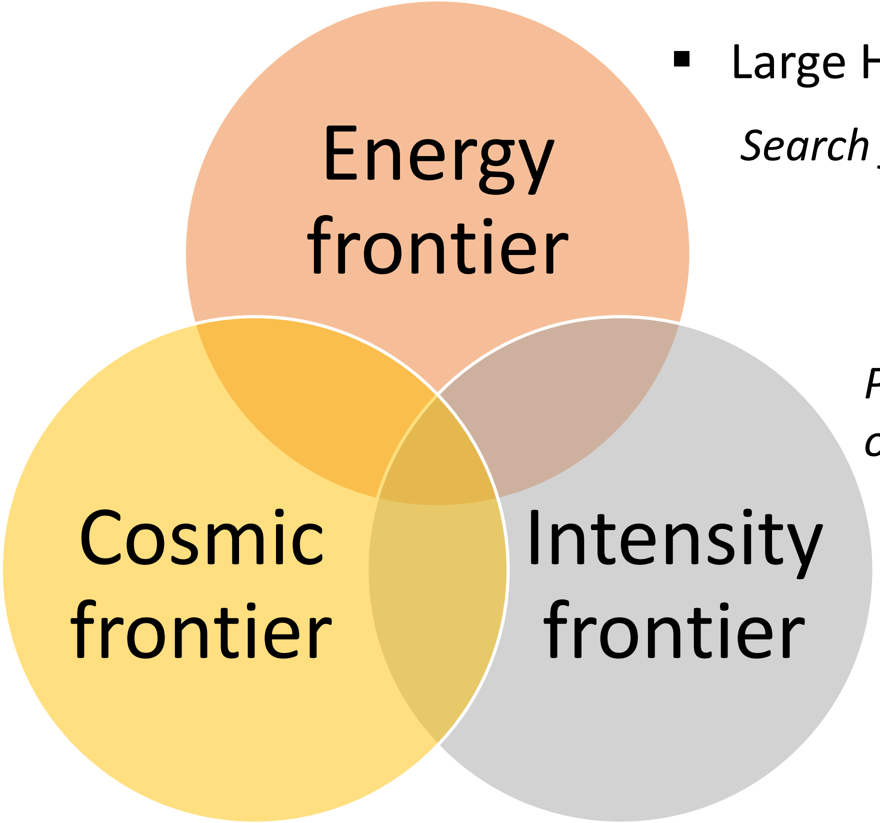
Partially supported by RSF grant 19-72-20114

Motivation

The global strategy for the particle physics

After the discovery of Higgs boson, the particle physics is focused on the deep understanding of the predictions of the Standard Model and on the search of phenomena beyond SM

There are many roads…



- Large Hadron Collider

Search for the new particles

- Dark matter
- Cosmic rays
- Space-based experiments

Precision study of properties of known particles

- **Colliders-Factories**
- Intensive beams
- Neutrinos
- Rare and precision experiments

Colliders-Factories

cτ-factories	**B-factories**	**Z- and H-factories**
BEPC-II (China)	PEP-II (USA), KEK-B (Japan)	LEP, LEP-2 (CERN)
⇩	⇩	⇩
Super $c\tau$ factory SCTF (Russia), STCF (China)	Super KEK-B (Japan) LHCb (CERN)	FCC-ee (CERN) CEPC (China)

Energy ranges of high luminosity colliders (factories) correspond to production thresholds of known particles.

Ultimate performance (precision) is determined by luminosity and detector quality

Generations of colliders-factories

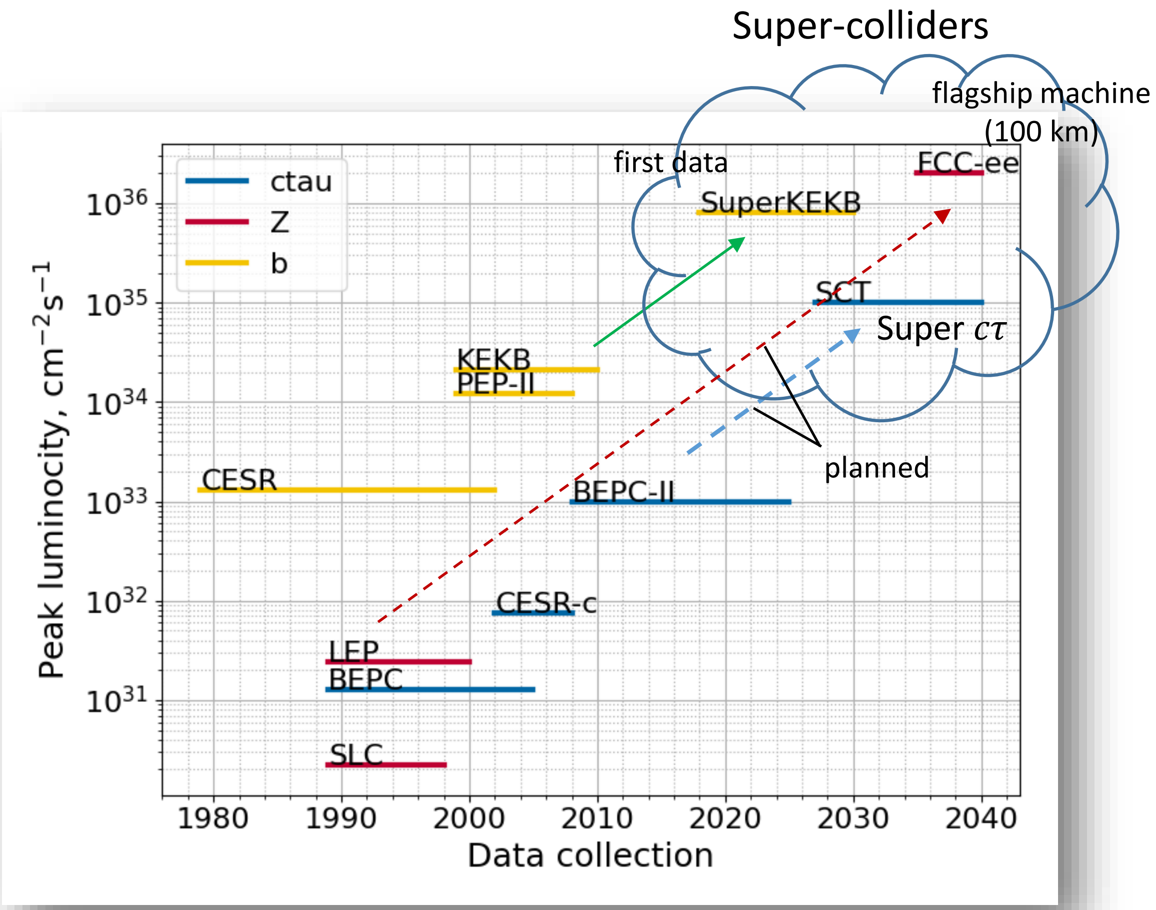
Today:

LHCb: 5 fb^{-1} → x10-60 → LHCb: 50/300 fb^{-1} (Run 3/4)

B-factories: 1 ab^{-1} → x50 → Super KEK-B: 50 ab^{-1}

BES-III: ~100 fb^{-1} → x100 → Super C-tau factory: ~10 ab^{-1}

Tomorrow:



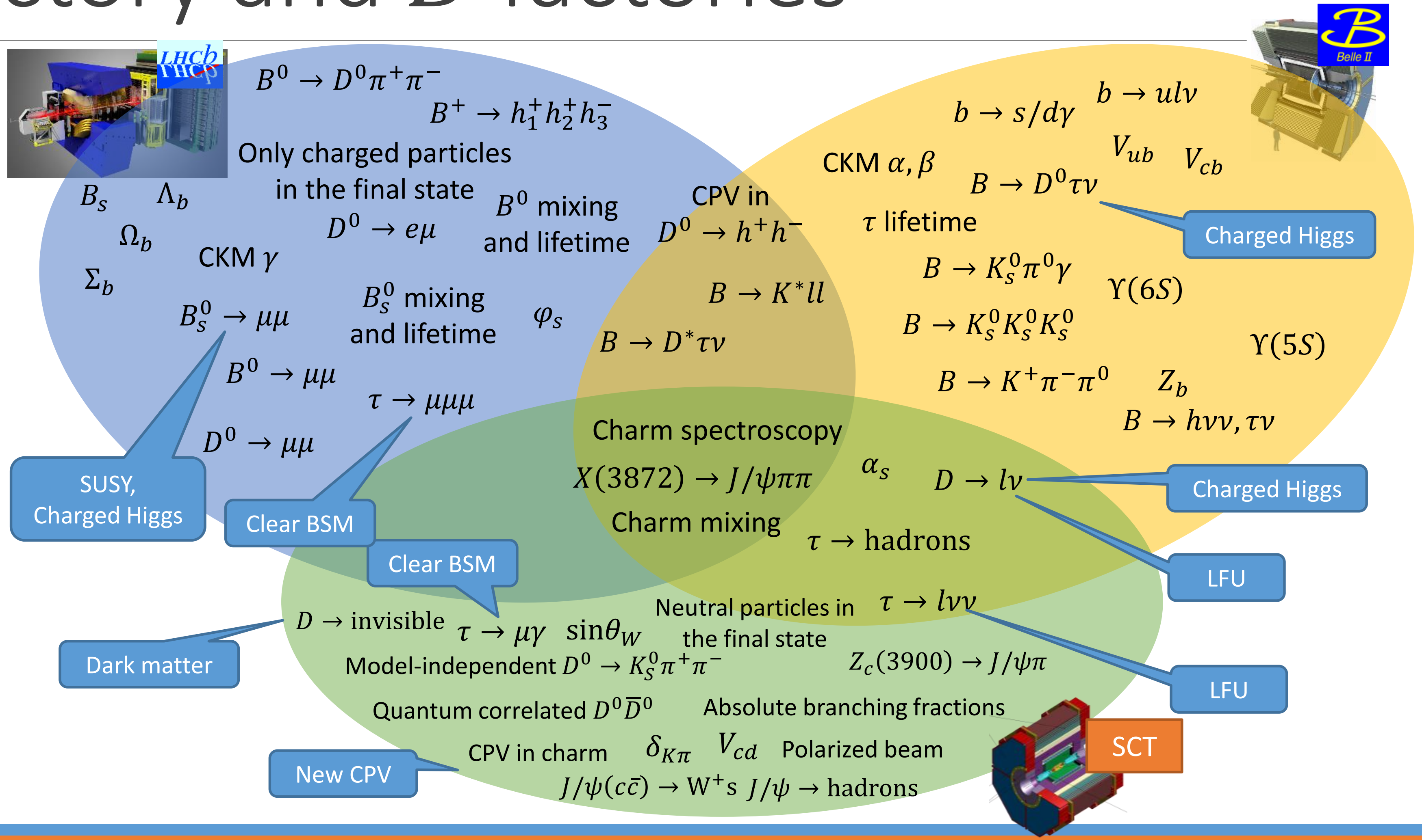
- There is balance/synergy between existing $c\tau$-factory (BES-III) and B-factories (BABAR, BELLE, LHCb)
- New generation B-factories started data taking (BELLE-2, LHCb)
- To keep balance, there is place for the new generation $c\tau$-factory

Super $c\tau$-factory is the natural part of the global particle physics strategy

Super $c\tau$ factory and B factories

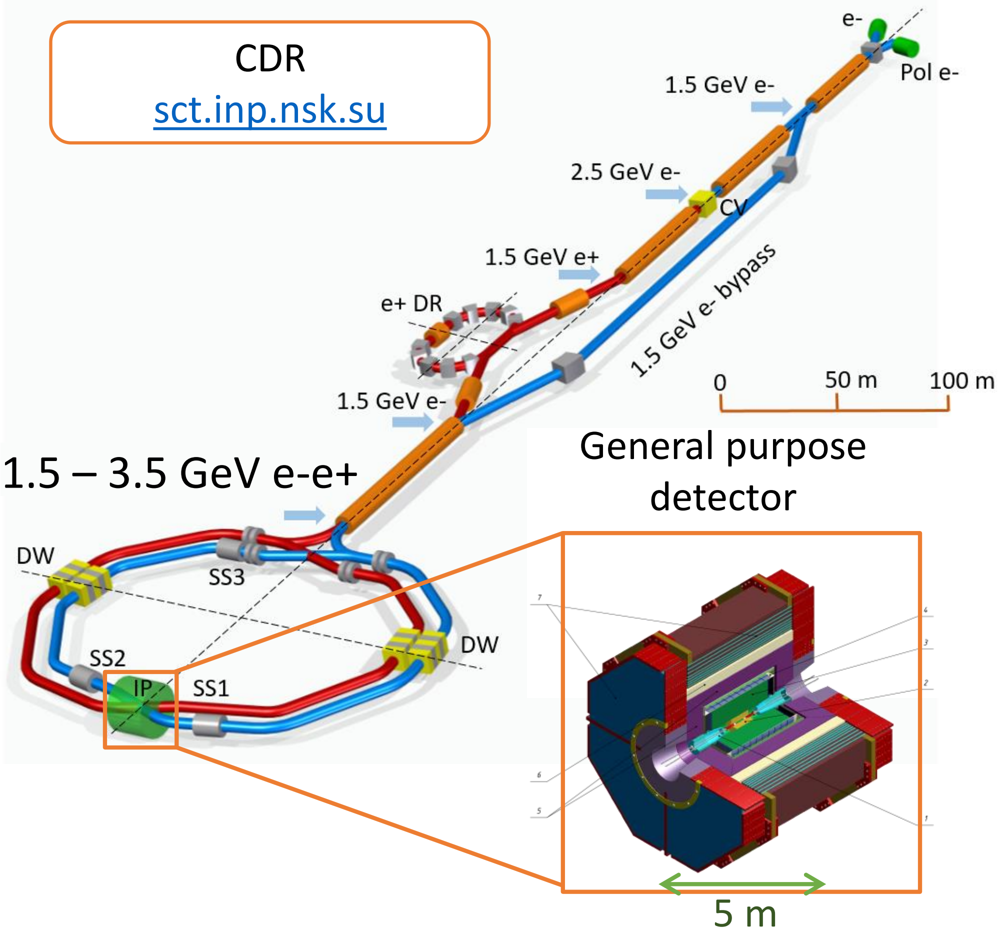
The experiments at Super charm-tau factory are complement to experiments at Super KEK-B and LHCb, with unique possibilities:

- Threshold production of particles
- Pair production
- Quantum correlations in $D^0\overline{D}^0$ production
- Low multiplicity, full reconstruction of decay chain
- Polarization of electron beam



Super charm-tau factory

- Super charm-tau factory is e^+e^- collider, dedicated to precision study of properties of charm-quark, tau-lepton, study of strong interactions, search of BSM physics
  - Beam energy from 1.5 (1.0) to 3.5 GeV
  - Luminosity $\mathcal{L} = 10^{35}\ cm^{-2}c^{-1}$ @ 2 GeV
  - Longitudinally polarized electron beam
- Experiments will be conducted using state-of-the-art general purpose detector
  - Tracking (including low p_t)
  - Calorimetry (high resolution, fast, π^0/γ sep.)
  - Particle ID ($\mu/\pi/K/p$ up to 1.5 GeV/c)

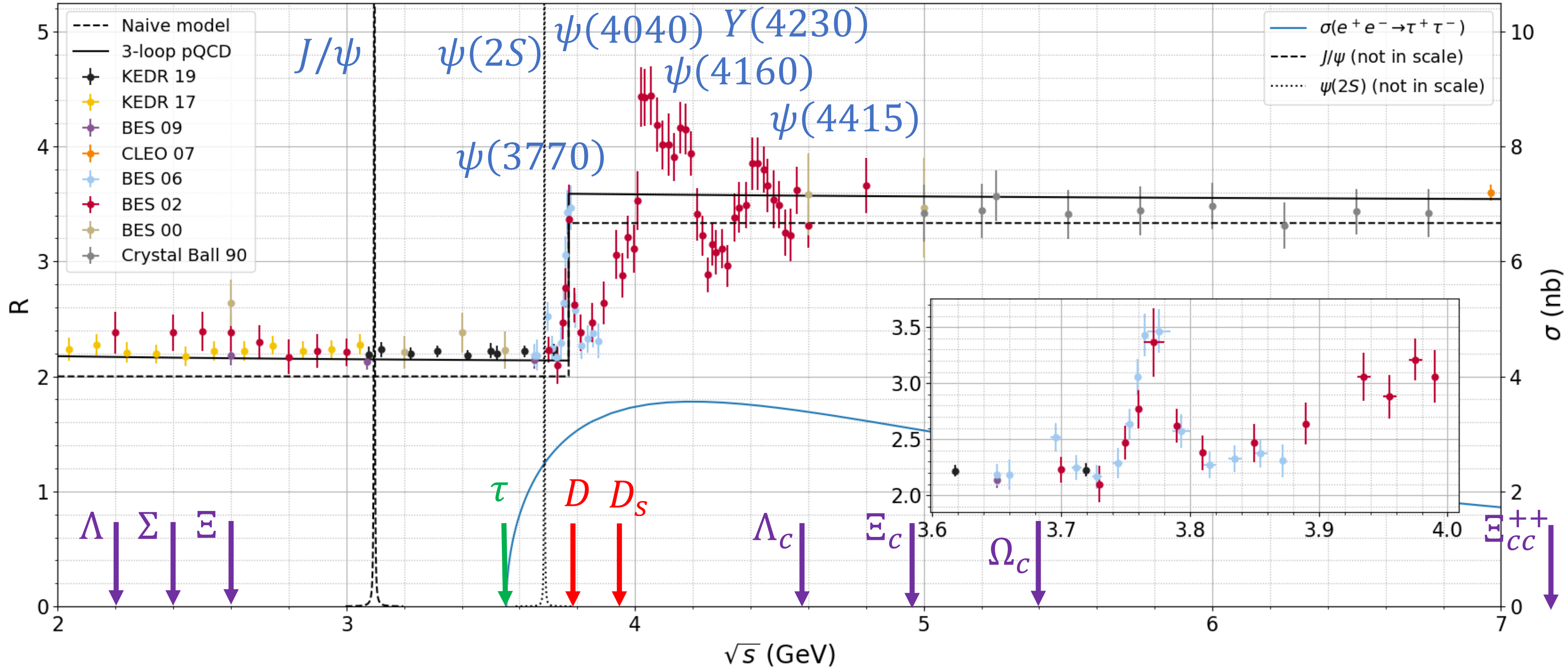


Physics program

SCTF energy range

$$R \equiv \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma_0(e^+e^- \to \mu^+\mu^-)}$$

Threshold production of nonrelativistic particles provides best conditions for their comprehensive study



$\mathcal{L} = 10^{35}\ \text{cm}^{-2}s^{-1}$

A one-year dataset

$2E$, GeV	Events recorded
3.1	$10^{12}\ J/\psi$
3.69	$10^{11}\ \psi(2S)$
3.77	$10^{9}\ D\bar{D}$
4.17	$10^{8}\ D_s\bar{D}_s$
3.55 ÷ 4.3	$10^{10}\ \tau\ \tau$
4.65	$10^{8}\ \Lambda_c^+\Lambda_c^-$

Overview of SCTF physics

charm

tau

QCD

charm

- ✓ Measurement of absolute branching fractions
- ✓ Searches for rare and forbidden decays of the charm quark
- ✓ CP violation in charm
- ✓ Measurement of the strong phases of D decay amplitudes
- ✓ …

Input for B meson studies at LHCb and Belle II

QCD

- ✓ Physics of highly-excited quarkonium
- ✓ Molecular states
- ✓ Baryon interaction at threshold
- ✓ Search for glueballs in decays of J/ψ and $\psi(2S)$
- ✓ …

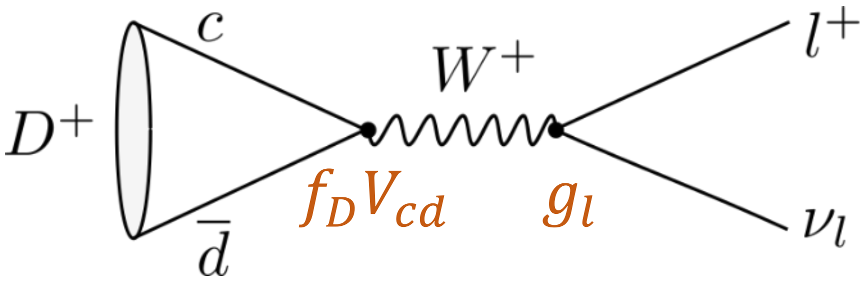
tau

- ✓ Precision measurement of the τ lepton properties
- ✓ Michel parameters, tests of lepton universality
- ✓ Precision measurement of hadronic τ decays
- ✓ Search for CP and T violation in τ decays
- ✓ …

Test of the electroweak sector of the SM

QCD, α_s, V_{us}. Test of the electroweak model, searches for non-standard contributions

(Semi-)leptonic $D_{(s)}$ decays



$$\Gamma(D^+ \to l\nu) = \frac{G_F^2}{8\pi} f_D^2 m_l^2 m_D \left(1 - \frac{m_l^2}{m_D^2}\right) |V_{cd}|^2$$

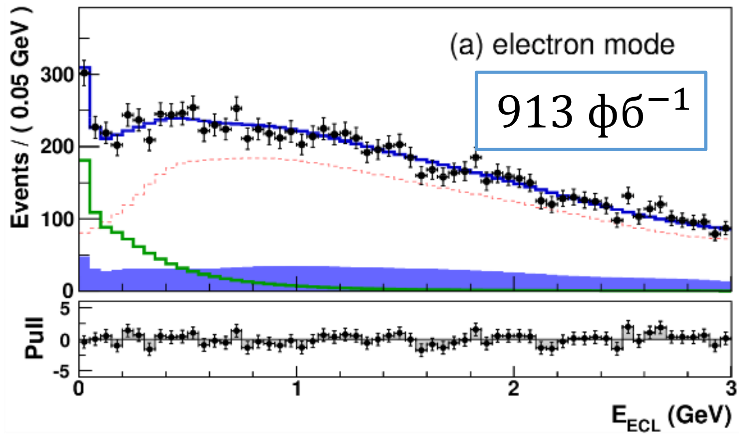
- Branchings measurement: f_D, V_{cd}, V_{cs}
- Lepton universality test

Table 1: LFU test at BESIII with (semi)leptonic D decays.

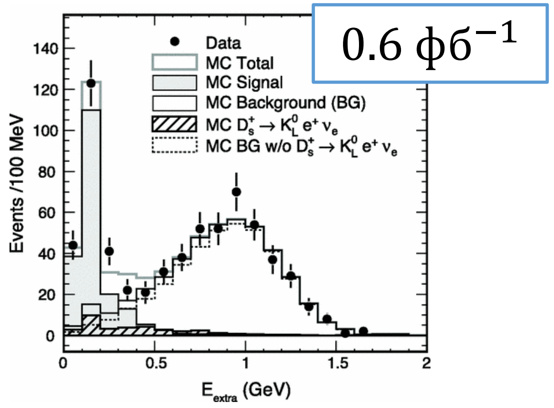
	$R(D_s^+)$	$R(D^+)$	$R(K^-)$	$R(\bar{K}^0)$	$R(\pi^-)$	$R(\pi^0)$
SM	9.74(1)	2.66(1)	0.975(1) [31]	0.975(1) [31]	0.985(2) [31]	0.985(2) [31]
BESIII	9.98(52)	3.21(64)	0.978(14)	0.988(33)	0.922(37)	0.964(45)

$D_s^+ \to \tau^+\nu, \tau^+ \to e^+\nu_e\bar{\nu}_\tau$

[Belle, JHEP 09 (2013), 139]

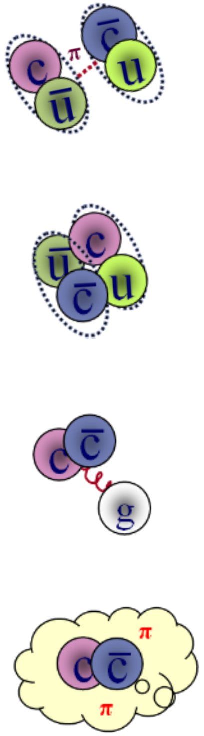


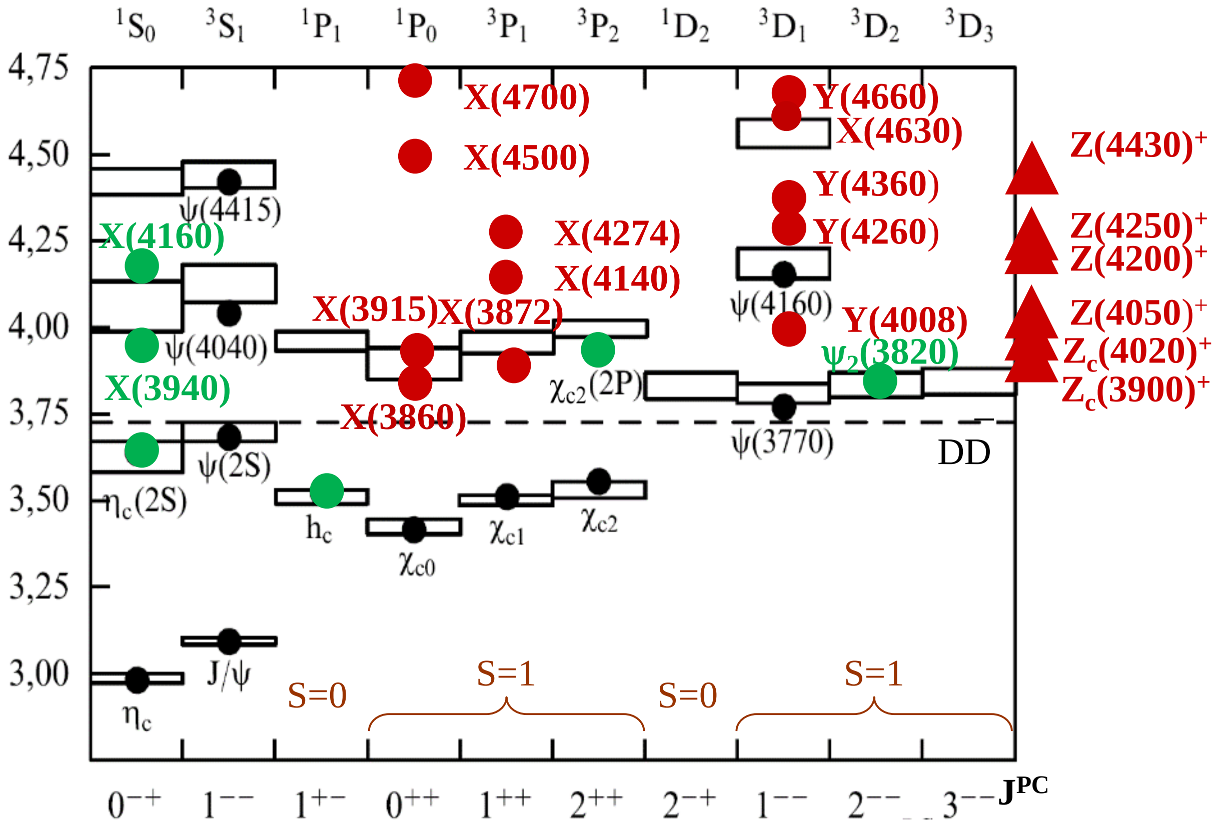
[CLEO-c, PRD 79 (2009), 052002]



Detailed study of the charmonium-like states

- Exiting QCD laboratory
- Cross sections to be measured:
  - $e^+e^- \to J/\psi\pi^+\pi^-$
  - $e^+e^- \to J/\psi\pi^0\pi^0$
  - $e^+e^- \to \psi(2S)\pi^+\pi^-$
  - $e^+e^- \to D\bar{D},\ D^*\bar{D}, \ldots$
  - $e^+e^- \to D\bar{D}\gamma$
  - $e^+e^- \to D\bar{D}(n\pi)$
  - $e^+e^- \to D_s^+D_s^-$
  - $e^+e^- \to D_s^+D_s^-(n\pi)$
  - $e^+e^- \to \Lambda_c\bar{\Lambda}_c$
  - …





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  - $e^+e^- \to D_s^+D_s^-(n\pi)$
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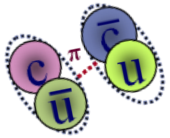
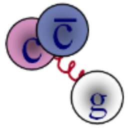
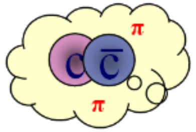
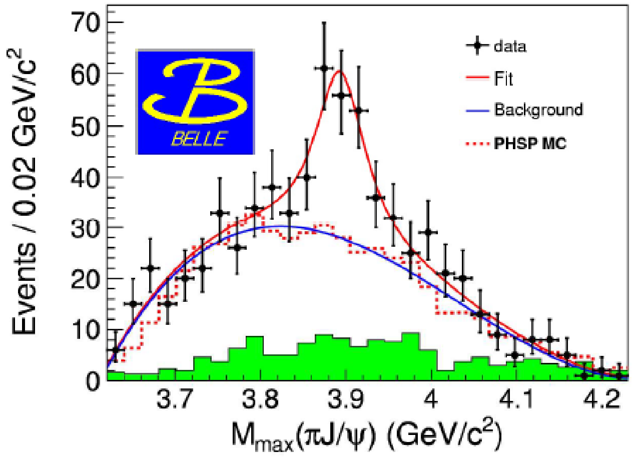
  - …





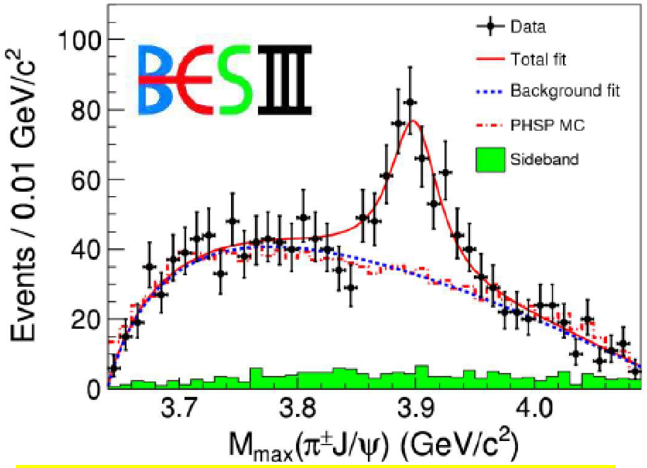


Belle with ISR: PRL110, 252002
967 fb^{-1} in 10 years running time



- M = 3894.5±6.6±4.5 MeV
- Γ = 63±24±26 MeV
- 159 ± 49 events
- >5.2σ

BESIII at 4.260 GeV: PRL110, 252001
0.525 fb^{-1} in one month running time

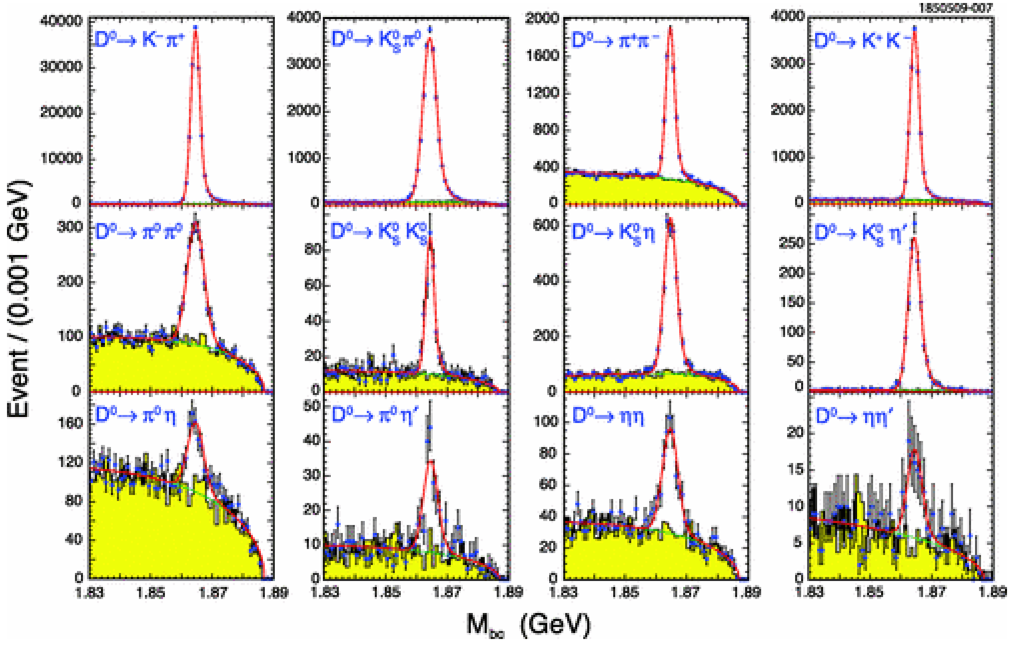


- M = 3899.0±3.6±4.9 MeV
- Γ = 46±10±20 MeV
- 307 ± 48 events
- >8σ

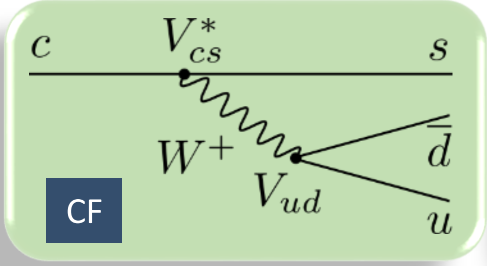
10 years vs. 0.1 year vs. 1 day at SCT

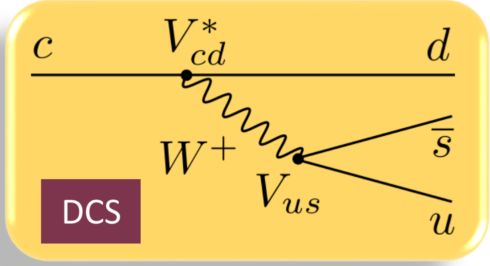
CPV in charm

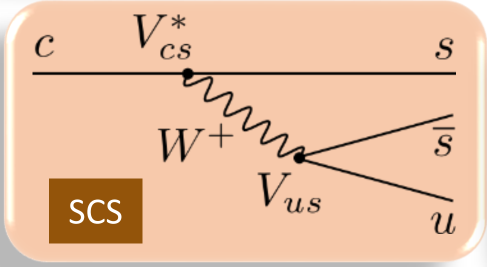
- Measurement of CP asymmetries in decays of D^0, D^+, D_s^+ at the precision level of $\sim 10^{-4}$
  - Advantage of full event reconstruction
  - Coherent $D^0\overline{D}^0$ pairs

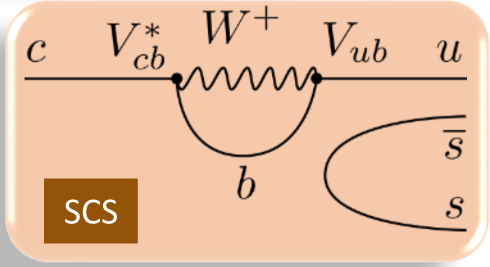


CLEOc $0.818\ \mathrm{fb}^{-1}$ @ 3774 MeV [PRD 81, 052013 (2010)]









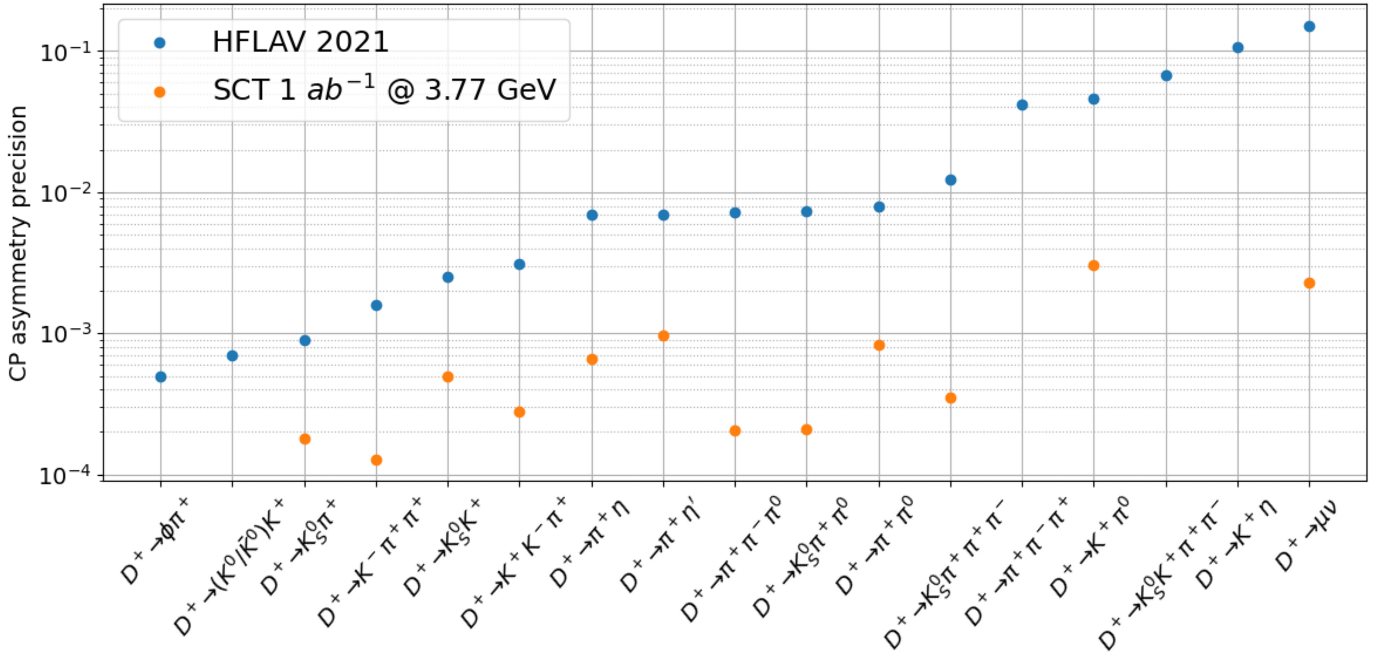
$$\Delta A_{CP} = (-15.4 \pm 2.9) \times 10^{-4}$$

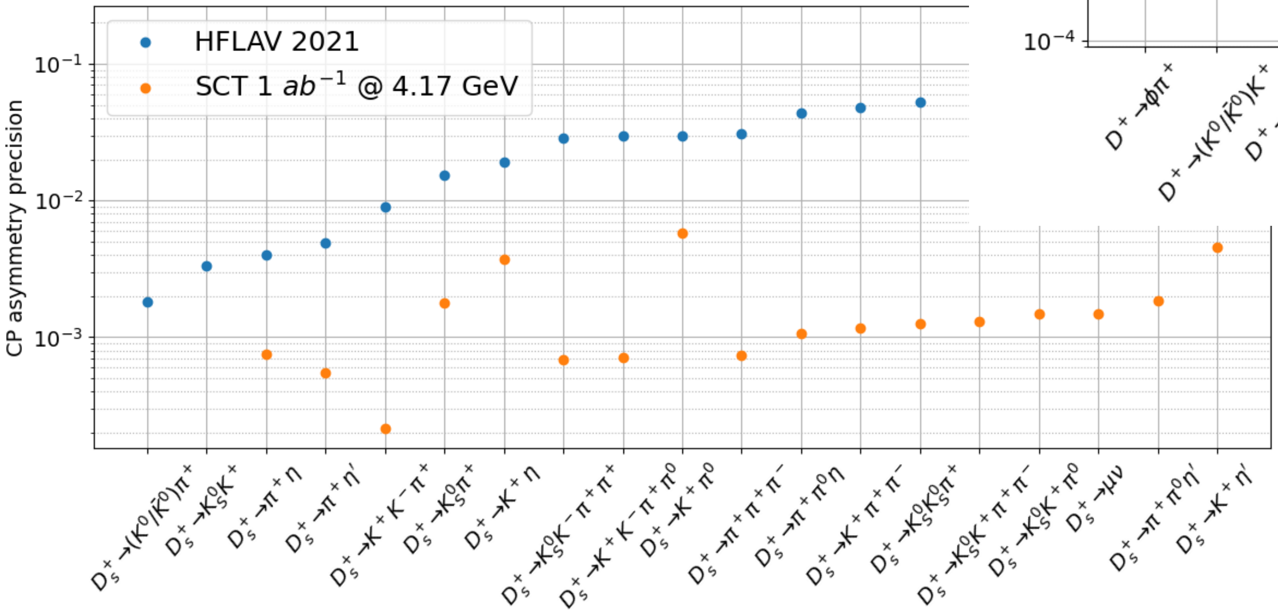
$D^0 \to h^+h^-$

2019

CPV in charm

- The only experiment able to observe CP-asymmetry in D-mesons decays at the level of $\mathcal{O}(10^{-3})$ simultaneously in many final states, including states with neutrals





Leptonic τ decays

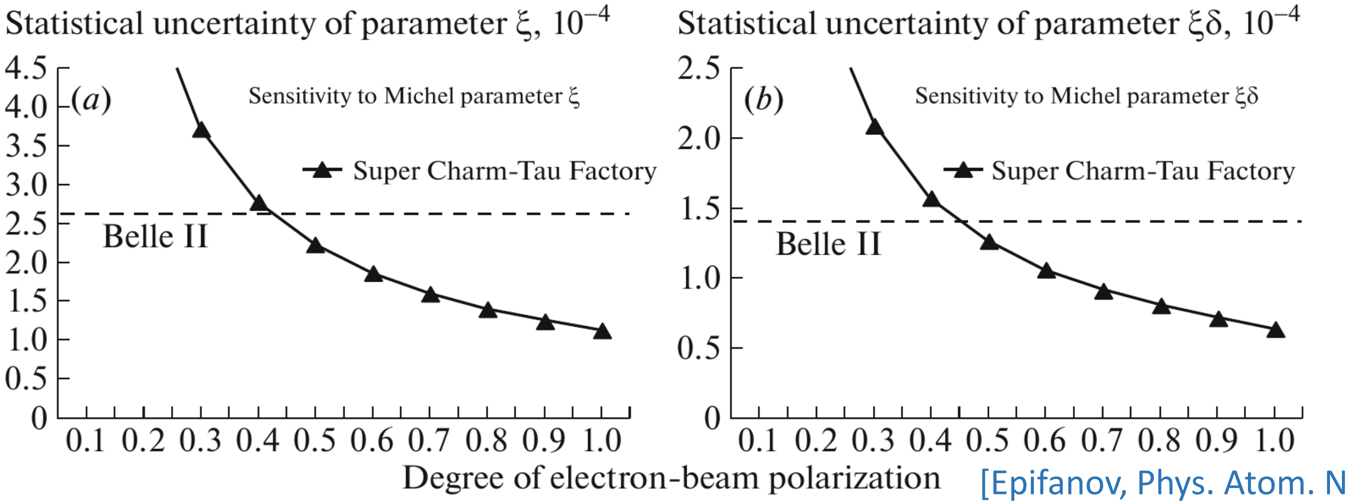
Michel parameters

Tau polarization

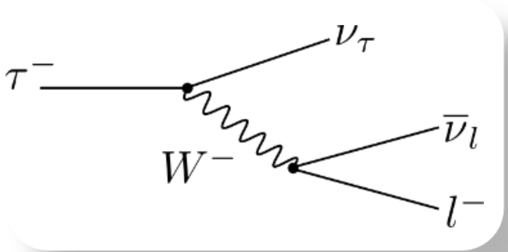
$$\frac{d\Gamma(\tau^{\mp})}{d\Omega dx} \propto x(1-x) + \frac{2}{9}\rho(4x^2 - 3x - x_0^2) + \eta x_0(1-x) \mp \frac{1}{3} P_\tau \cos\theta_l\, \xi \sqrt{x^2 - x_0^2}\left[1 - x + \frac{2}{3}\delta\left(4x - 4 + \sqrt{1 - x_0^2}\right)\right]$$

- SCT with polarized electrons allows measurement the tau lepton Michel parameters with precision better then that of Belle II

$$x \equiv \frac{E_l}{E_{\max}}, \qquad x_0 \equiv \frac{m_l}{E_{\max}}$$



[Epifanov, Phys. Atom. Nucl. 83 (2020) 944]



LFV and CPV with tau

$\tau \to \mu\gamma$

- Allowed in several BSM scenario, including SUSY, leptoquarks, technicolor, extended Higgs models etc.
- $\mathcal{O}(10^{-9})$ – reachable upper limit at SCT for the branching of $\tau \to \mu\gamma$.

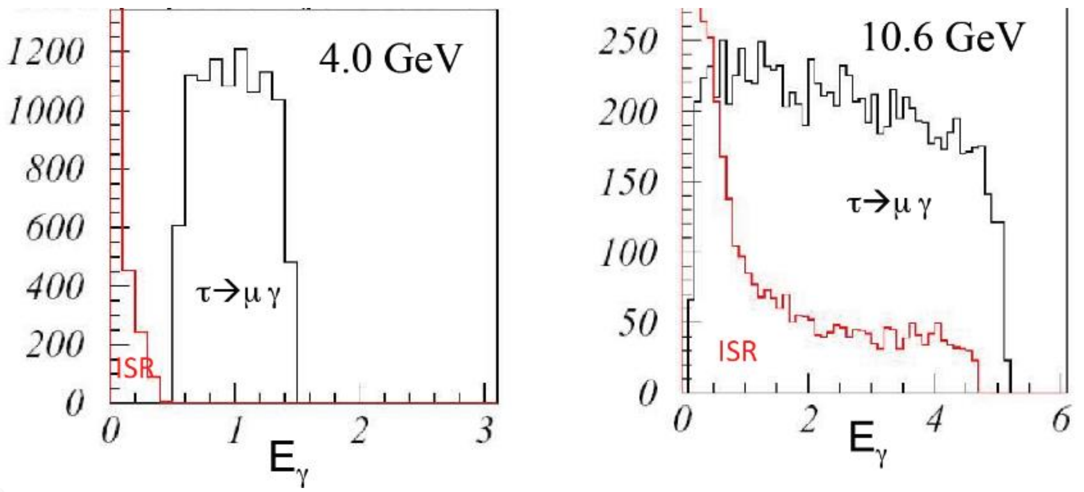
CP symmetry breaking

- CPV in tau production

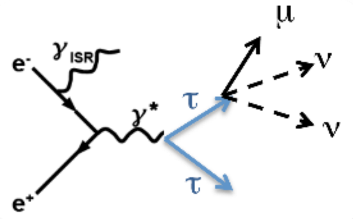
$$J_{EM} \propto F_1\gamma^\mu + \left(\frac{i}{2m_\tau}F_2 + \gamma^5 F_3\right)\sigma^{\mu\nu}q_\nu$$

  - Current limit: $|d_\tau| \lesssim 10^{-17}\ e \cdot \mathrm{cm}$
  - Tau EDM with polarized electrons [PRD 51 (1995) 5996]: $\sigma(d_\tau) \sim 10^{-20}\ e \cdot \text{см}$
- CPV in tau decays (e.g., $\tau \to K\pi\nu_\tau$)

ISR photon background [arXiv:1206.1909 [hep-ex]]



Beam polarization is essential for these measurements



J/ψ cross section asymmetry

- Interference between the $e^+e^- \to \gamma^*, Z \to J/\psi$ processes produces left-right total cross section asymmetry

$$A_{LR} \equiv \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{3/8 - \sin^2\theta^c_{\mathrm{eff}}}{2\sin^2\theta^c_{\mathrm{eff}}\left(1 - \sin^2\theta^c_{\mathrm{eff}}\right)}\left(\frac{m_{J/\psi}}{m_Z}\right)^2 P_e \approx 4.7\times10^{-4} P_e$$

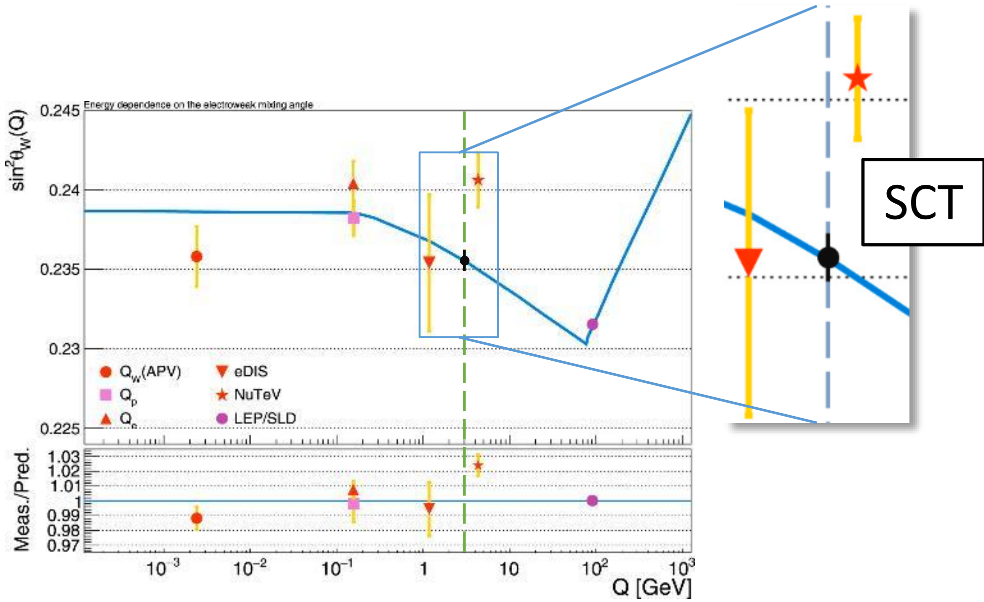
  - σ_+ (σ_-) is the total $e^+e^- \to J/\psi$ cross section for right- (left-)handed electrons
  - P_e is the average electrons polarization, $P_e < 1$

- Statistical precision with a one-year data set:

$$\frac{\sigma(\sin^2\theta^c_{\mathrm{eff}})}{\sin^2\theta^c_{\mathrm{eff}}} \approx 0.3\%, \qquad \sigma(\sin^2\theta^c_{\mathrm{eff}}) \approx 5\times10^{-4}$$

- It tests weak interaction of the charm quark

- An opportunity to observe deviation of the $\sin^2\theta^c_{\mathrm{eff}}$ from its value at Z peak (test of the EW model)



JHEP 2020, 76 (2020)

Physics program: 2022 update

Оглавление

6

7

- 2021: ≈ 40 pages
- 2022: ≈ 120 pages
- In Russian
- Editors:
  - G.Pakhlova (LPI)
  - A.Bondar (BINP)

Shorter (extracted) version prepared as a white paper for Snowmass

http://sct.inp.nsk.su

Collider

Super charm-tau factory

- Super charm-tau factory is e^+e^- collider, dedicated to precision study of properties of charm-quark, tau-lepton, study of strong interactions, search of BSM physics
  - Beam energy from 1.5 (1.0) to 3.5 GeV
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- Experiments will be conducted using state-of-the-art general purpose detector
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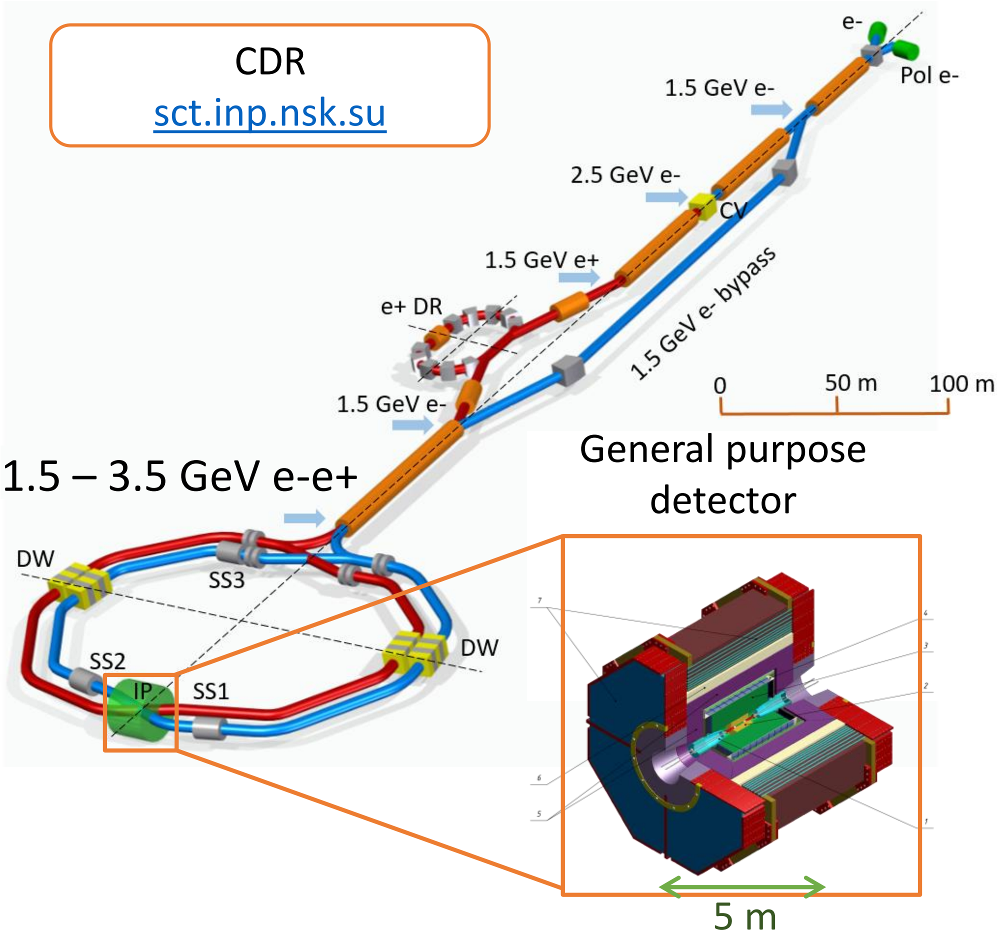
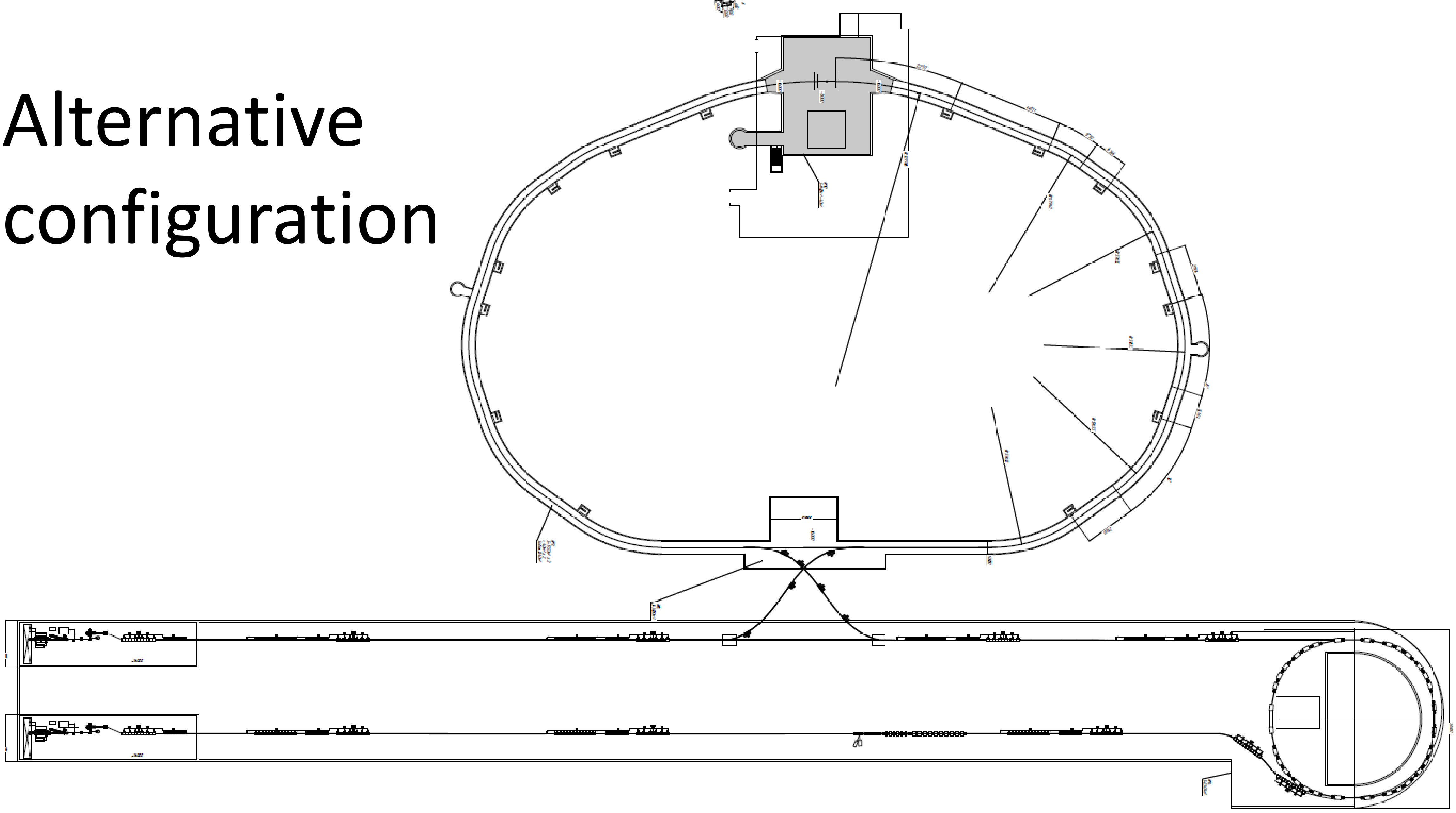
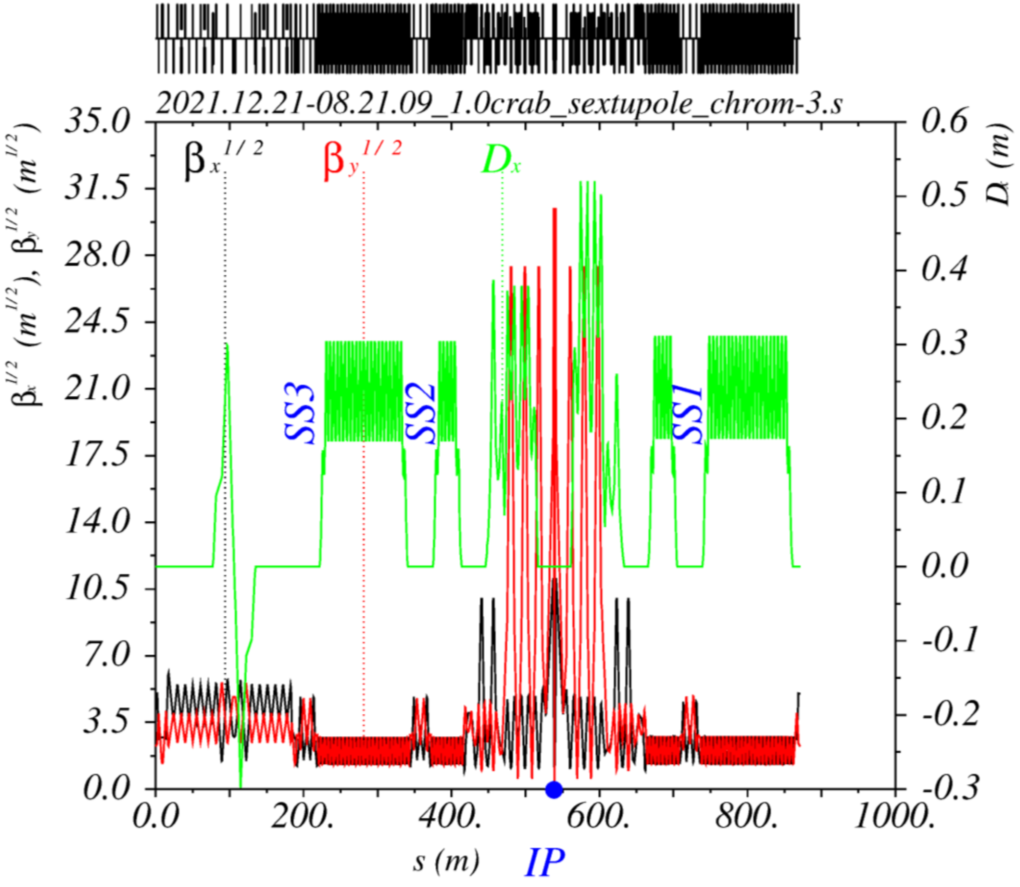
CDR
[sct.inp.nsk.su](sct.inp.nsk.su)

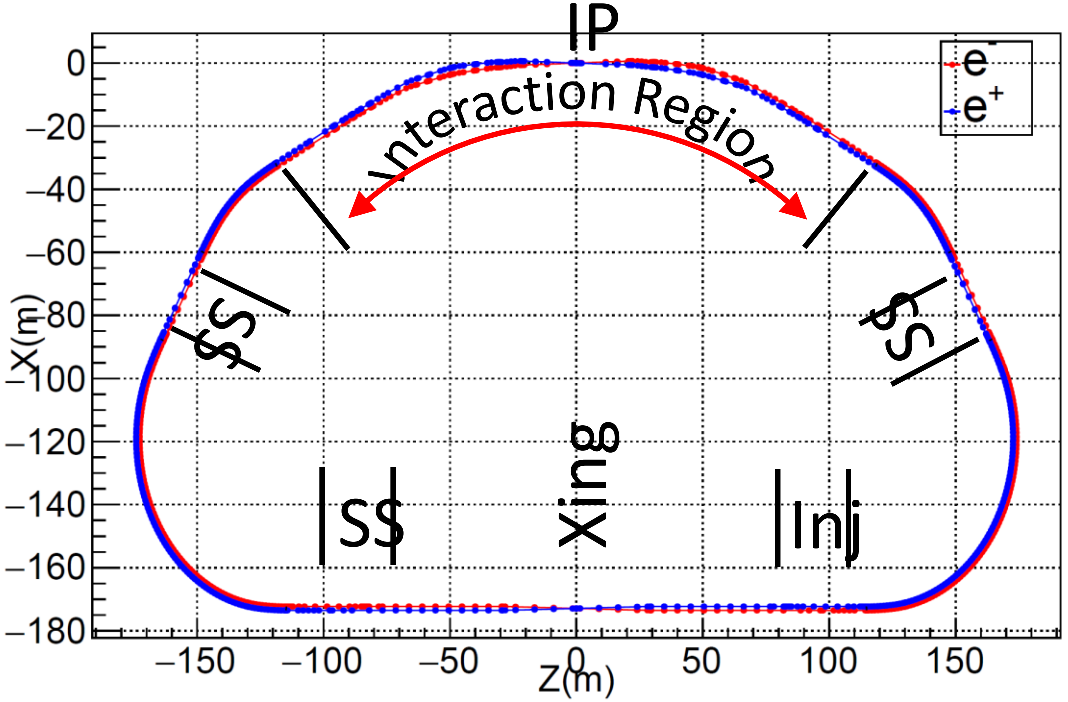


Alternative configuration



Lattice and layout (2021)





Design parameters (2021)

- Design parameters meet the luminosity requirements
- Similar parameters have been achieved at other colliders
- Dynamic aperture was not taken into account

The key problem now is to find configuration with sufficient dynamic aperture

E(MeV)	1500	2000	2500	3000	3500
Π(m)			870.949		
F_{RF}(MHz)			350		
2θ(mrad)			60		
$\varepsilon_y/\varepsilon_x$(%)			0.5		
β_x^*/β_y^* (mm)			100/1		
I(A)	2	2	2	2	2
$N_{e/bunch} \times 10^{-10}$	9	8	7	8	[illegible]
N_b	420	472	540	47[illegible]	[illegible]
U_0(keV)	115.6	294	516	845	1314
V_{RF}(kV)	1500	2300	3000	3500	4500
ν_s	0.0152	0.0162	0.0165	0.0162	0.0168
δ_{RF}(%)	1.9	2	2	1.8	1.8
$\sigma_\varepsilon \times 10^3$ (SR/IBS+WG)	0.28/1.1	0.37/1.1	0.5/1.1	0.6/1.2	0.7/1.5
σ_s(mm) (SR/IBS+WG)	3.6/14	5/14	6/14	7/15	8/15
ε_x(nm) (SR/IBS+WG)	2.3/7.3	4/4.9	6/4.3	[illegible]	[illegible]
$L_{HG} \times 10^{-35} (cm^{-2}s^{-1})$	0.87	1.1	1	1	1
ξ_x/ξ_y	0.008/0.17	0.005/0.14	0.004/0.1	0.003/0.09	0.003/0.07
$\tau_{Luminosity}$ (s)	2400	2100	2300	2300	2400

SuperKEKB 03.12.2019 $\beta_y^* = 1\ mm$

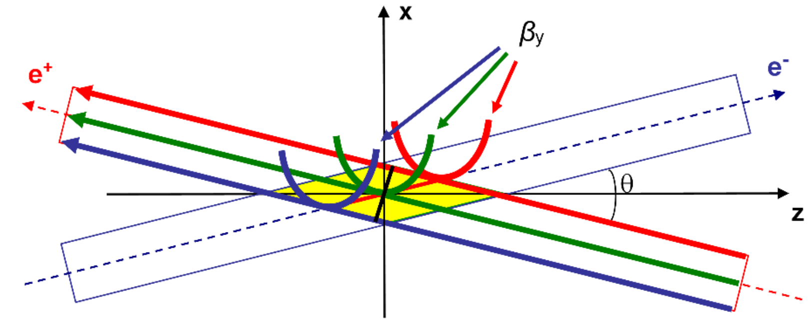
PEPII: I(e+)=3.2 A PEPII
DAFNE : I(e-)=2.45A

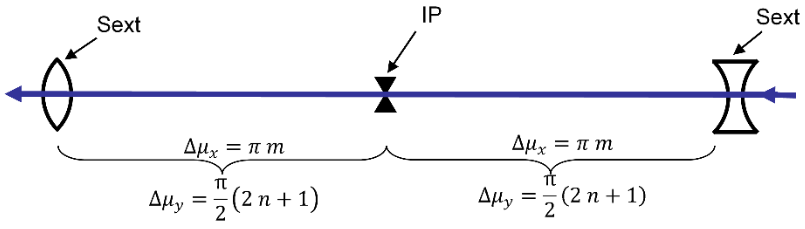
SuperKEKB: $L = 4.7 \times 10^{34}$

To remind: Crab waist (P.Raimondi 2006)

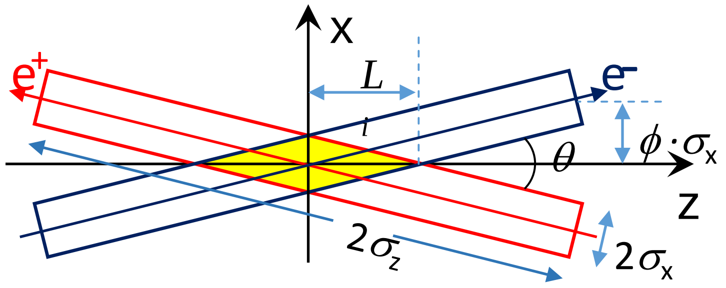
Large Piwinski angle: $\phi = \frac{\sigma_z}{\sigma_x} \tan\left(\frac{\theta}{2}\right)$

1. Transverse beam separation in parasitic IPs
   - distance between bunches is not limited by beam-beam
2. Interaction area length $L_i \ll \sigma_z$
   - $\beta_y^* \approx L_i \ll \sigma_z$ no hour-glass
3. CRAB waist (CRAB sextupoles) suppresses betatron and synchro-betatron resonances
   - $\xi_y \sim 0.2$





But CRAB sextupoles introduce large nonlinearity, which reduces dynamic aperture, for off-momentum particles

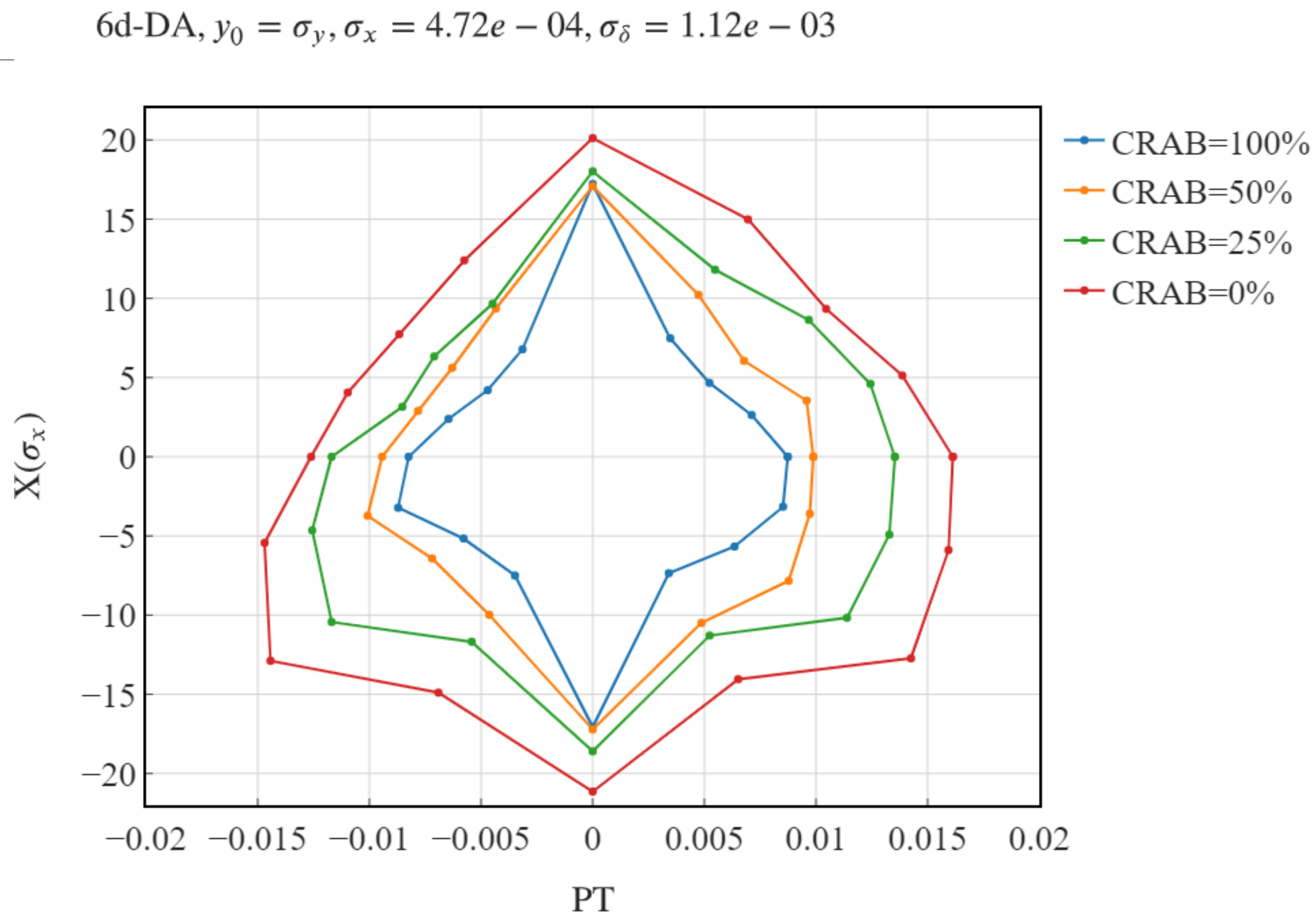


CRAB sextupole influence on 6d DA, E=1.5 ГэВ, IP1

"Interaction region 1" configuration

- Off momentum dynamic aperture with CRAB ON is insufficient at 1.5-2.5 GeV to provide necessary Touschek lifetime

$E = 1.5$ GeV	CRAB 0%	CRAB 25%	CRAB 50%	CRAB 100%
N_{part}, $\times 10^{-10}$	9	4	1.6	0.6
$\tau_{Touschek}$(s)	265	255	240	230
$L(cm^{-2}s^{-1}) \times 10^{-34}$	~~9.9~~	~~5.4~~	1.2	0.19

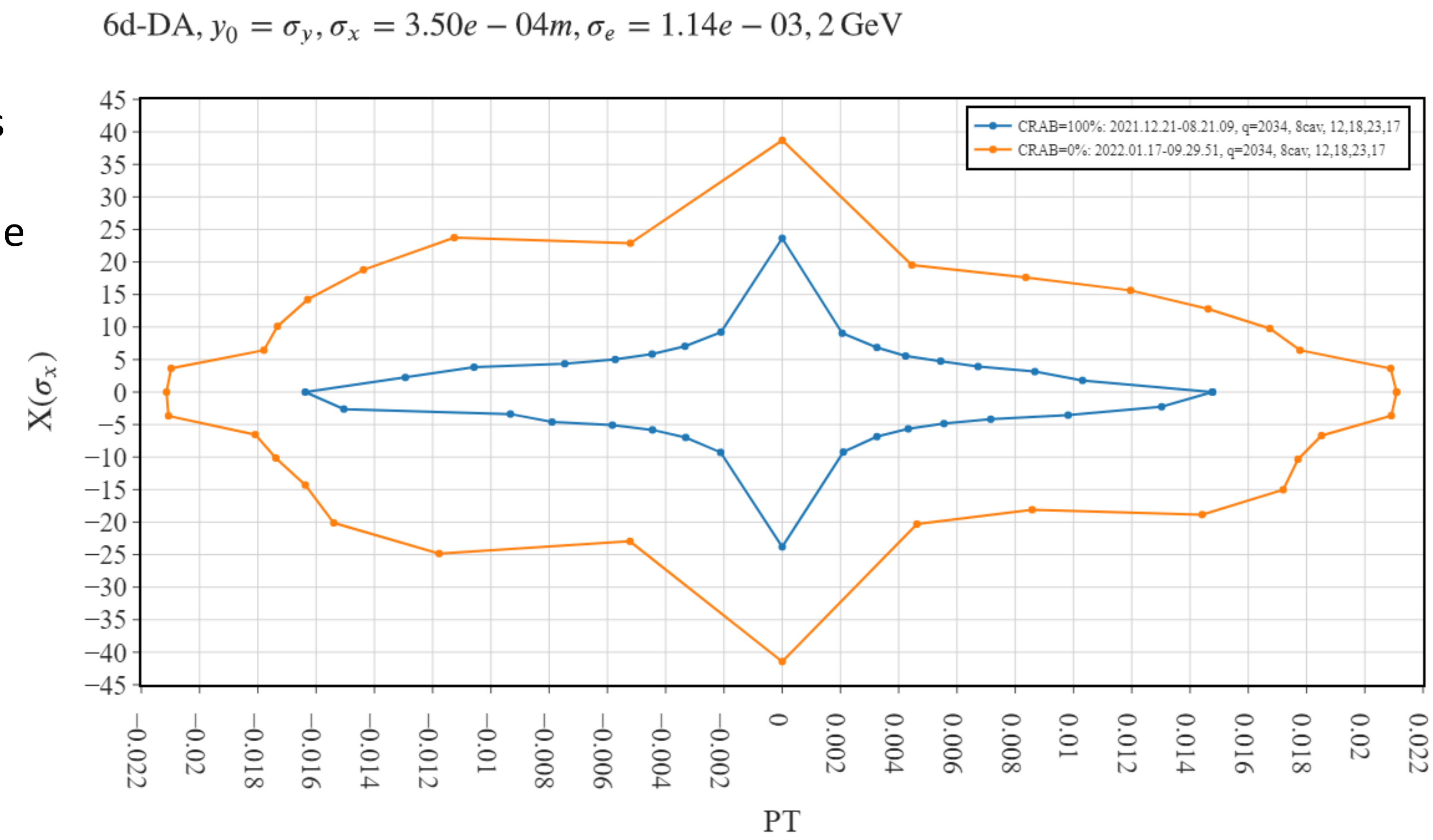


Touschek lifetime with CRAB ON and OFF at 2 GeV, IP3

"Interaction region 3" configuration

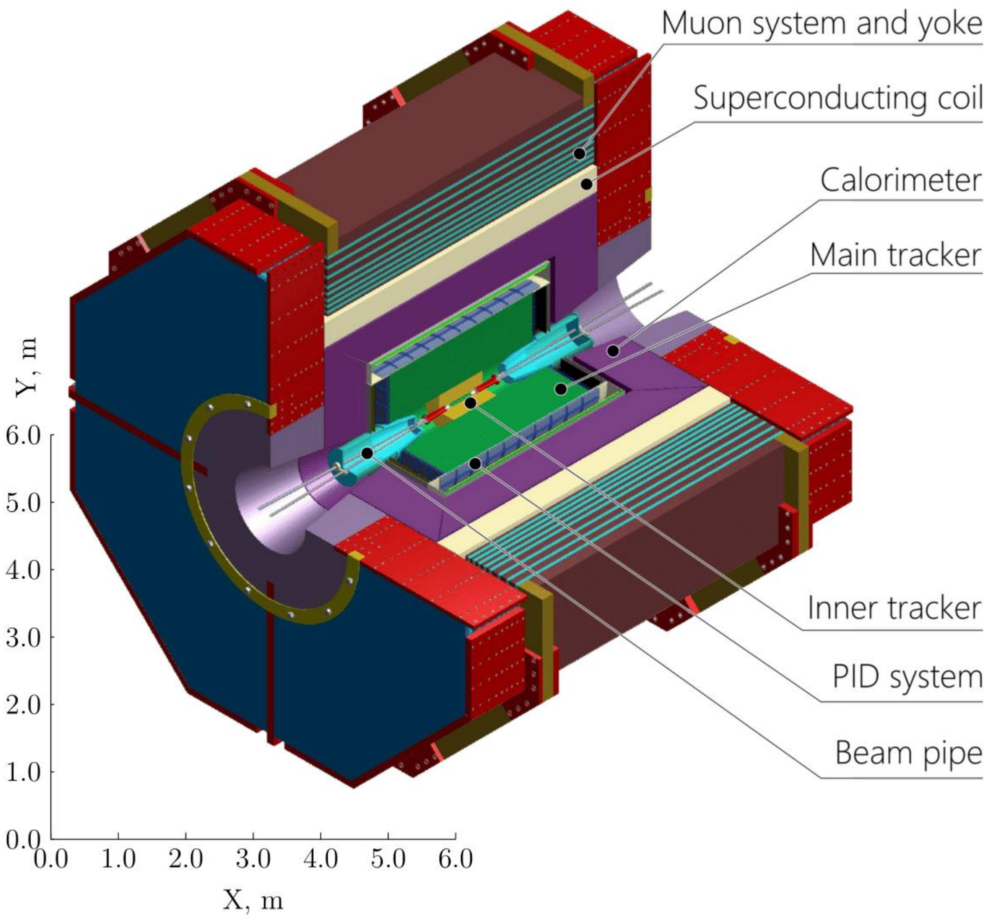
- Placing CRAB sextupoles closer to IP gives larger energy aperture
- But still not sufficient for Touschek lifetime at 1.5, 2 GeV with CRAB sextupole 100%

	CRAB OFF	CRAB ON
$\tau_T(s)$	740	108
$N_p(10^{10})$	2.7	2.7



Detector

Detector concept



Momentum resolution $\sigma_p/p \leq 0.4\%$ at 1 GeV

Very symmetric and hermetic

Able to detect soft tracks ($p_t \geq 50\ MeV/c$)

- Inner tracker should be able to handle 10^4 tracks/cm²s

Very good particle identification: $e/\mu/\pi/K$

- π/K in the whole energy range, e.g. for $D\overline{D}$ mixing
- μ/π up to 1.5 GeV, e.g. for $\tau \rightarrow \mu\gamma$ search
- dE/dx better than 7%

Able to detect γ from 10 MeV to 3.5 GeV, good π^0/γ separation

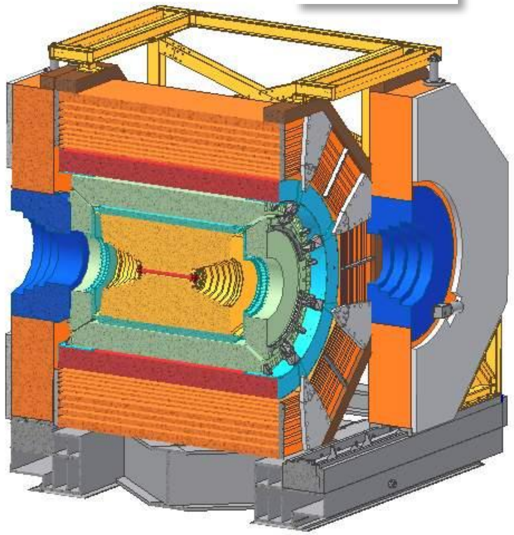
- Calorimeter energy resolution $\sigma_E/E \leq 1.8\%$ at 1 GeV
- Calorimeter time resolution $\sigma_t \leq 1$ ns

Efficient “soft” trigger

Ability to operate at high luminosity, up to 300 kHz at J/ψ

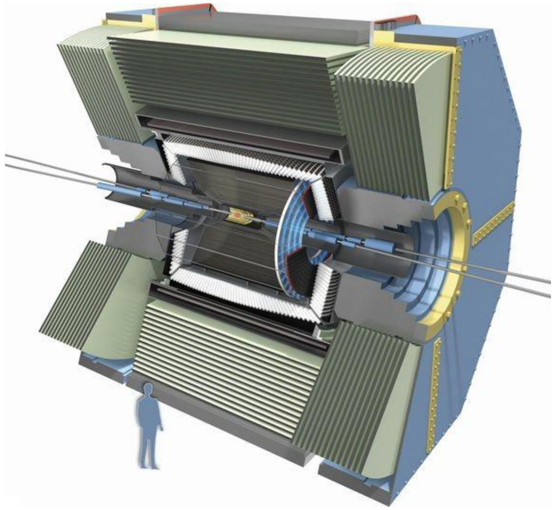
Brothers, sisters and cousins…

BES-3



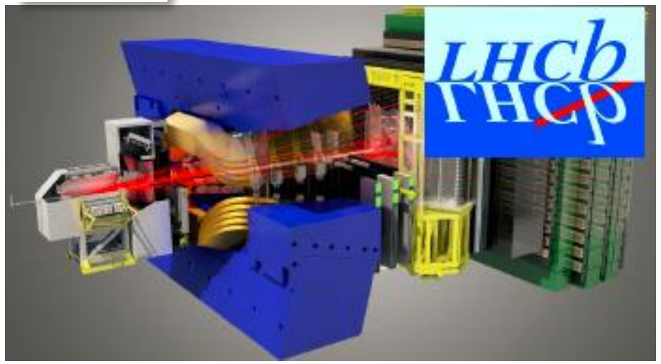
Very similar
1% luminosity

BELLE-2

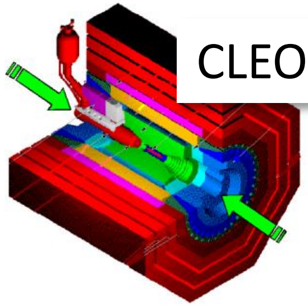


Super B-factory (10.58 GeV)
5-10x luminosity

LHCb

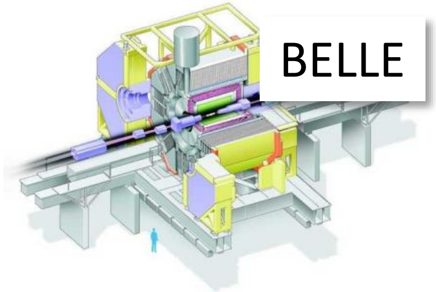


pp collisions

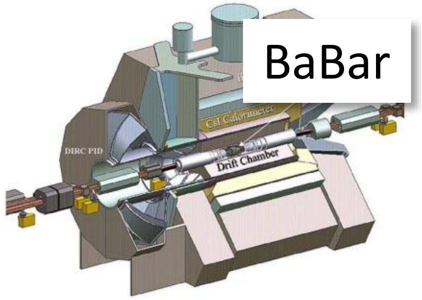


CLEO-c

Previous generation

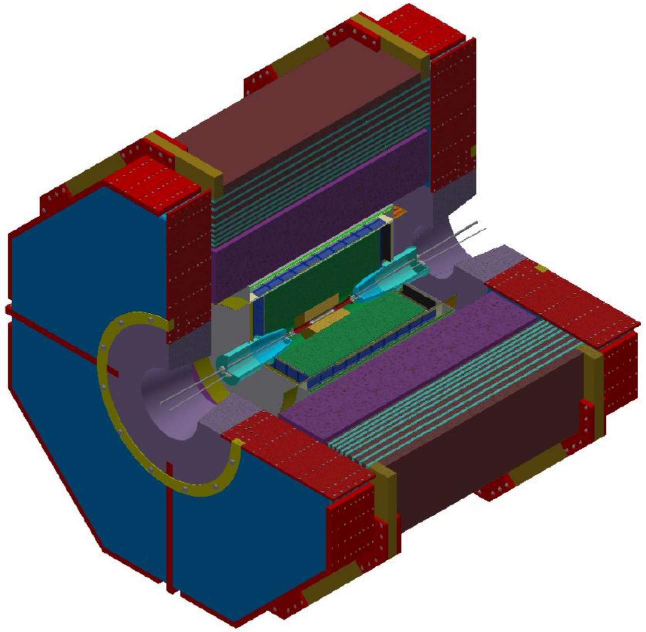


BELLE



BaBar

On-going R&Ds for detector



- Inner tracker
  - Time projection chamber (TPC) option by BINP
  - Cylindrical μRWELL option by INFN (LNF, Ferrara)*
- Main tracker
  - Drift chamber option by BINP
  - Ultra thin DC (TraPID) option by INFN (Lecce, Bari)*
- PID system
  - FARICH option by BINP
  - FDIRC options by Giessen University*
- Electromagnetic calorimeter – BINP
- Muon system – Lebedev Physics Institute (LPI)
- Magnet – BINP
- Detector software – the AURORA framework released in 2021

* Before spring 2022

Inner Tracker: TPC

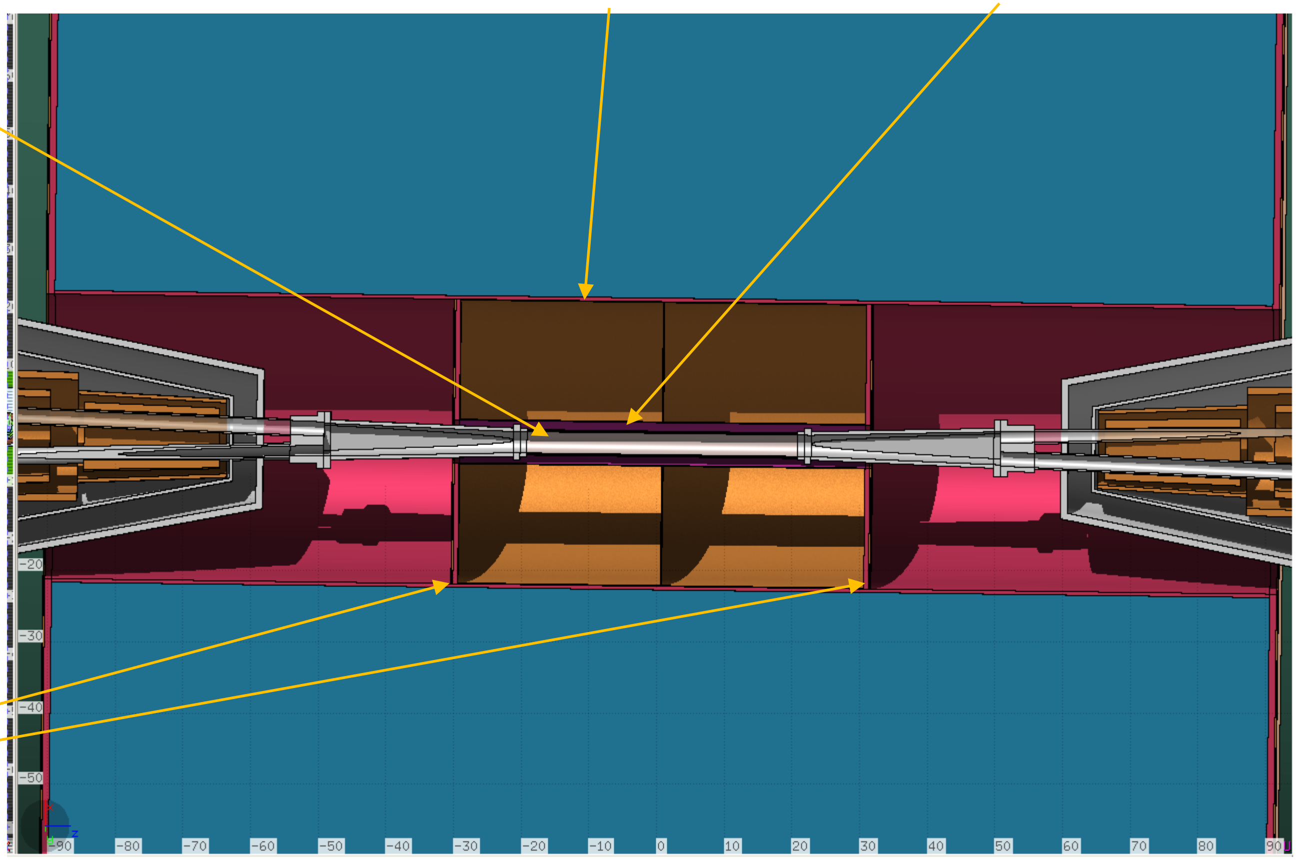
Outer radius 20 cm

Inner radius 3 cm

Beam pipe, inner radius 1.5 cm

TPC advantages:

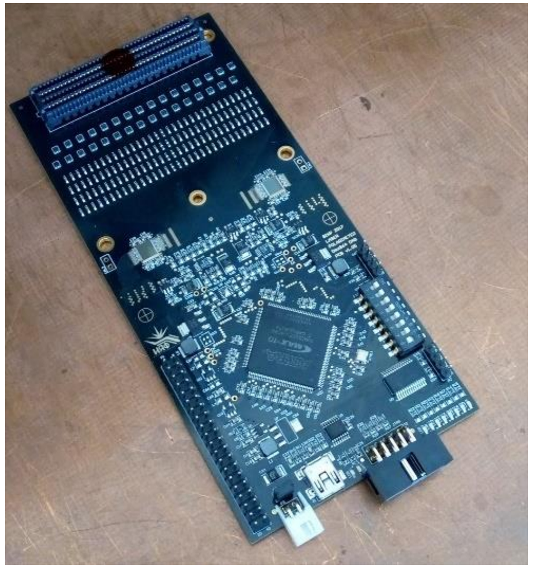
- Highest number of hits per track
- Great dE/dx measurement



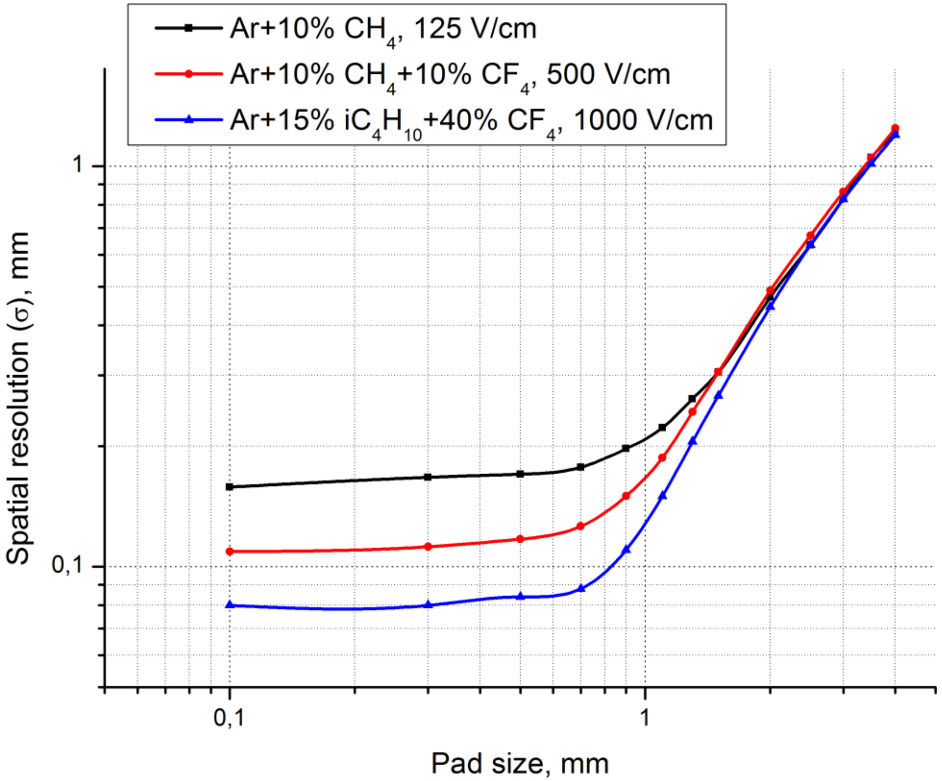
-30 cm < Z < 30 cm

Inner Tracker: simulations and prototyping

The prototype is being built at BINP



Simulation of spatial resolution in TPC



Inner Tracker: C-mRWELL

The c-μRWELL option for IT was proposed by G.Bencivenni (INFN)

INFN LNF-DDG

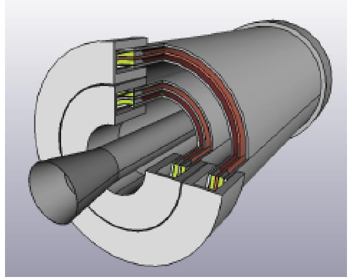
The Cylindrical u-RWELL

CREMLIN PLUS
Connecting Russian and European Measures for Large-scale Research Infrastructures

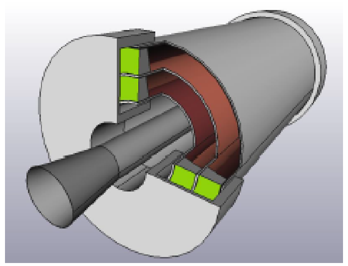
The **two schemes** under study are both based on a **B2B layout** (a **double radial TPC – with a central cathode**), characterized by **low material budget** and **modular roof-tile shaped active device**

"2 - B2B small drift gap" cylindrical detector

"1 - B2B large drift gap" cylindrical detector



micro-TPC readout mode allowing **space resolution** of O(**100 µm**) for **inclined tracks**
(on the radial view)



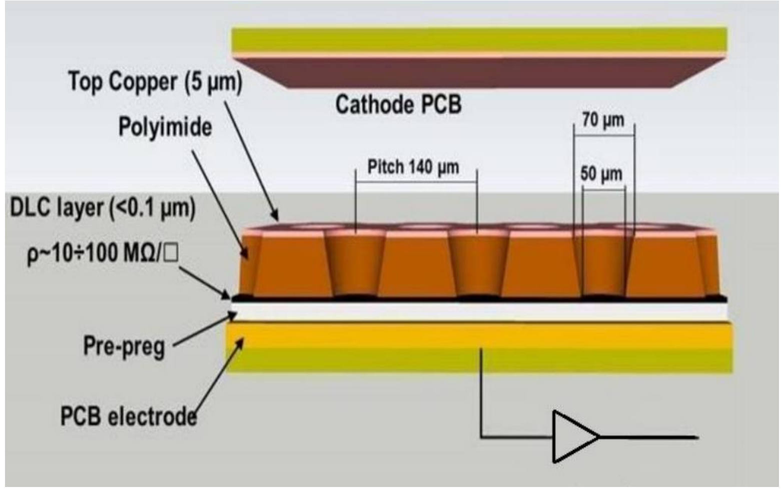
N.2 small gap B2B C+layers → 1.72% X0
2 × 1 cm gas gap/B2B device
4 cm global sampling gas

N.1 large gap B2B C+layers→ 0.86% X0
2 × 1 cm gas gap/B2B device
10 cm global sampling gas

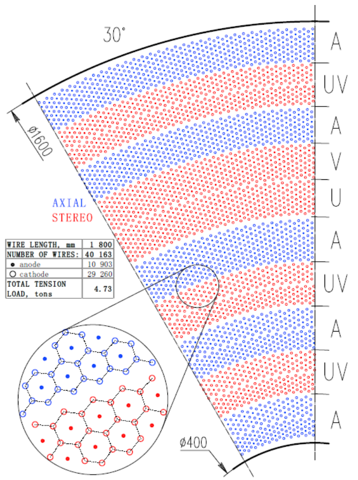
1.46 % X0 ← Further **material budget reduction** by using:
- **high module FR4**
- **low resistivity DLC cathode**
- **aluminum Faraday-Cage/shielding**

→ **0.75 % X0**

9

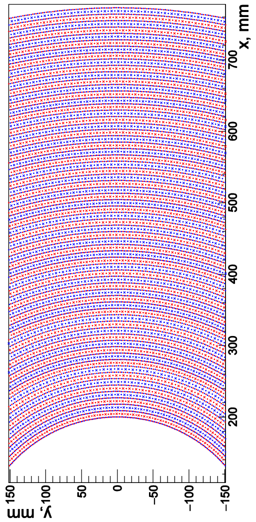


Drift chamber



Measurement of momentum and dE/dx (PID)

- Spatial resolution ~100 μ
- Small cell
- Minimal material (reduce MS)
- Approximate size: Ø (400-1600) x 1800 mm



"Traditional" option BINP	"Beyond-traditional" option INFN
Babar, BES-3, Belle-2	KLOE, MEG-2, IDEA
Axial and stereo superlayers	Full stereo
Traditional dE/dx	dE/dx by cluster counting
Feed-through wiring	Robotic wiring

Drift chamber: "traditional" option (BINP)

~40000 wires
- 11k sensitive, W-Rh(Au)
- 29k field, Al(Au)

Hexagonal cell, 6.3-7.5 mm

41 layers

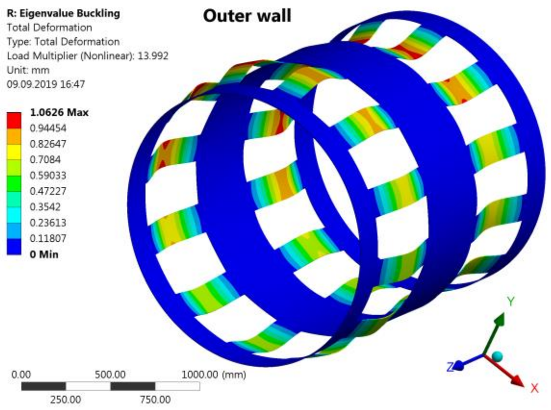
60% He + 40% C_3H_8

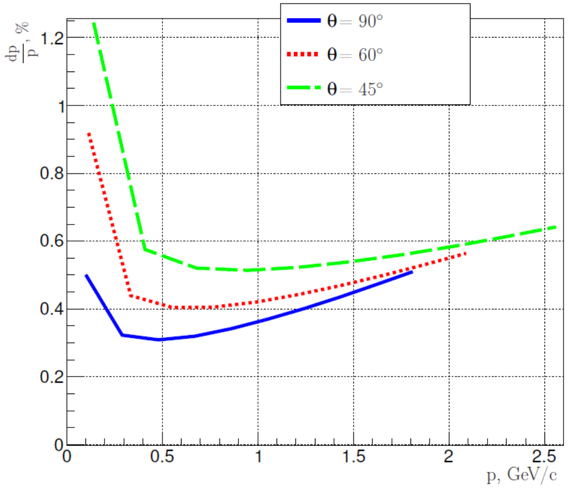
330 ns drift time (1.5 T)

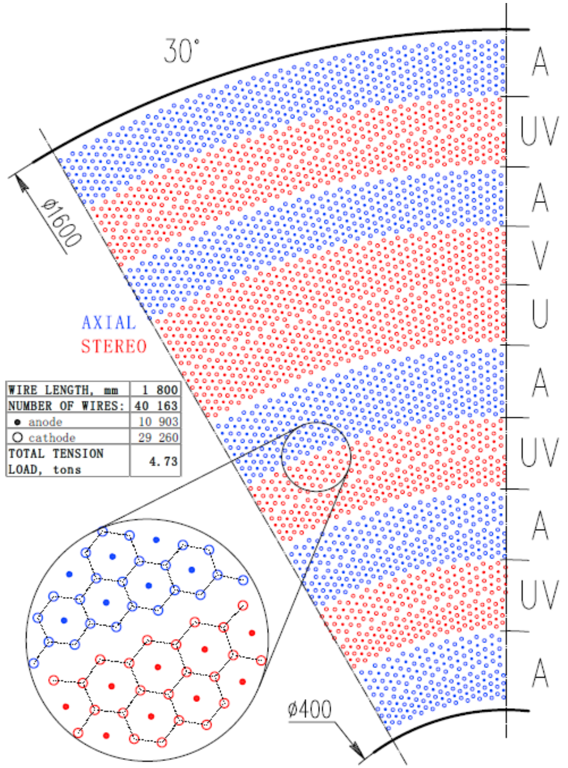
$$\frac{\sigma_{p_t}}{p_t} \approx \sqrt{0.21\%^2 p_t^2 + 0.31\%^2}$$

$\approx$0.4% at 1 GeV

$$\frac{\sigma_{dE/dx}}{dE/dx} \approx 6.9\%$$







I.Yu.Basok et al., NIM A1009 (2021) 165490

Drift chamber: TraPid option (INFN)

~141000 wires
- 23k sensitive, W
- 117k field, Al ($\rightarrow$ C)

Square cell, 7.2-9.1 mm

Full stereo

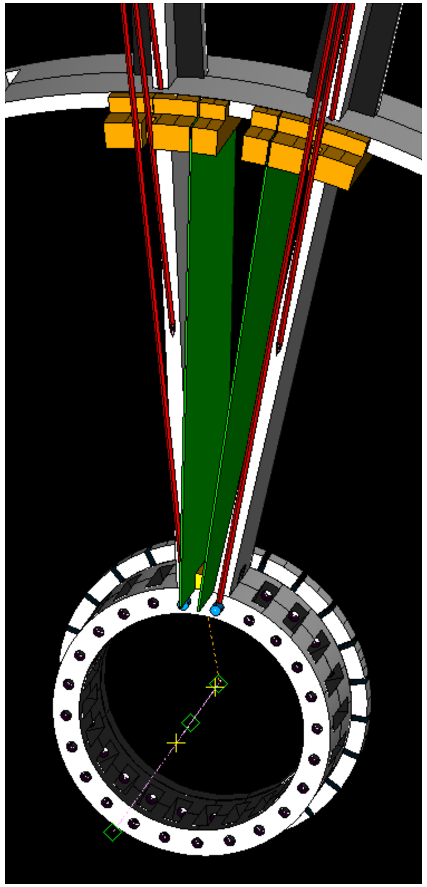
64 layers

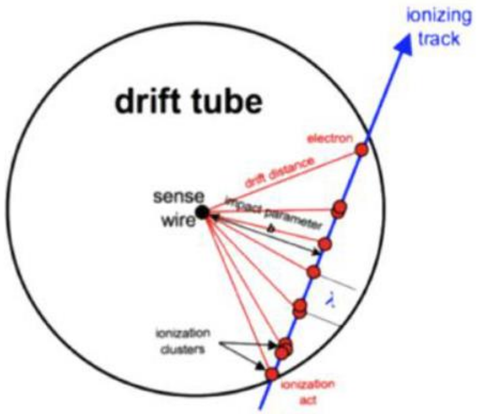
90% He + 10% iC_4H_{10}

$$\frac{\sigma_{p_t}}{p_t} \approx \sqrt{0.078\%^2 p_t^2 + 0.18\%^2}$$

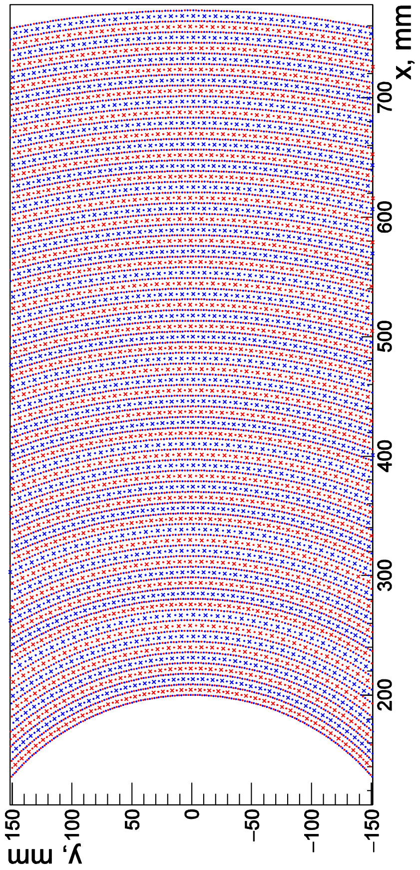
≈0.2% at 1 GeV

$$\frac{\sigma_{dN/dx}}{dN/dx} \approx 3.6\%$$



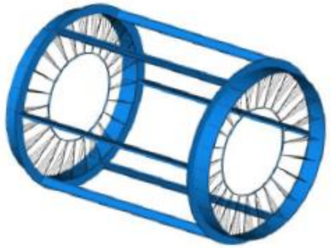


Measurement of individual clusters improves time and dE/dx resolution



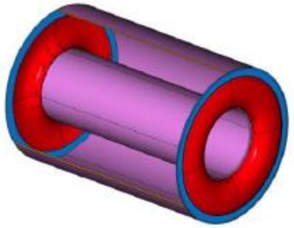
MEG-2 drift chamber

- Separation of the wire anchoring function from the mechanical and wire containment



Wire support

Wire cage structure not subject to differential pressure can be light and feed-through-less.



Gas containment

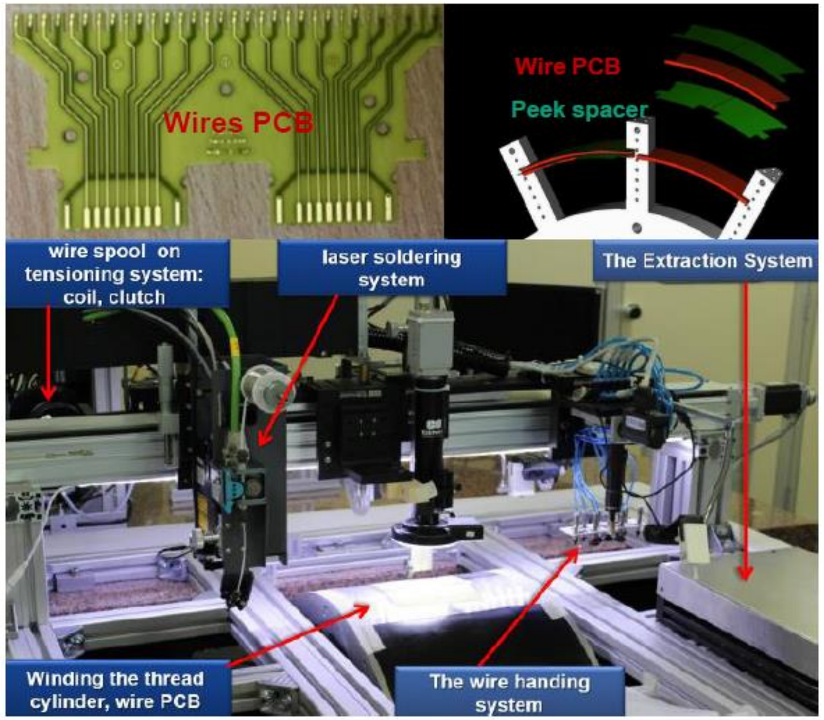
Gas envelope can freely deform without affecting the internal wire position and tension.

- Wire PCB

The high wires density (12 wires/cm^2) imposes the use of ***wires PCBs*** where the wires are accurately positioned and strung at the correct mechanical tension.

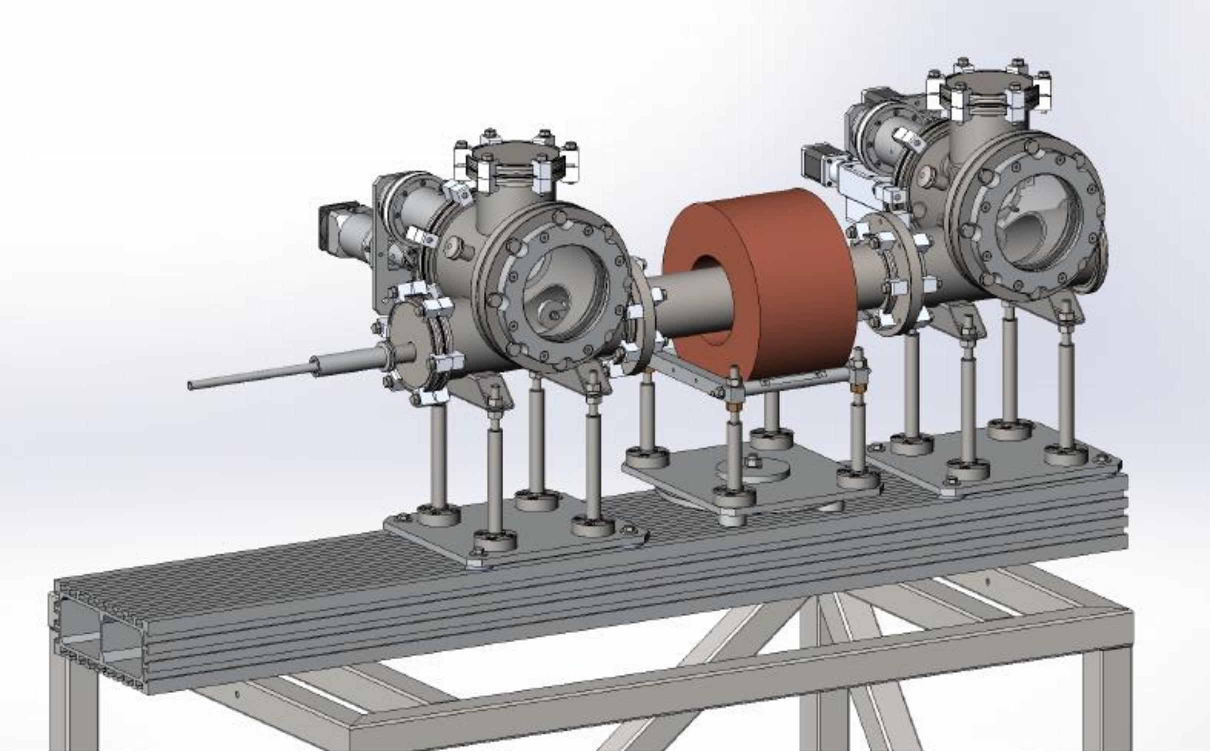
- Wiring robot

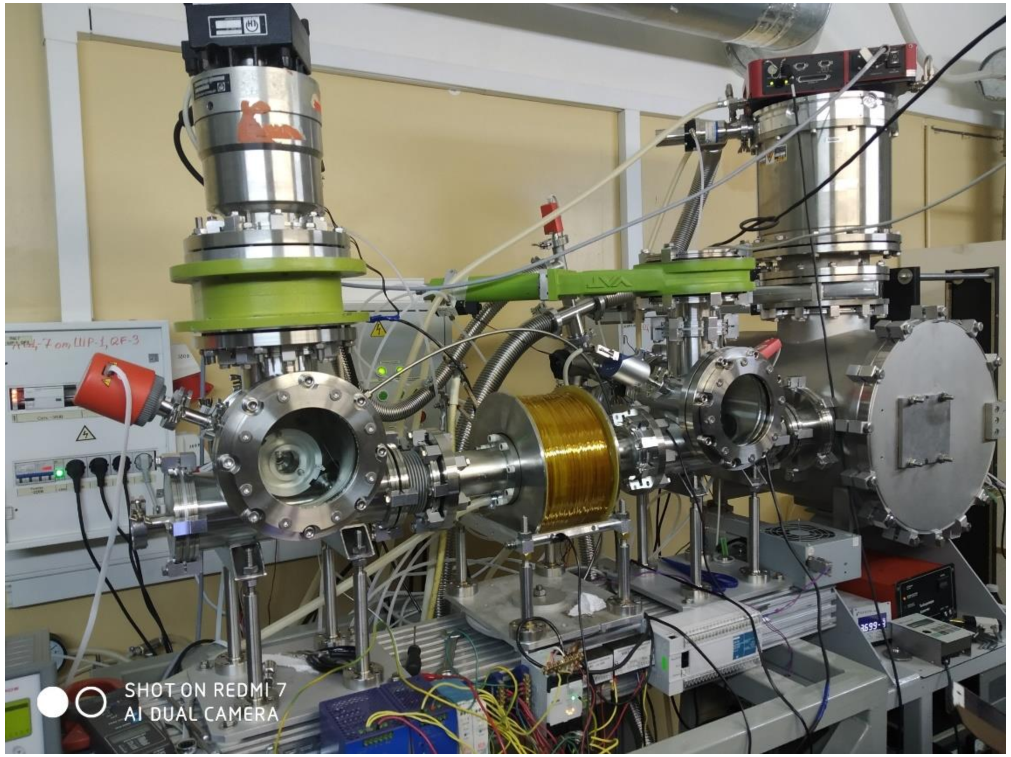
Stringent requirements on the precision of wire position and on the uniformity of the wire mechanical tension impose the use of an automatic system (Wiring Robot), to operate the wiring procedures.



Magnetron coating of wire

Technology for magnetron coating of thin wires (up to 40 μm) has been developed at BINP.





Magnetron coating of wire

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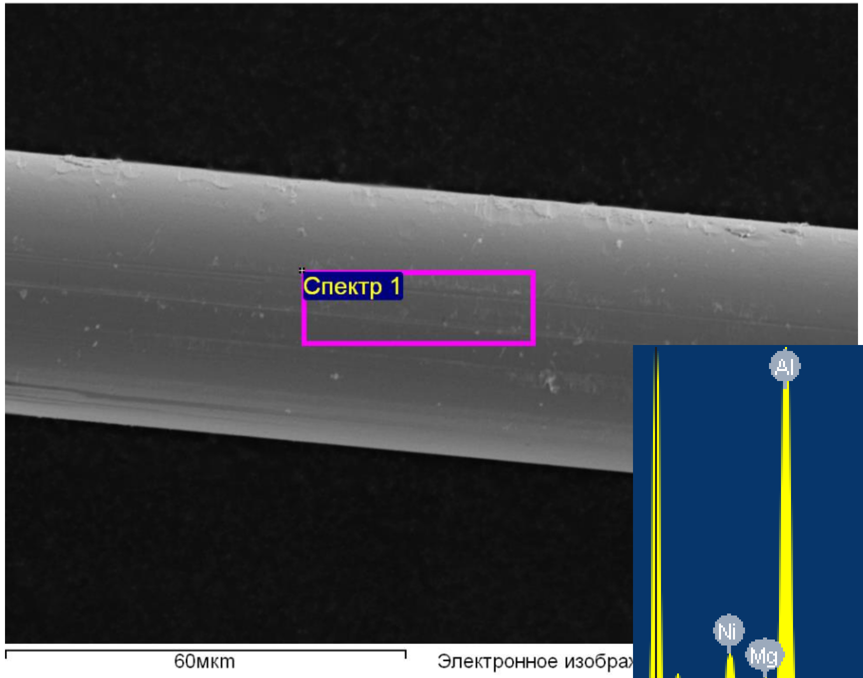
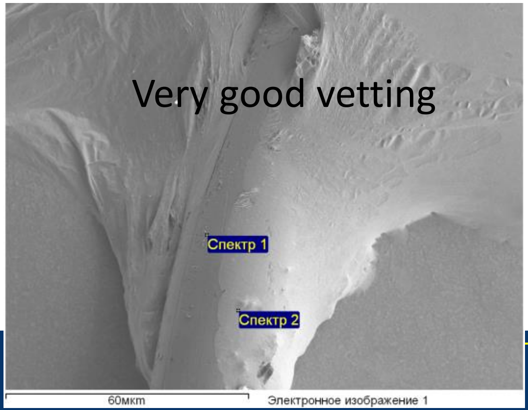
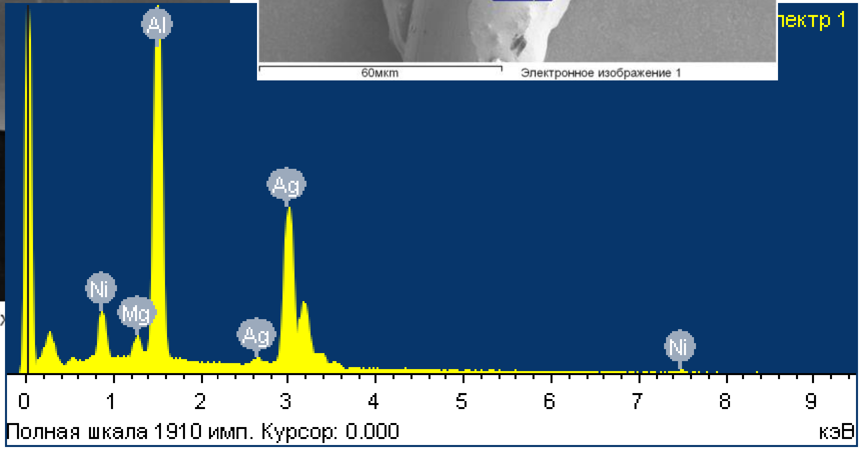
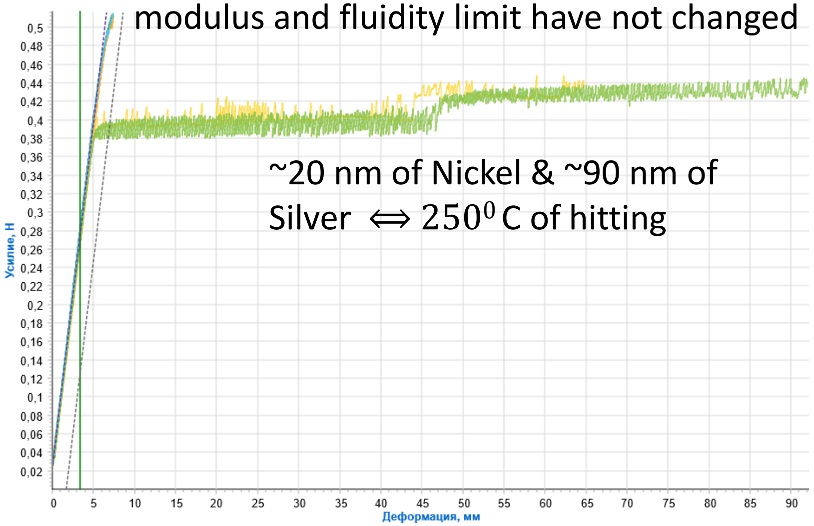






Nickel 20 nm
Silver 60-70 nm

~20 nm of Nickel & ~60 nm of Silver , Young's modulus and fluidity limit have not changed

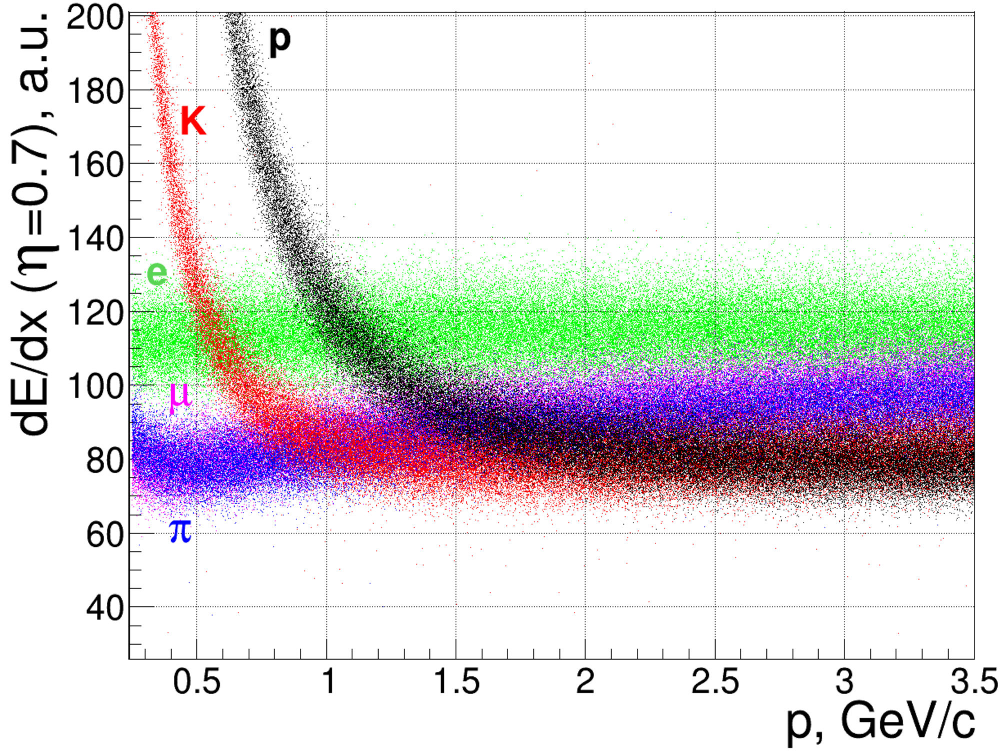


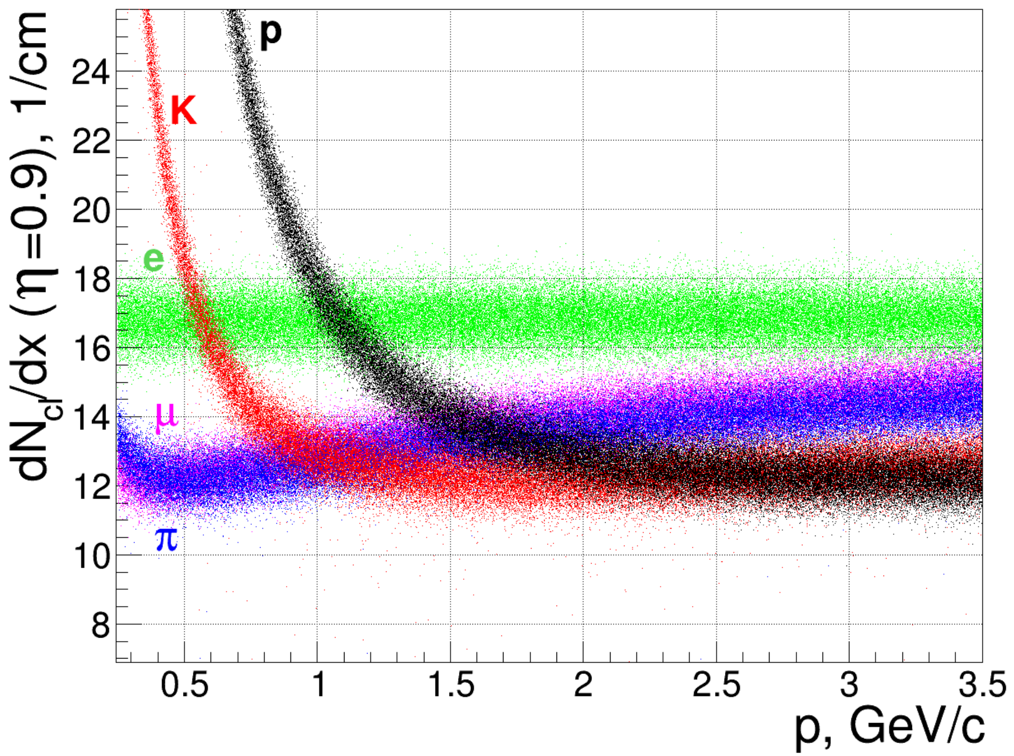
~20 nm of Nickel & ~90 nm of Silver $\Longleftrightarrow$ 250^0 C of hitting

Mechanical properties tests of coated 40-micron wires

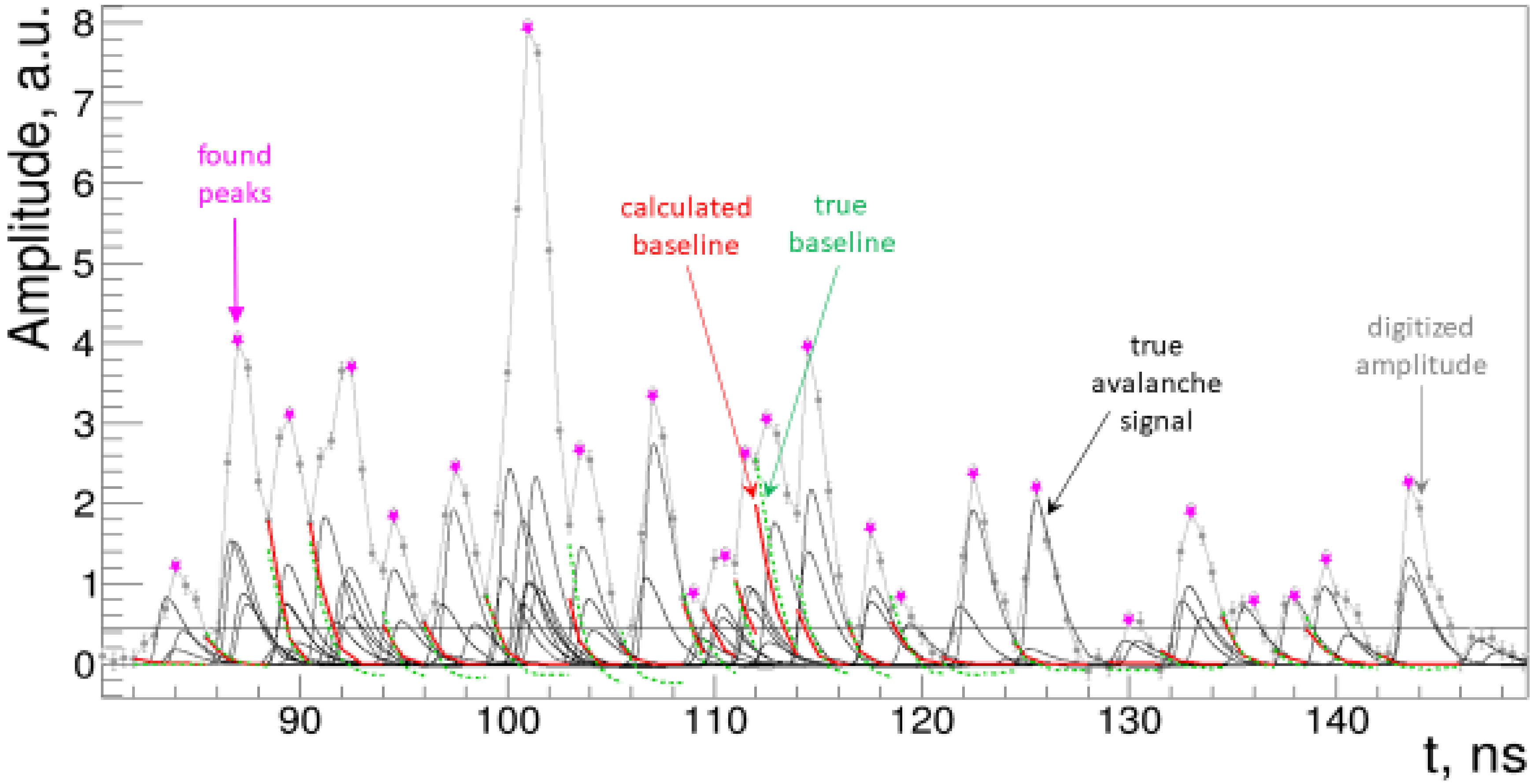
Cluster counting

Counting number of ionization clusters (rather that deposited energy) can improve dE/dx resolution up to x2!

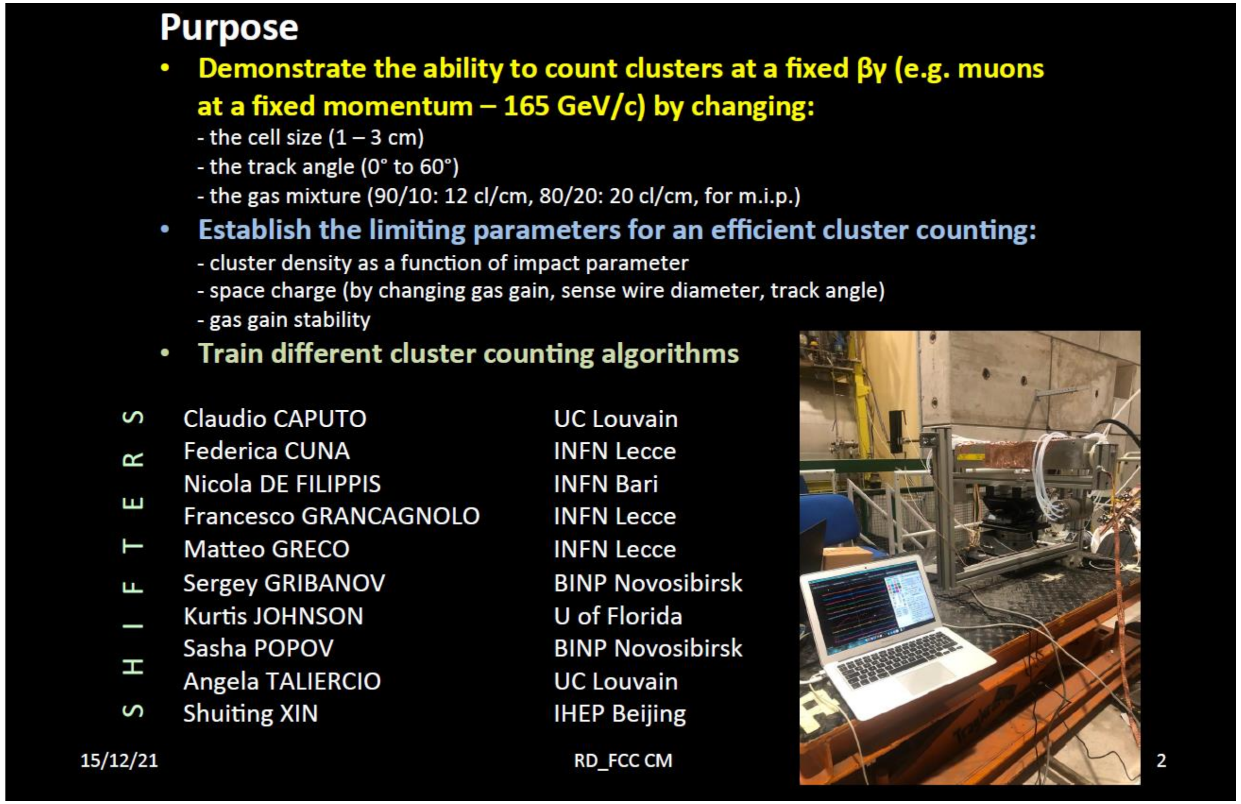


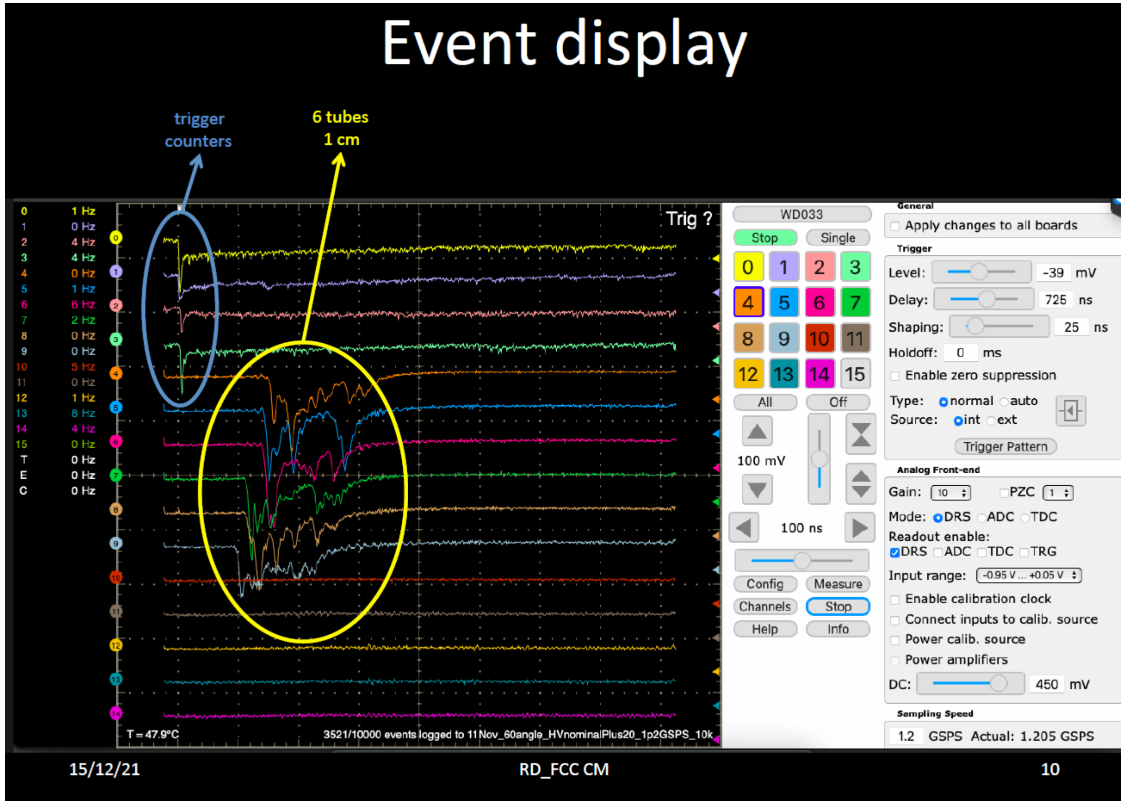


Cluster counting – simulations



Cluster counting - test beam at CERN





PID

Requirements for PID system

π/K separation $> 4\sigma$ up to 2.5-3.5 GeV/c

TOF (BES-3): 3σ at 0.9 GeV/c, DIRC (BaBar): 4σ at 2.5 GeV/c

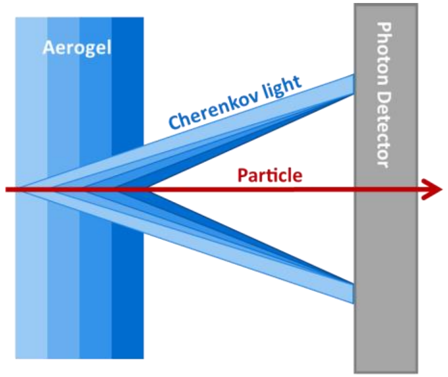
ASHIPH (KEDR): 4σ at 1.5 GeV/c

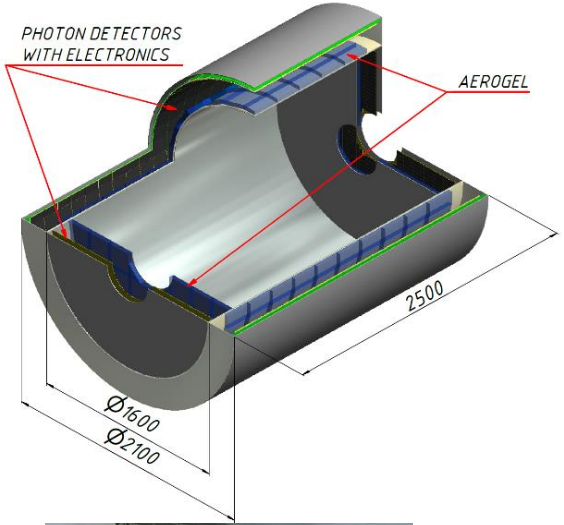
μ/π suppression <1/40 for to 0.5-1.2 GeV/c

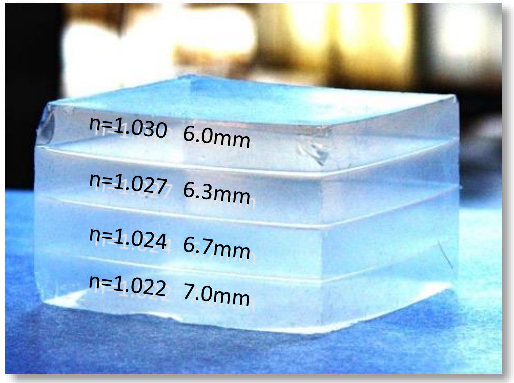
good μ/π separation at low momentum

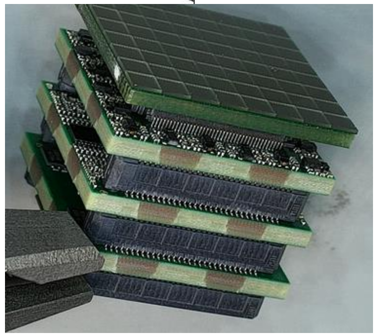
Several option are being considered:

FARICH, ASHIPH, TOF, FDIRC

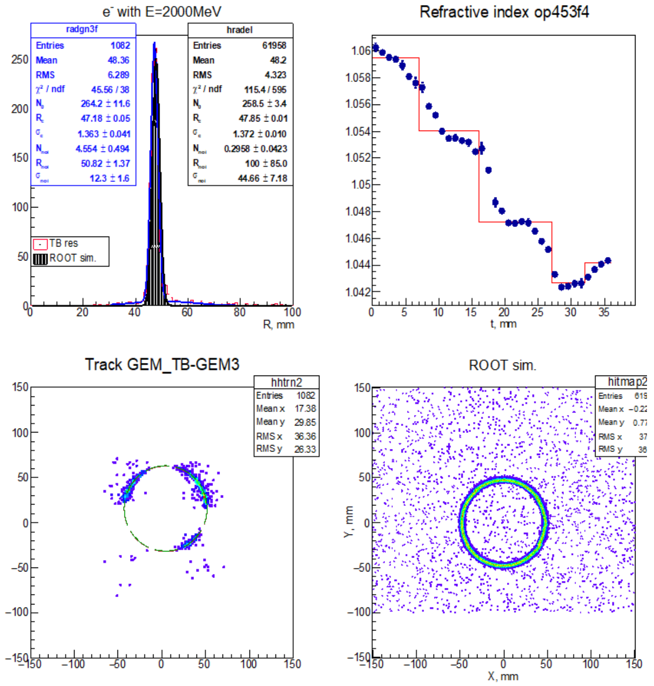


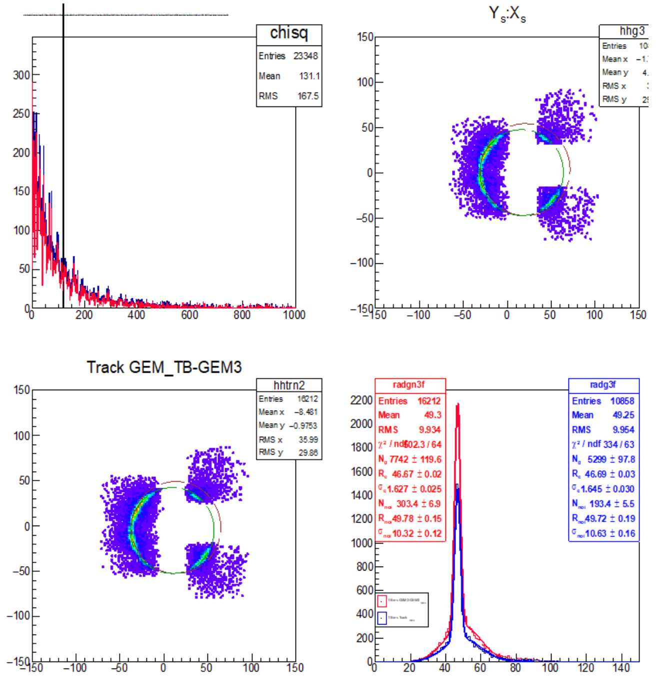






FARICH beam tests (2021)





Pixel ø1 mm
$\sigma_R = 1.36 \pm 0.04\ mm$

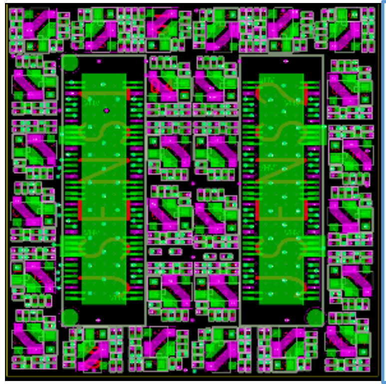
Beam test results in May-Dec of 2021 show us that we are very close to target resolution
$\sigma_R(\blacksquare 3\text{ mm}) = 1.4\ mm$ (from G4 simulation)

Pixel ■3 mm
$\sigma_R = 1.63 \pm 0.03mm$

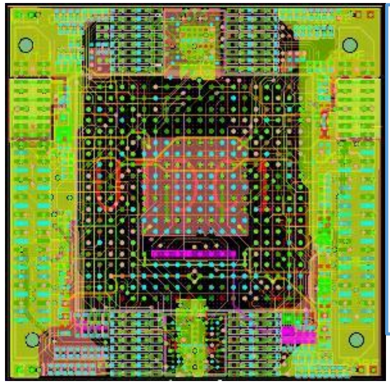
$$\sigma_R^{calc}(\blacksquare 3\text{mm}) = \sqrt{1.36^2 + \left(\frac{3}{\sqrt{12}}\right)^2} = 1.613\ mm$$

A.Yu.Barnyakov et al., NIMA 1039 (2022) 167044

FARICH: FEE based on FPGA-TDC

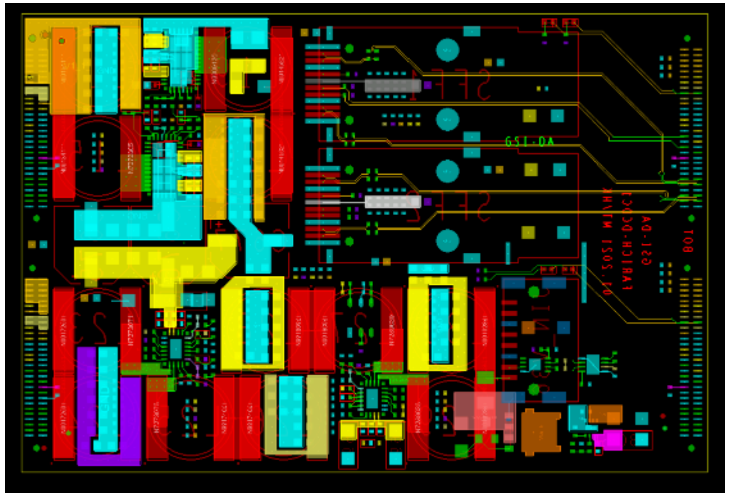


Amplifier board
- 27×27 mm^2 size
- 14-layer PCB
- 30x gain, 64 channels
- couples to KETEK 8×8 SiPM array

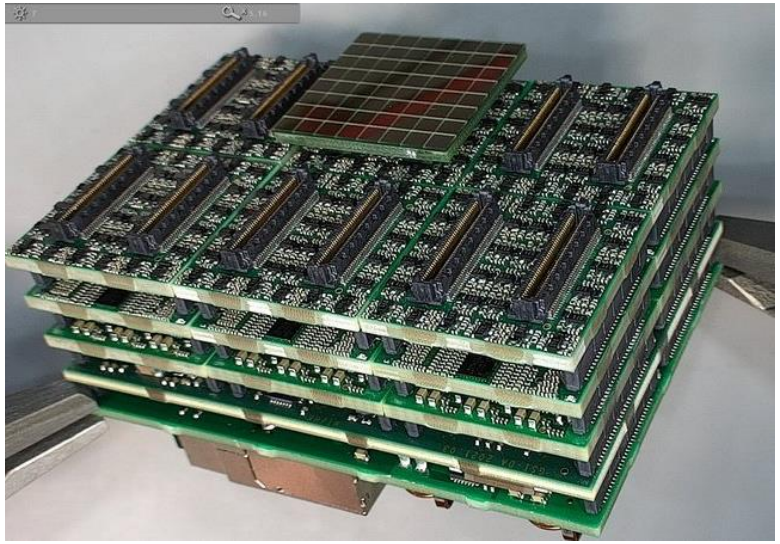


TDC board
- 64 channels
- 2 TDC + 4 threshold FPGAs
- 10ps precision

- Each module readouts 6 arrays 8x8 pixels and equipped with optical transceiver.
- Thickness of 5-layer design is less than 5 cm.



DC-DC convertor board
- goes behind the backplane
- 51×84 mm^2 size
- provides power to SiPMs, amplifiers, FPGA
- uses air inductive coils to operate in the detector magnetic field
- power, trigger & clock connectors



Calorimeter

Baseline:

BELLE/BELLE-2-like electromagnetic crystal calorimeter

Scintillator:

CsI(Tl) has large light yeild, “cheap”, very popular – but slow

LSO, LYSO, etc. – have large LY, very fast – but very expensive (x10)

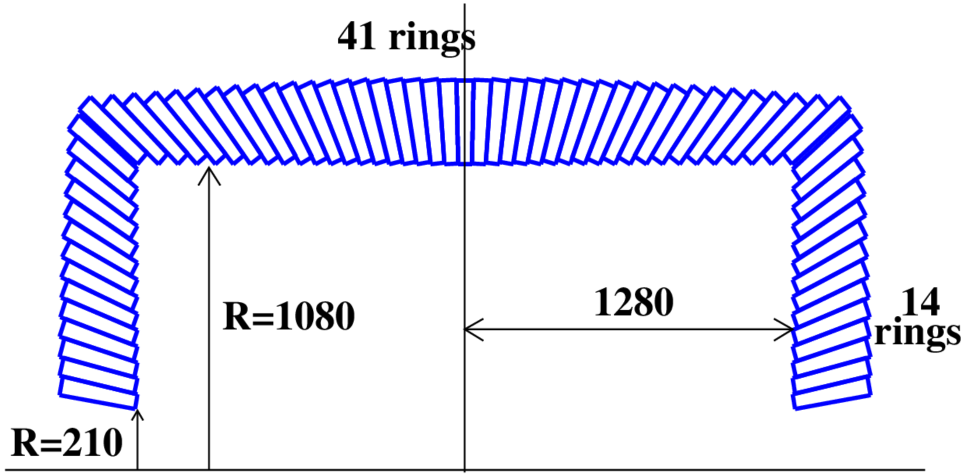
pure CsI – good compromise: reasonable LY, 30 ns component, reasonable price

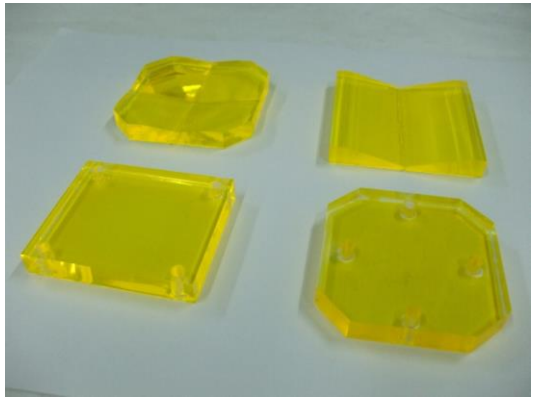
7424 crystals pCsI + WLS + 4 APD

$$\frac{\sigma_E}{E} \approx \frac{1.9\%}{\sqrt[4]{E(GeV)}} \oplus \frac{0.33\%}{\sqrt{E}} \oplus \frac{0.11\%}{E}$$

There are extensive studies with prototype at BINP.

SiPM readout is being tested as well (as an option to improve time resolution)





CMD-3 calorimeter

Muon system

- detect muons
  - mult.scat. of O(1cm)
- μ/π separation
- K_L detection

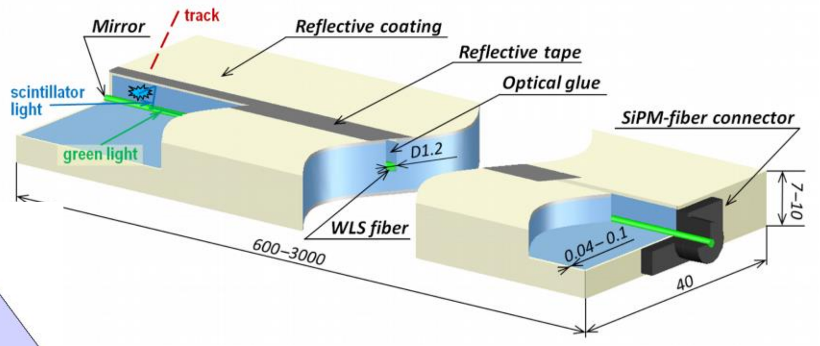
Baseline option:

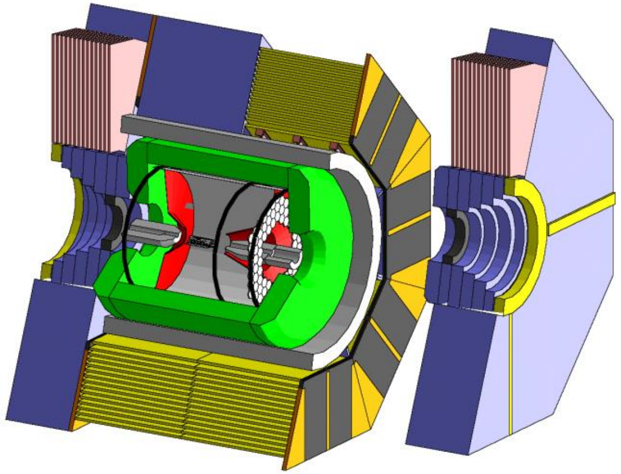
scintillator strips + WLS fiber + SiPM

(BELLE-2, CMD-3)

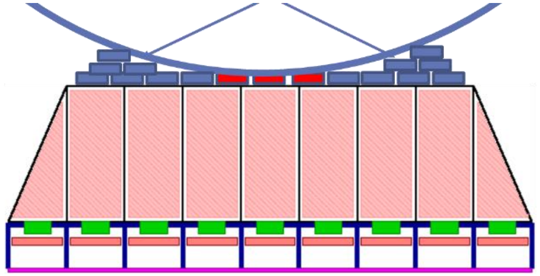
8-9 layers inside iron yoke

~1500 m^2





BELLE-2



CMD-3

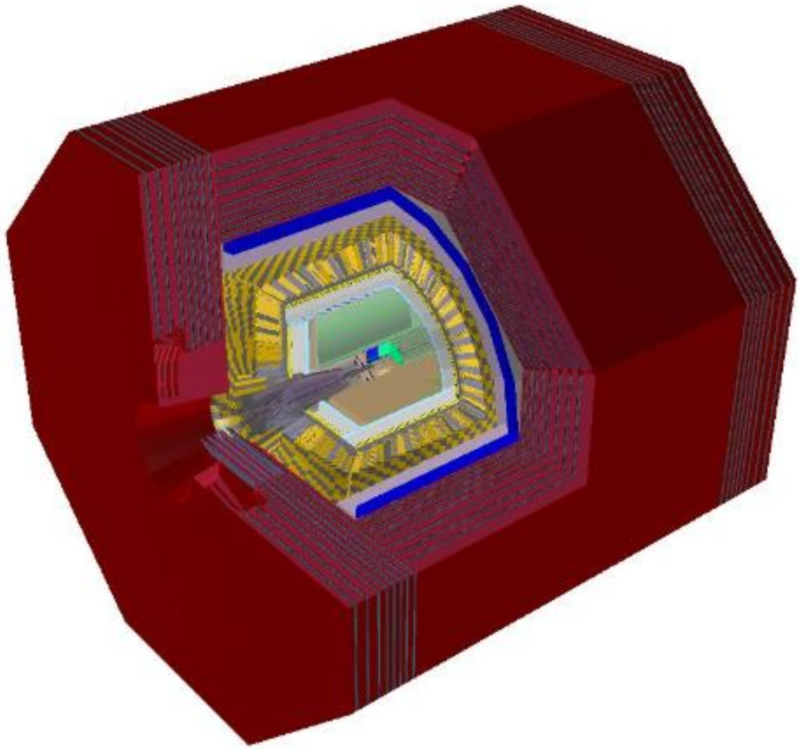
Simulation software

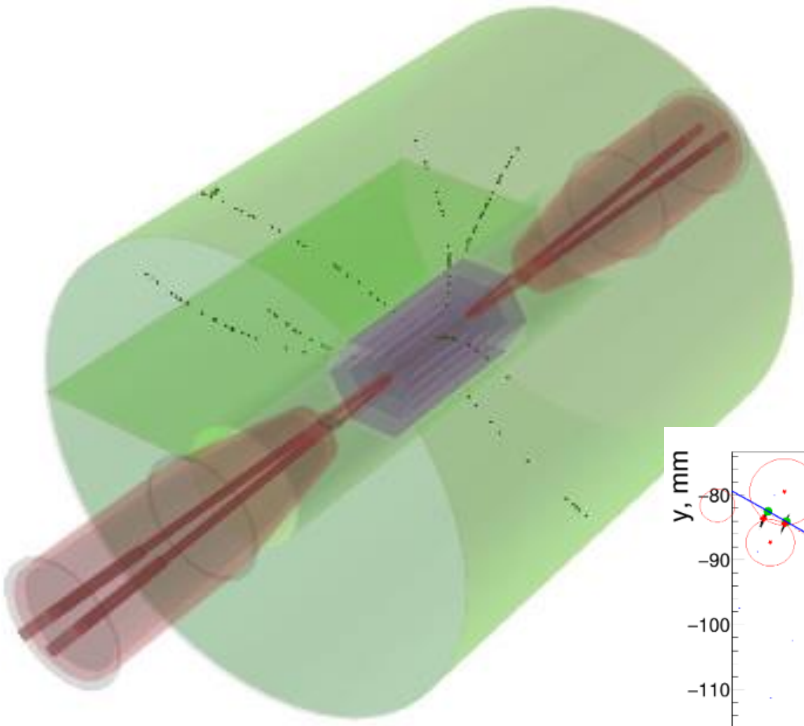
- SCT detector software framework AURORA is released. It includes
  - Full geometry description
  - Unified description of sensitive detectors
  - Realistic magnetic field
  - Digitization and reconstruction for some subsystems
  - Full parametric simulation
  - Basic data analysis tools
  - Stack of external software
- Publications
  - Presented at AFAD-2021
  - Presented to vCHEP21

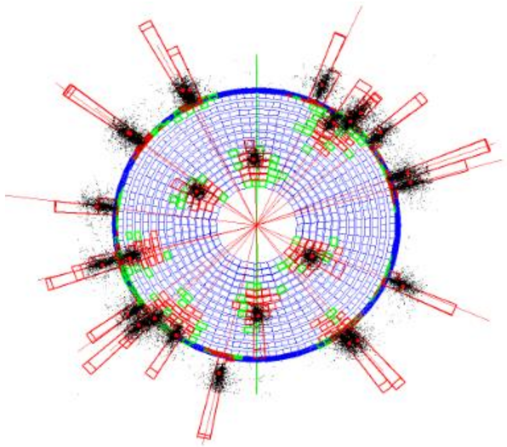
Aurora internals:

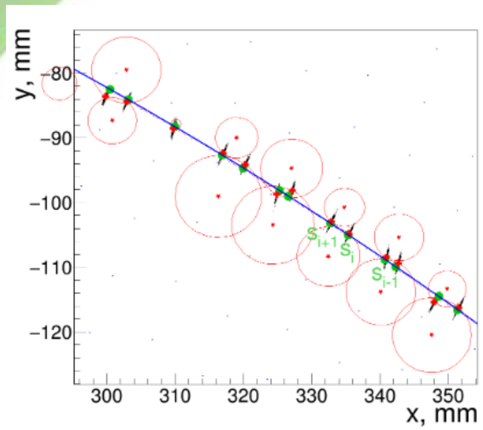
- Based on Gaudi (de-facto HEP standard)
  - allows to develop software components in a convinient way (Algorithms, Tools, Services)
  - mixing C++ and Python code
- Conventional and recently emerged HEP software tools:
  - ROOT, Geant4...
  - Key4HEP (DD4hep, PODIO...)
- Other experiments software
  - Belle II, ILC, FCCSW...
- Build & configuration system inspired by ATLAS Athena
- `lcgcmake` system to build external packages
- Nightly builds
- Standard computing environment is Scientific Linux 7 x86_64, GCC8 + Python2&3

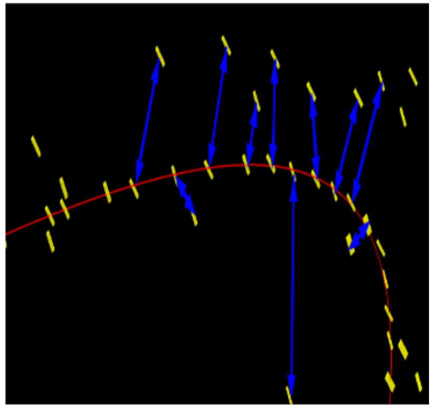
Simulations









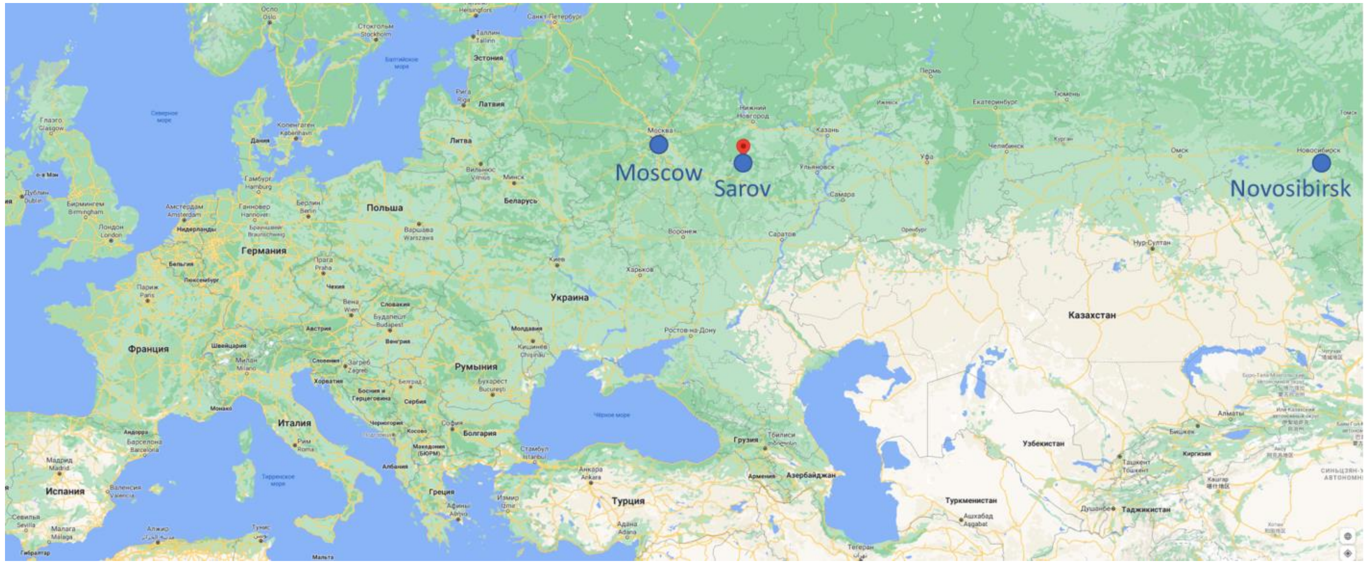


Development supported by RSF grant 19-72-20114

Project

Potential location: Sarov

- National Center of Physics and Matematics is a new scientific center, located near Sarov
- It includes a branch of Moscow State University (first programs are launched in 2021)
- SCTF is discussed as one of the anchor science infrastructures for NCPM



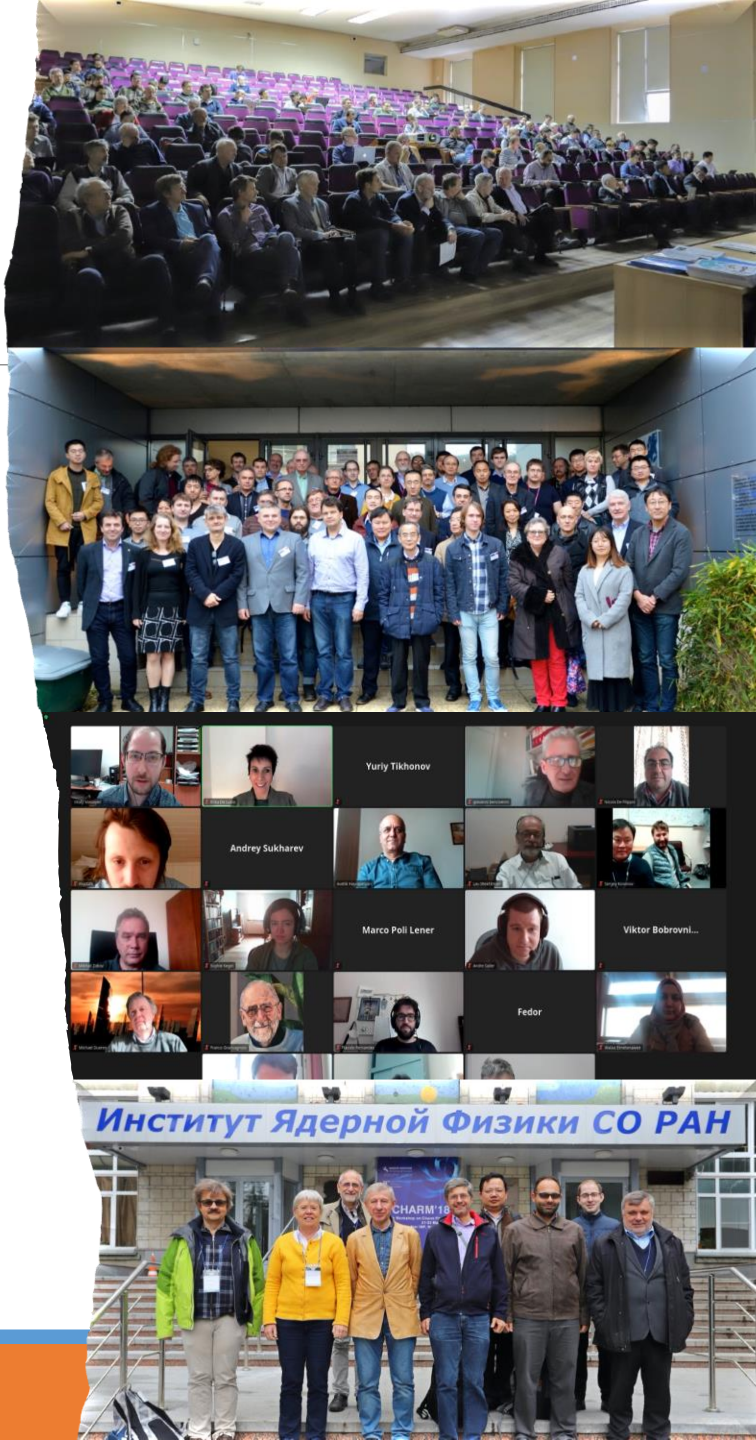
International workshops

Workshops on future super charm tau factories:

1. December 2017, Novosibirsk (link)
2. March 2018, Beijing (link)
3. May 2018, Novosibirsk (link)
4. December 2018, Orsay (link)
5. November 2019, Moscow (link) + 1^{st} general WP5 meeting
6. November 2020, Hefei (online, link)
7. November 2021, Novosibirsk (hybrid, link) as 5^{th} general WP5 meeting

CREMLINplus WP5 meetings: *(CREMLIN+ terminated in April 2022)*

8. 2^{nd} general WP5 meeting, September 2020 (online, link)
9. 3^{rd} general WP5 meeting, February 2021 (online, link)
10. 4^{th} general WP5 meeting, July 2021 (online, link)
11. The SCT Partnership kick-off meeting, November 18^{th}, 2021 (link)



Participation in global strategy forums

European Strategy for Particle Physics Update

- The SCT physics potential is reflected in Physics Briefing book: arXiv:1910.11775 [hep-ex]

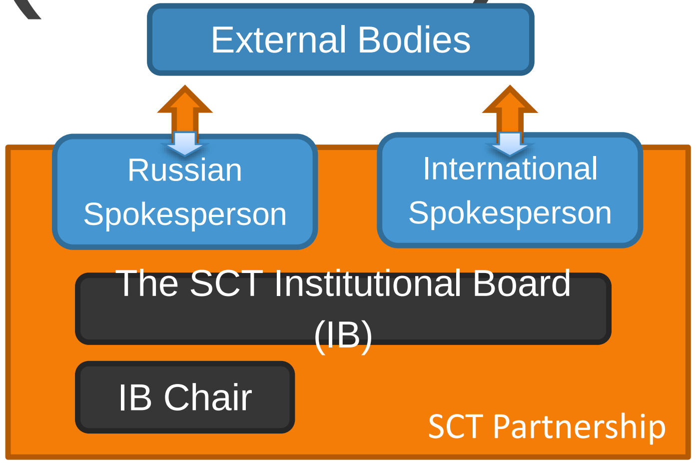
Snowmass2021

- Letter of intent for SCT is signed by 100 colleagues from 38 organizations (including 10 Russian organizations)
- February 2022: white paper submitted

The SCT Partnership (SCTP)

Ivan Logashenko
IB Chair

Pavel Pakhlov
Russian Spokesperson



Proto-collaboration (SCT Partnership) launched in November 2021.

1. Preparation of TDR
2. Development of the physics program
3. Shaping future collaboration

- sct.inp.nsk.su/partnership

A Annex 1. The Partners

List of all Partners. To be updated each time a new Partner has joined.

Country	Affiliation	LoI signing date
Germany	Justus Liebig University (JLU) Giessen	2021.09.22
Russia	Novosibirsk State Technical University (NSTU)	2021.09.24
Russia	Novosibirsk State University (NSU)	2021.10.11
Russia	P.N. Lebedev Physical Institute of Russian Academy of Science (LPI RAS)	2021.10.11
Russia	Budker Institute of Nuclear Physics (BINP)	2021.10.13
Russia	Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics (SINP MSU)	2021.10.29
Mexico	Physics Department, Center for Research and Advanced Studies (Cinvestav)	2021.11.12
International	Joint Institute for Nuclear Research (JINR)	2021.11.15
Russia	Higher School of Economics (HSE) University	2021.11.15
Russia	Institute of Nuclear and Radiation Physics (INRP) RFNC-VNIIEF	2021.11.16

Table 1: Updated on November 18, 2021.

Summary

1. There is rich physics program of experiments at Super c-tau factory
2. There is conceptual design of the Super c-tau factory
3. There are ongoing studies of collider and injector designs, simulations of the experiments at SCTF, developments of the detector subsystems – on the way to TDR
4. The collaboration on the project is growing. The proto-collaboration, SCT Partnership, has been established.
5. There is new possible location for SCTF: the recently established National Center of Physics and Mathematics near Sarov