STATUS OF THE BINP SCTF PROJECT

Ivan Logashenko

BINP/NSU

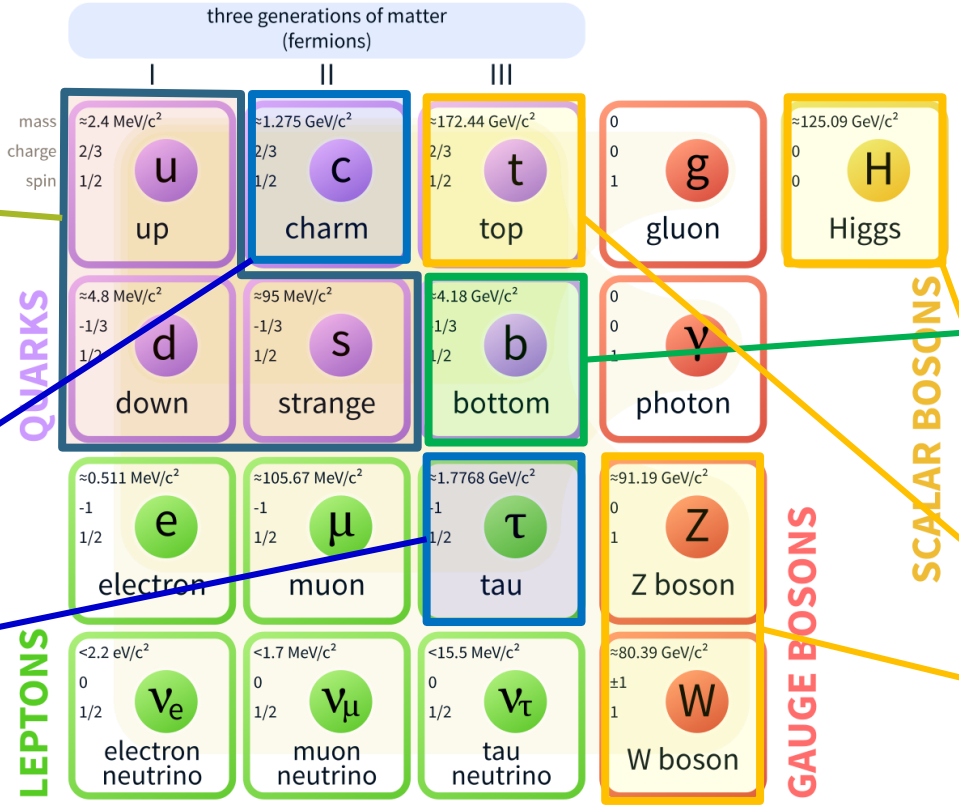
Joint Workshop on Future charm-tau Factory,

Sep 24-28, 2019, Moscow

Existing and future flavor factories

Фи-фабрики
1-2 ГэВ
DAFNE (Italy)
ВЭПП-2000 (BINP)

$c\tau$-фабрики
2-6 ГэВ
BEPC-2 (China)
SCTF(BINP)
STCF(China)
x100



B-фабрики
10 ГэВ
PEP-2 (USA)
KEK-B (Japan)
Super KEK-B (Japan)
LHCb (CERN)
x50

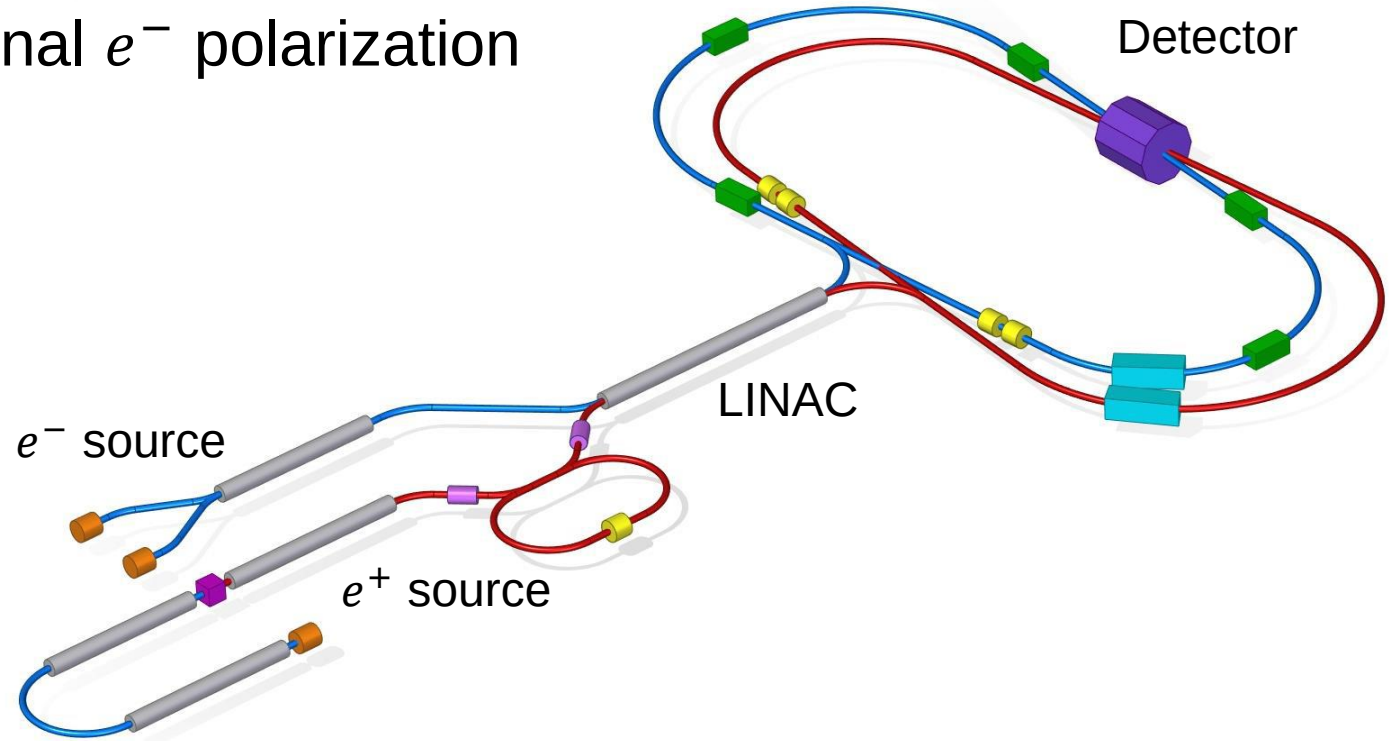
Z-фабрики
Хиггс-фабрики
45-175 ГэВ
LEP/LEP-2 (CERN)
FCC-ee (CERN)
CEPC (China)
x10000

finished operational future

Super Charm-tau factory @BINP

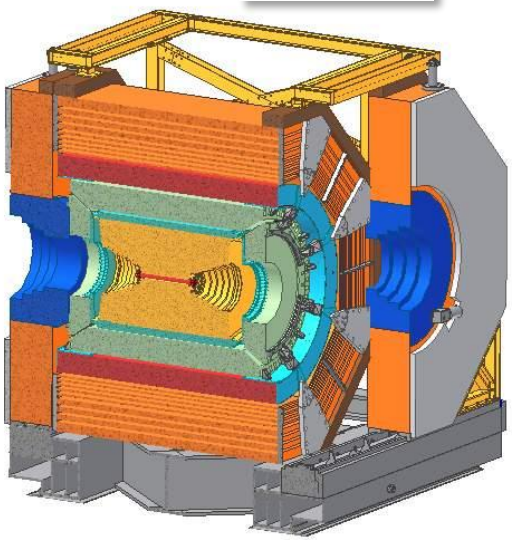
- Symmetric e^+e^- collider, $2E = 2 \div 6$ ГэВ
- Luminosity $10^{35}\ 1/cm^2s$
- «Crab Waist» beam collision
- Longitudinal e^- polarization

Factory of c, τ, J/ψ



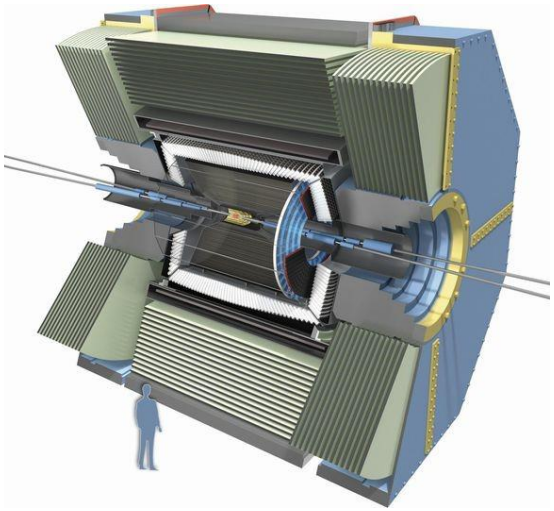
Brothers, sisters and cousins…

BES-3



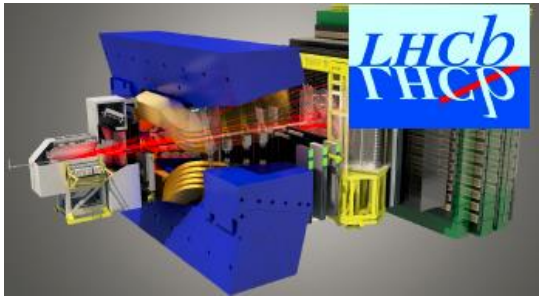
Very similar
1% luminosity

BELLE-2



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

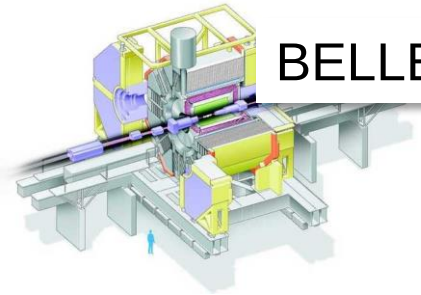
LHCb



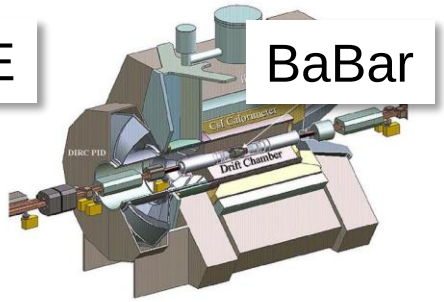
pp collisions

Previous generation:

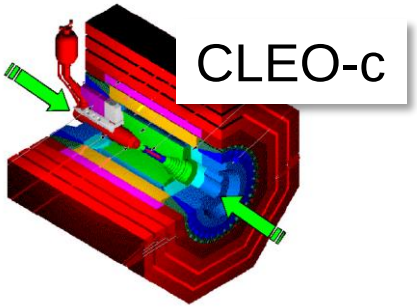
BELLE



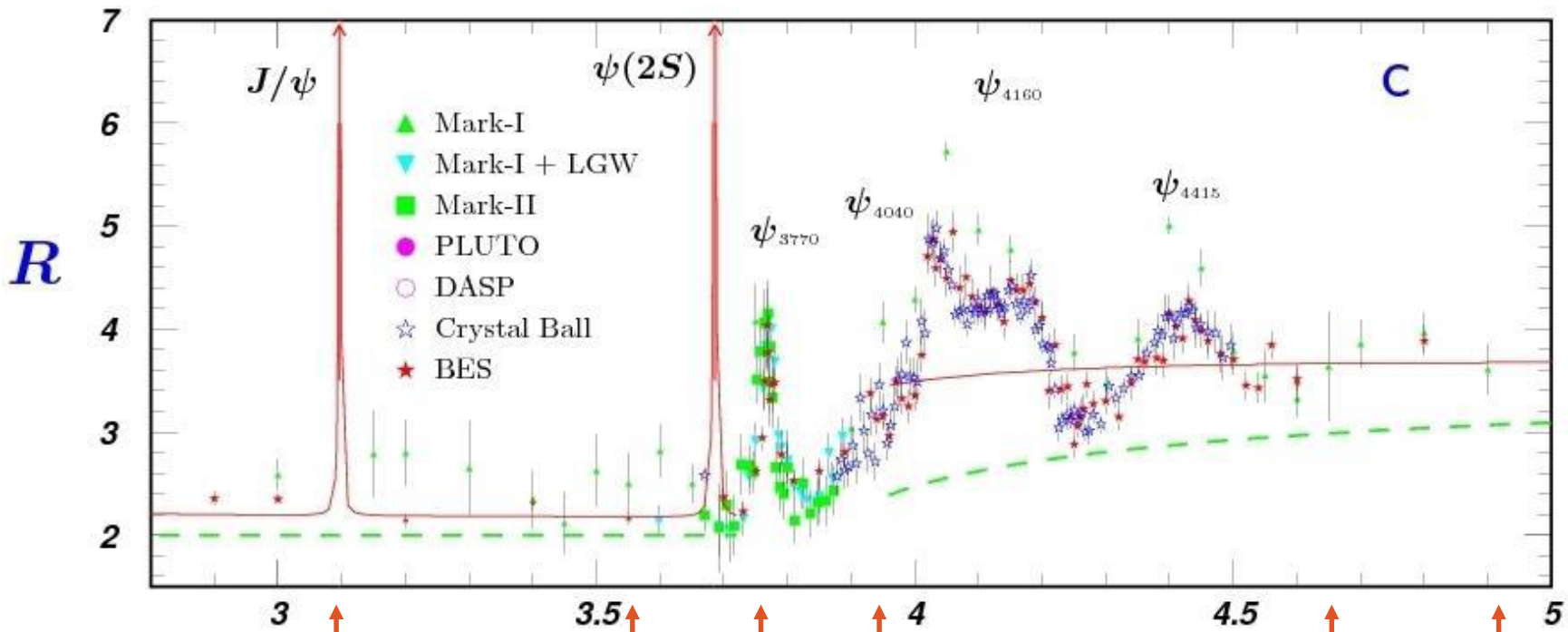
BaBar



CLEO-c



One year at SCTF



J/ψ τ D D_s Λ_c Ξ_c

1 year at $10^{35}\ 1/cm^2 s$

$10^{12}\ J/\psi$ $10^{10}\ \tau\tau$ $10^{9}\ D\bar{D}$ $10^{8}\ D_s\bar{D}_s$ $10^{8}\ \Lambda_c^+\Lambda_c^-$

$10^{11}\ \psi(2S)$

Physics program

- Strong phase measurements in D-decays.
- Search for very suppressed c-quark decays.
- Search for CPV.
- ...

c

QCD

- Strong excited quarkonium physics.
- Molecular states.
- Threshold baryon interactions.
- Search for glueballs in J/ψ and Ψ' decays.
- ...

...

- ...

τ

- Precise measurements of τ–lepton parameters.
- Michel parameters.

Lepton Universality tests.

- Precise measurements of $\tau \to$ hadrons decays.
- Search for CPTV in τ-decays.
- ...

SCTF advantages

- Threshold production.
- Well determined initial state.
- Quantum correlated production of neutral D meson pairs.
- Double tag technique.
- Low multiplicity (4-5).
- Longitudinal beam polarization.
- ...

Physics program

- The physics program of Super Charm-Tau factory was discussed in details at previous meetings:
  - December 2017, Novosibirsk
  - March 2018, Beijing
  - May 2018, Novosibirsk
  - December 2018, Orsay
- and continue to be discussed at this meeting with particular focus on beam polarization:
  - Andrzej Kupsc, *Hyperon physics at SCT with polarized beams*
  - Denis Epifanov, *Measurement of Michel parameters in tau decays at the Super Charm-Tau factory with polarized electron beam*
  - Denis Epifanov, *Search for CPV in* $\tau \to K\pi\nu$ *at* e^+e^- *colliders, effect of the polarized electron beam*
  - Emilie Passemar, *CPV in tau decays with polarization*
  - …

SCTF and B-factories

There is strong competition/synergy between $c-\tau$ and B factories:

- LHCb will have more D's
- Belle-II will have more D's and τ's

But statistics is not everything – SCTF has potential for higher systematic accuracy (e.g. $\tau \to \mu\gamma$)

Today:		Tomorrow:
• 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}

Now there is delicate balance between the experiments

Super $c-\tau$ factory will allow to maintain the balance in future

There are ongoing MC studies of SCTF performance for various cases

Brief history of $c\tau$-factories

- 1993, Dubna JINR ($E_{cm} = 2\ \mathrm{GeV}, L = 9.4 \times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$)
- 1994, Argonne National Laboratory ($E_{cm} = 3 - 5\ \mathrm{GeV}, L = 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$)
- 1995, BINP, round beams ($E_{cm} = 2 - 4.2\ \mathrm{GeV}, L = 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$)
- 1996, Spain & France ($E_{cm} = 4\ \mathrm{GeV}, L = 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$)
- 1997, Beijing IHEP ($E_{cm} = 2.0 - 4.2\ \mathrm{GeV}, L = 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$)

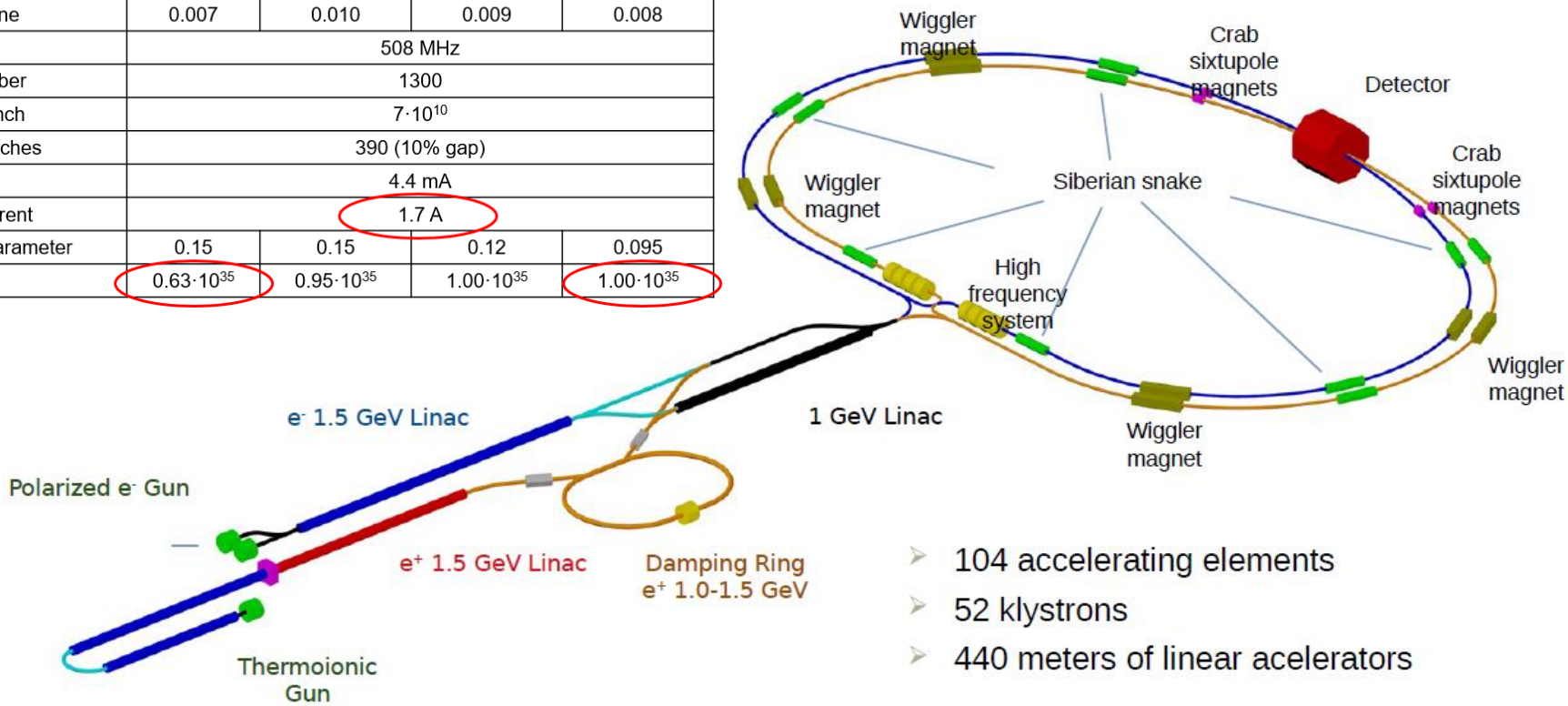
The only one built and running

- 2006: Crab waist collision scheme (P.Raimondi):

$$10^{33} \rightarrow 10^{35}$$

Collider conceptual design (2011)

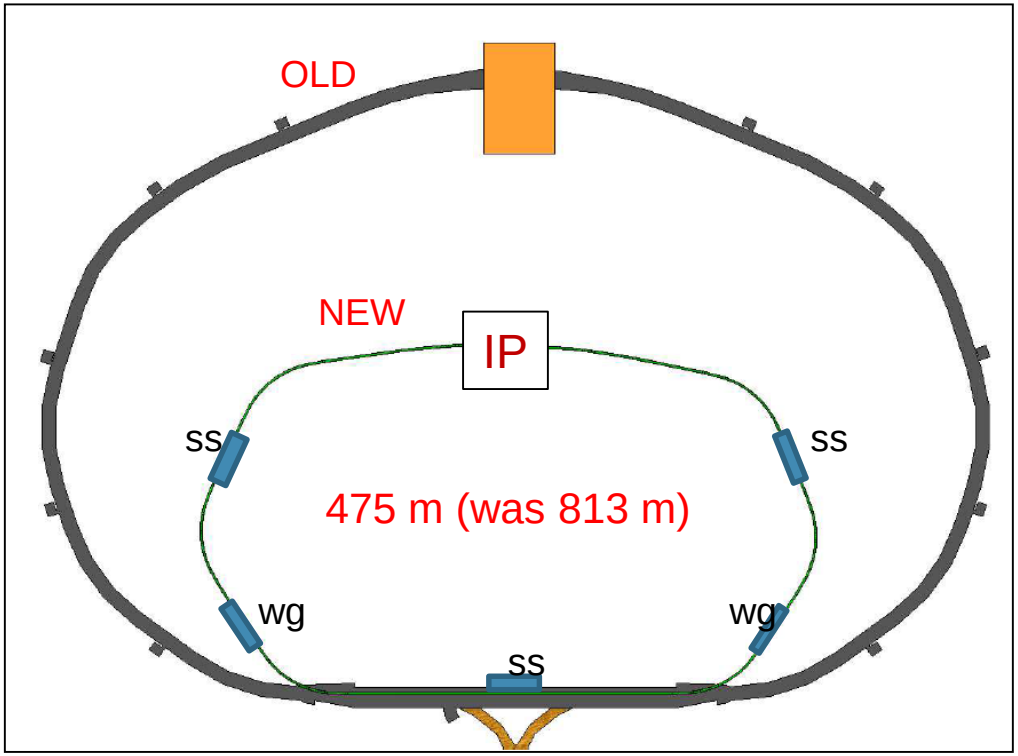
Energy	1.0 GeV	1.5 GeV	2.0 GeV	2.5 GeV
Circumference	780 m			
Emittance hor/ver	8 nm/0.04 nm @ 0.5% coupling			
Damping time hor/ver/long	30/30/15 ms			
Bunch length	16 mm	11 mm	10 mm	10 mm
Energy spread	$10.1\cdot10^{-4}$	$9.96\cdot10^{-4}$	$8.44\cdot10^{-4}$	$7.38\cdot10^{-4}$
Momentum compaction	$1.00\cdot10^{-3}$	$1.06\cdot10^{-3}$	$1.06\cdot10^{-3}$	$1.06\cdot10^{-3}$
Synchrotron tune	0.007	0.010	0.009	0.008
RF frequency	508 MHz			
Harmonic number	1300			
Particles in bunch	$7\cdot10^{10}$			
Number of bunches	390 (10% gap)			
Bunch current	4.4 mA			
Total beam current	1.7 A			
Beam-beam parameter	0.15	0.15	0.12	0.095
Luminosity	$0.63\cdot10^{35}$	$0.95\cdot10^{35}$	$1.00\cdot10^{35}$	$1.00\cdot10^{35}$



- 104 accelerating elements
- 52 klystrons
- 440 meters of linear acelerators

Updated conceptual design (2018)

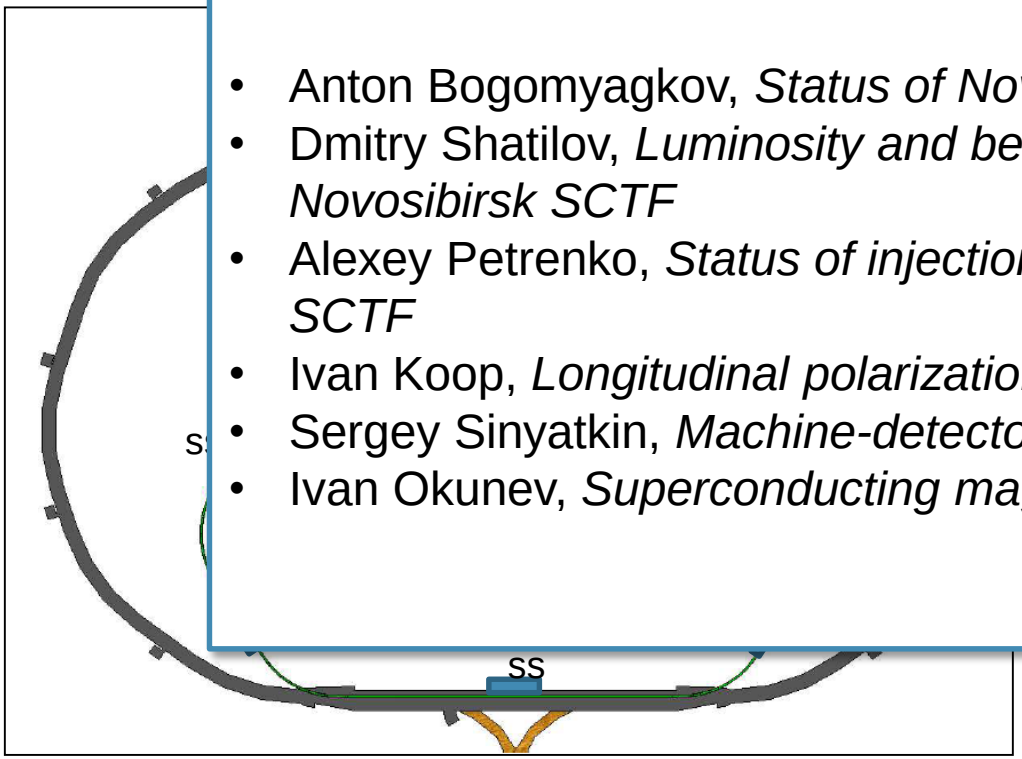
The project continued to evolve.
2018: smaller ring, more robust and realistic design



	1 GeV	2 GeV	3 GeV
Π [m]	475.768		
2θ [mrad]	60		
N_{part} $[10^{10}]$	5.5 (2.1)	5.2	13 (7)
N_{bunch}	400 (500)	420	280 (150)
I [A]	2.2 (1)	2.2	2
β_x^*/β_y^* [cm]	5/0.05		
ε_x [nm]	20 (15)	6.5	11
$\varepsilon_y/\varepsilon_x$ [%]	0.5	0.5	0.5
$\mathcal{L}$ $[10^{35}]$	0.5 (0.14)	1	1.9 (1)
V_{RF} [MV]	1	0.7	2

Updated conceptual design (2018)

The proj
2018: sm
design



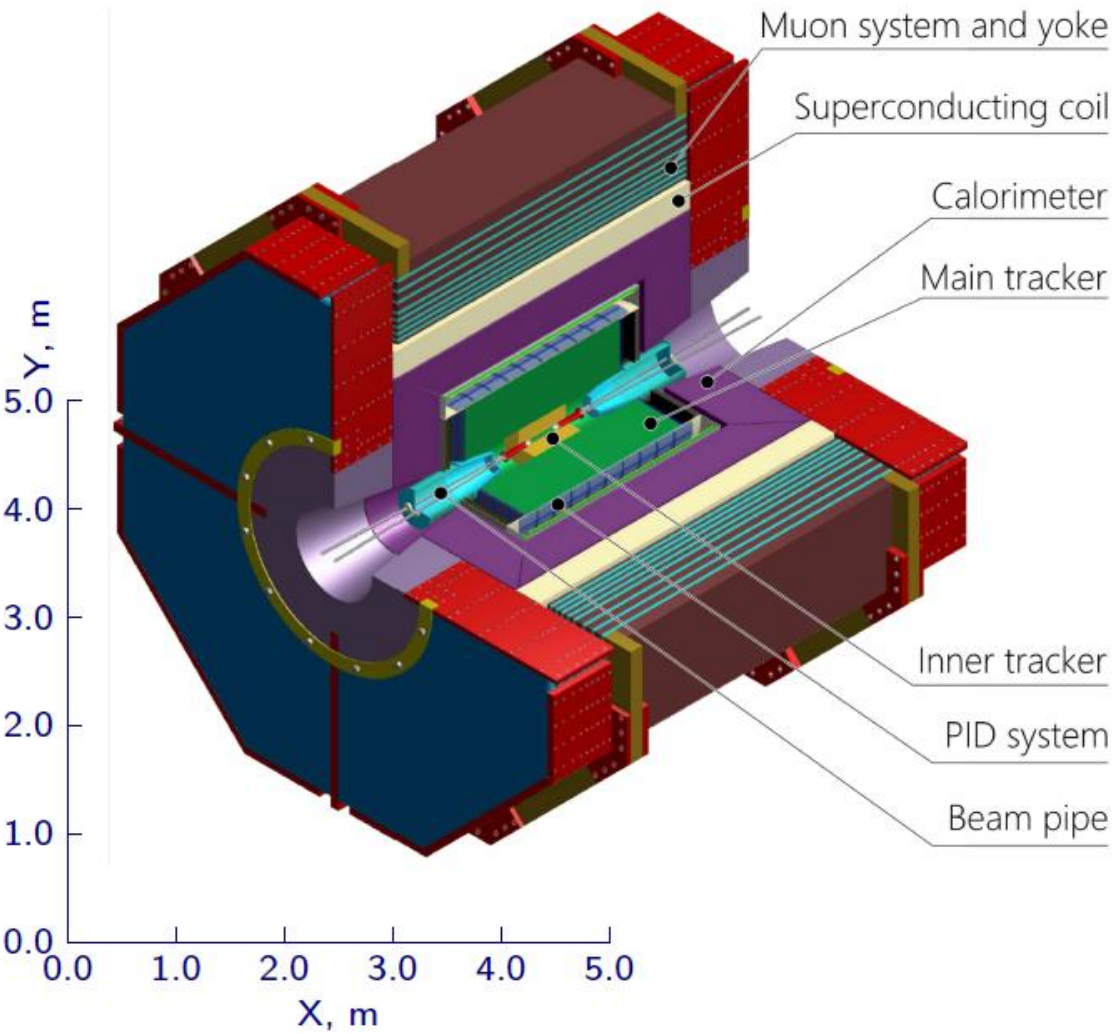
The design continue to be improved/detailed.

See talks on Thursday by:

- Anton Bogomyagkov, *Status of Novosibirsk SCTF*
- Dmitry Shatilov, *Luminosity and beam-beam effects for Novosibirsk SCTF*
- Alexey Petrenko, *Status of injection facility for Novosibirsk SCTF*
- Ivan Koop, *Longitudinal polarization*
- Sergey Sinyatkin, *Machine-detector interface*
- Ivan Okunev, *Superconducting magnets of the final focus*

	1 GeV	2 GeV	3 GeV
			13 (7)
			280 (150)
			2
			11
			0.5
$\mathcal{L}$ $[10^{35}]$	0.5 (0.14)	1	1.9 (1)
V_{RF} [MB]	1	0.7	2

Detector concept and requirements

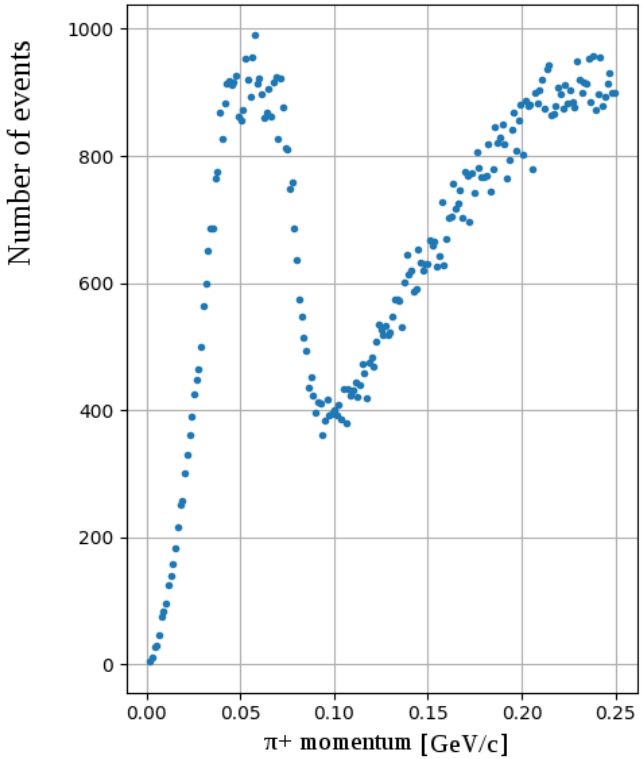


Physics requirements:

- Good $\frac{\sigma_P}{P}$ for charged particles.
- Good symmetry and hermeticity;
- Soft track detection;
  - Inner tracker to work with rate of charged tracks $\geqslant 10^4 \frac{\text{tracks}}{cm^2 \cdot s}$;
- 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 $\sim$ 300 kHz at J/ψ-peak.

Inner tracker

- Resolution similar to drift chamber ($\sim 100\ \mu$)
- Sensitive to particles with low momentum (~ 50 MeV/c)
- Able to handle high particle flux
- Compatible with final focus constraints
- Approximate size: Ø (40-400) x 600 mm



Simulation of π^+ momentum distribution in $e^+e^- \longrightarrow DD^*$

Talk by Andrey Sokolov on Wednesday, *Inner tracker options for SCTF: status and perspectives*

Artistic view of interaction point

Cryostat with SC FF magnets

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	**“TraPid” option**
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
BINP	INFN (Lecce)

Talk by Korneliy Todyshev on Wednesday, *Drift chamber R&D progress in Novosibirsk*

TraPid development is part of CREMLIN+ working package 5

Particle identification

Requirements for PID system

- π/K separation $> 4\sigma$ up to 2.5-3.0 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

Talks on Wednesday:

- Sergey Kononov, *FARICH PID system option: prototyping and simulation results*
- Mustafa Schmidt, *DIRC options for the SCTF Detector*

Calorimeter

Baseline option:

- BELLE/BELLE-2-like electromagnetic crystal calorimeter

Scintillator:

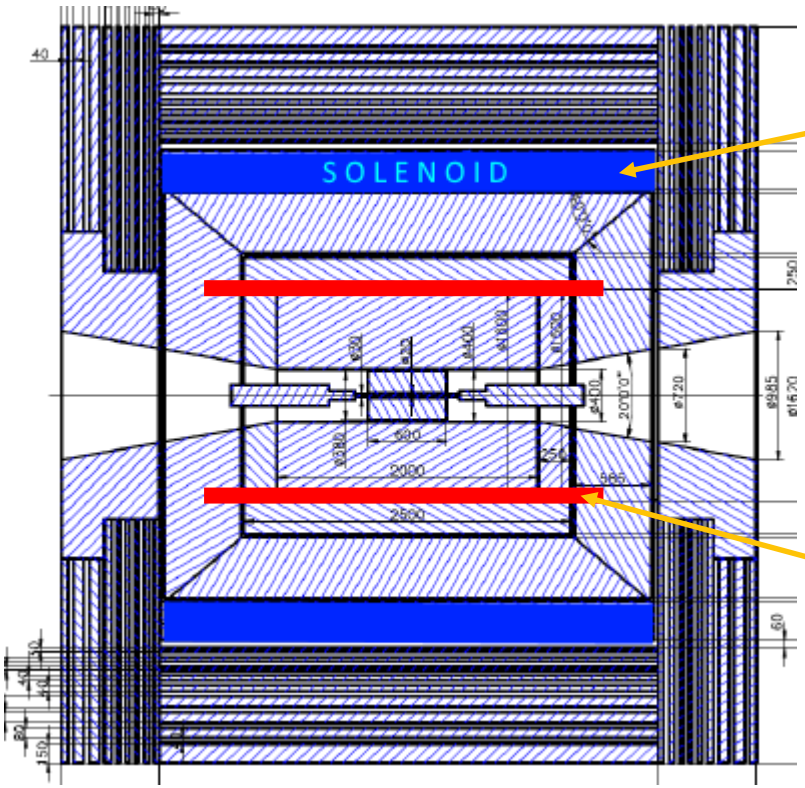
- CsI(Tl) has large light yeild, “cheap”, very popular – but slow
- LSO, LYSO, etc. – have large LY, very fast – but very expensive (x10)
- **pure CsI – good compromise: reasonable LY, 30 ns component, reasonable price**

Other options being considered:

- LXe calorimeter, combined LXe + pCsI calorimeter (CMD-3: LXe+CsI(Tl))

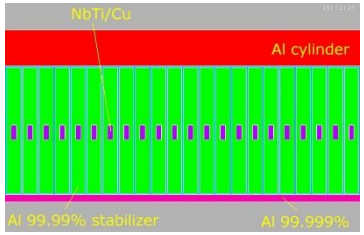
Talk by Ivan Bulyzhenkov on Tuesday, *Progress in simulation of SCT calorimeter*
Talk by Sergey Oreshkin on Wednesday, *Status of the R&D on the calorimeter based on pure CsI crystals for the Super Charm-Tau factory*

Magnet

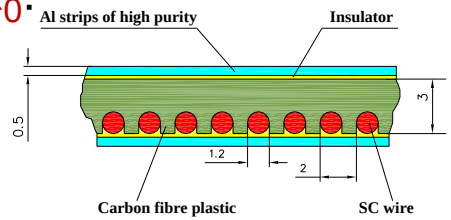


Baseline field 1.5 T

Two options considered:



- Outside calorimeter
  - “thick” design
  - Al-stabilized coil, established technology
  - Similar to PANDA magnet
  - Baseline option
- Just outside drift chamber
  - “thin” design, 0.1 X_0!
  - CMD-3 and KEDR experience



Talk by Aleksey Bragin on Wednesday, *Thin solenoid option proposal*

Muon system

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

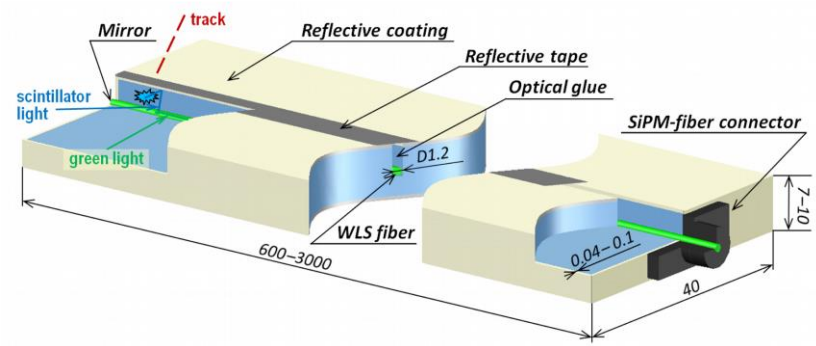
Baseline option:

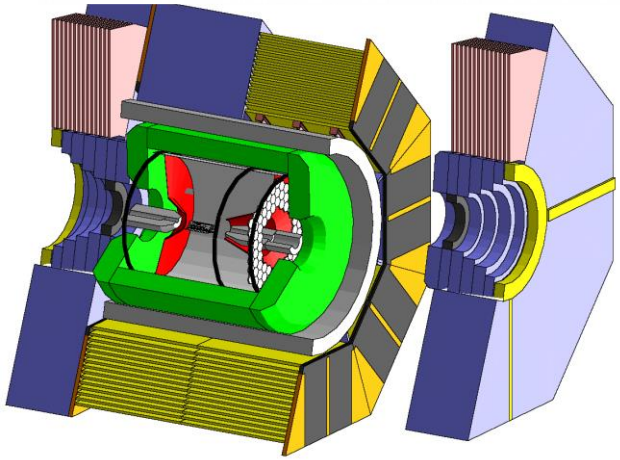
scintillator strips + WLS fiber + SiPM

(BELLE-2, CMD-3)

8-9 layers inside iron yoke

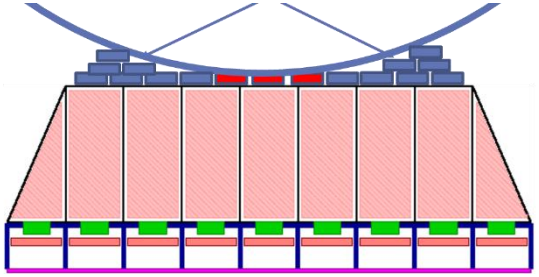
~1500 m^2





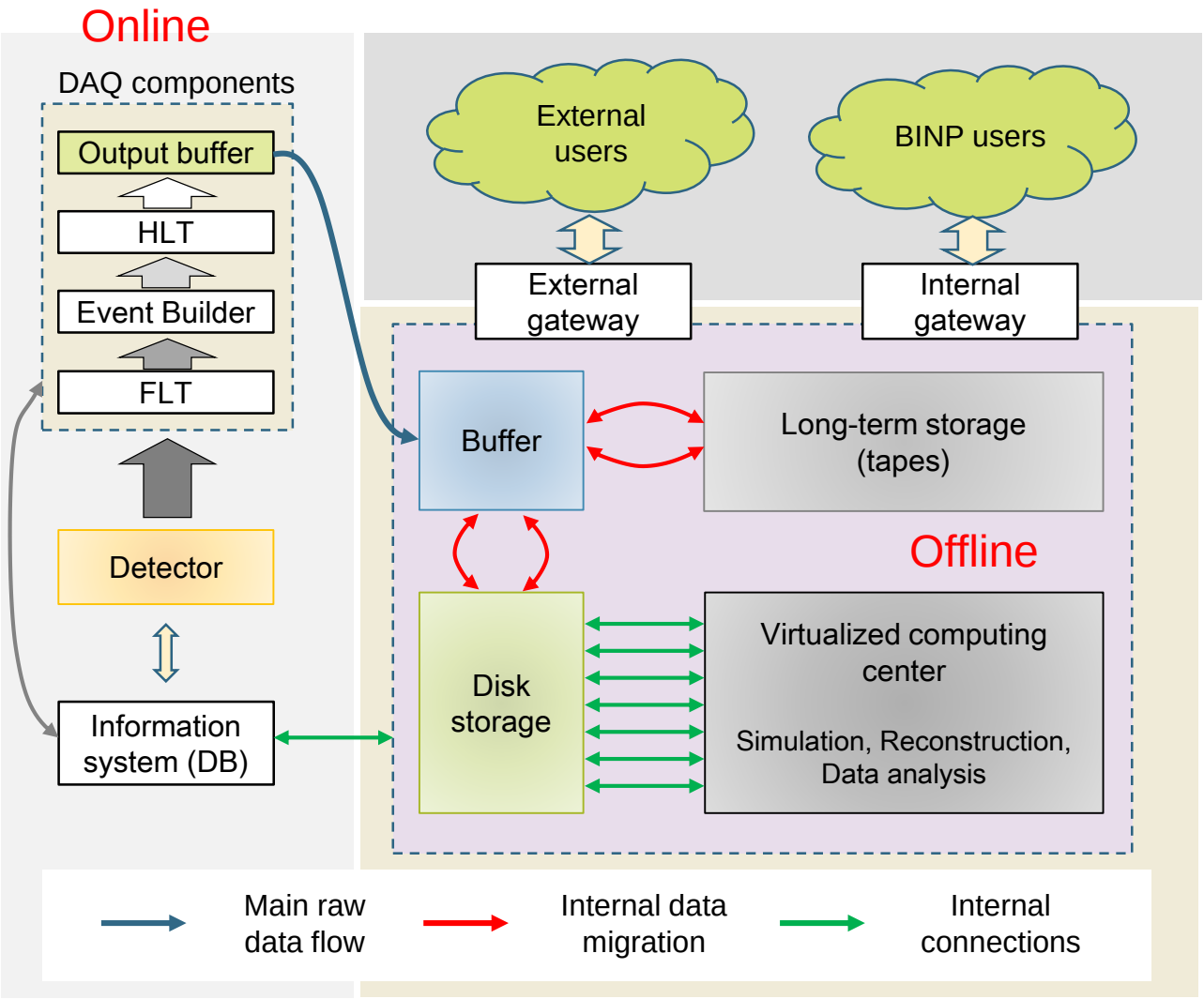
BELLE-2

CMD-3



Talk by Timofey Uglov on Wednesday, *Muon system for SCTF: Belle2 design adaptation status*

DAQ and data analysis/storage



Requirements

Maximum input data rate:
10 GB/s

Total storage system capacitance
~300 Pbytes

Computing power
~1 Pflops

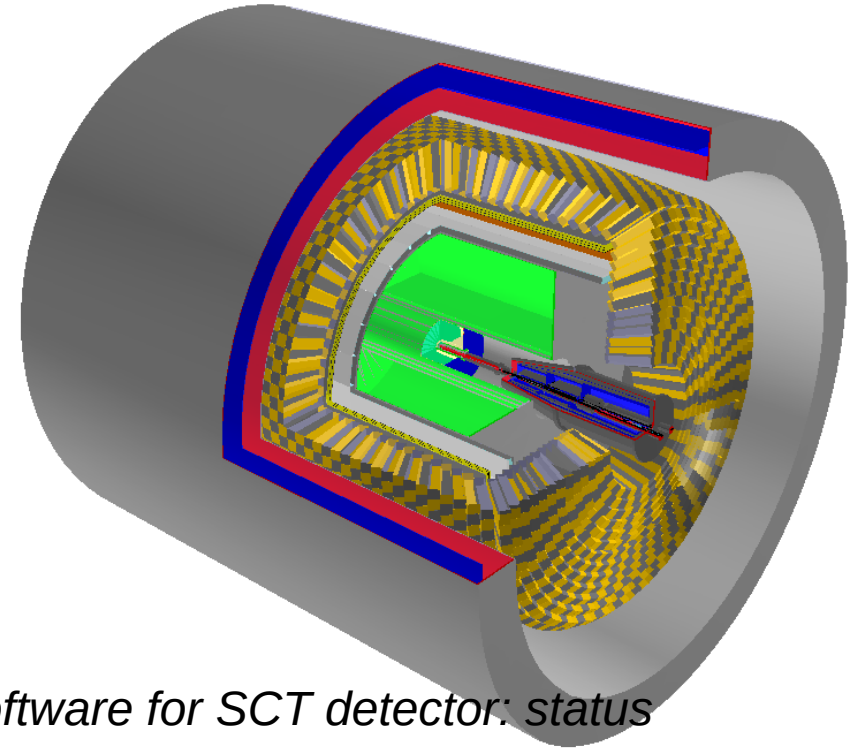
Can be realized with commercial solutions

Simulation and analysis software

The full scale simulation of experiments at SCTF is rapidly developed

Aurora framework

- widely used HEP tools (ROOT, Geant4, …)
- Gaudi and Athena-inspired build and config system
- FCCSW (DD4Hep, PODIO,…)
- SCTF modules



Talk by Andrey Sukharev on Tuesday, *Software for SCT detector: status*

Dedicated RSF grant for development of SCTF software and design of data analysis hardware infrastructure

Status of project

- 2011: selected as one of six mega-science projects to be built in Russia
- There are roadmap, conceptual design, preliminary civil engineering design
- CERN, IHEP, INFN, KEK and other organizations expressed their interest in the project
- In 2017 SCTF was included in the 2017-2019 plan for the implementation of the first phase of the Russian Strategy for Science and Technology Development. 2019: expected to submit updated CDR to government
- SCTF is discussed in the framework of the Update of the European Strategy for Particle Physics

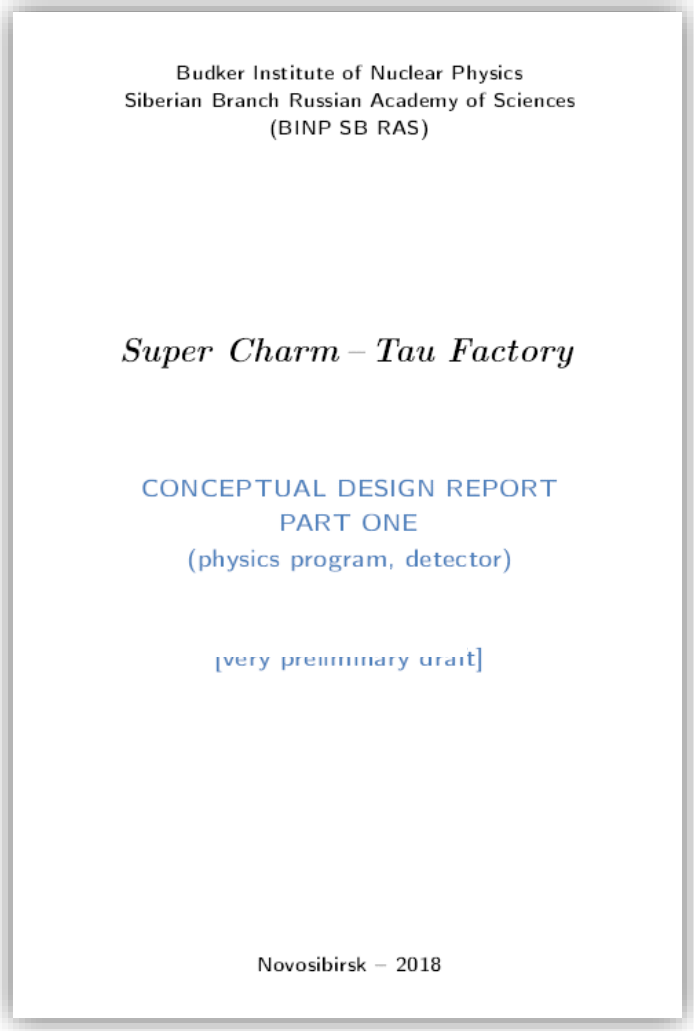
The collaboration

Working groups

- Inner tracker
- Drift chamber
- PID
- Calorimeter
- Muon system
- Magnet
- Physics and simulations
- Computing
- DAQ and trigger
- Beam background
- Engineering

- International advisory committee
- Dedicated international workshops
  - May 2018, BINP
  - December 2018, Orsay
  - November 2019, Moscow
- Collaboration in growing.

Conceptual Design Report


Budker Institute of Nuclear Physics
Siberian Branch Russian Academy of Sciences
(BINP SB RAS)

Super Charm – Tau Factory

CONCEPTUAL DESIGN REPORT
PART ONE
(physics program, detector)

[very preliminary draft]

Novosibirsk – 2018

- First release in 2011
- Includes physics program, collider and detector conceptual design
- Revised in 2018
- Authors from 19 institutions (10 from Russia)

Available at
https://ctd.inp.nsk.su/c-tau/

CREMLIN+

EUROPEAN COMMISSION

Horizon 2020 - Research and Innovation Framework Programme

EUROPEAN COMMISSION

Horizon 2020 Framework Programme

Project **CREMLINplus**

48 months, starting 2020

“This CREMLINplus project proposal is about European-Russian scientific and technical collaboration in the field of research infrastructures.”

Working package 5:

“Joint technology development around SCT and future lepton colliders”

- Task 5.1: Fostering internationalization and visibility of the SCT project, support of outreach activities related to SCT (BINP, CERN, INFN)
- Task 5.2: Development of collider technologies and fostering synergy between SCT, CLIC, and FCC-ee collider projects (CERN, BINP, LAL-CNRS)
- Task 5.3: Development of software for the design of an SCT detector (BINP, CERN)
- Task 5.4: Development and design of Inner Tracker for the SCT detector (BINP, INFN LNF/Ferrara)
- Task 5.5: Development and design of Central Tracker for the SCT detector (BINP, INFN Lecce/Bari)
- Task 5.6: Development and design of a Particle Identification system for the SCT detector (BINP, JLU)

Conclusion

- Super charm-tau factory has rich physics program, which is complementary to Belle II and LHCb.
- There are conceptual designs of the collider and the detector and they continue to be improved and detailed by the international collaboration
- R&D for the Super charm-tau factory is partially supported by Russian government, Russian science fund, European Commission
- We are open to collaboration proposal.

Backup slides

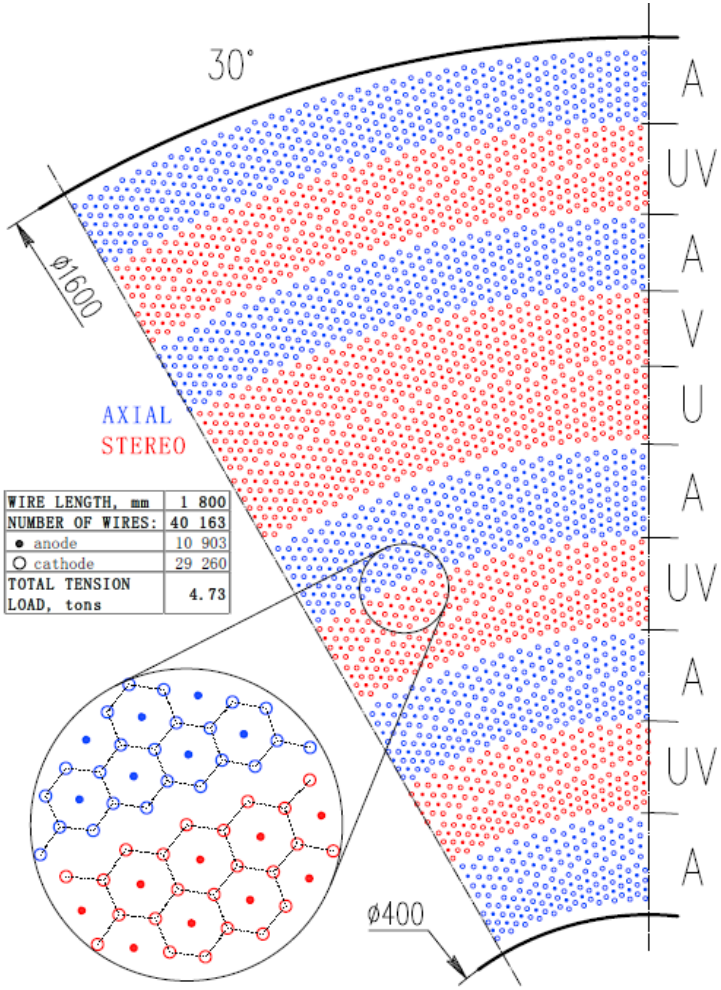
Drift chamber: traditional option

- ~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)

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

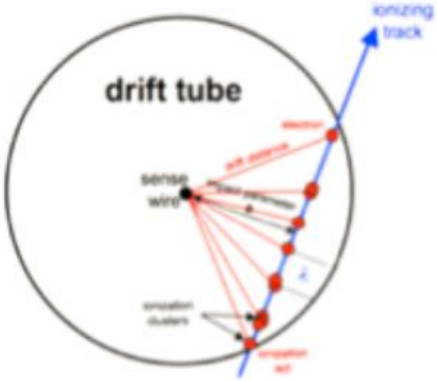
≈0.4% at 1 GeV

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



Drift chamber: TraPid

- ~141000 wires
  - 23k sensitive, W
  - 117k field, Al
- Square cell, 7.2-9.1 mm
- 64 layers
- 90% He + 10% iC_4H_{10}



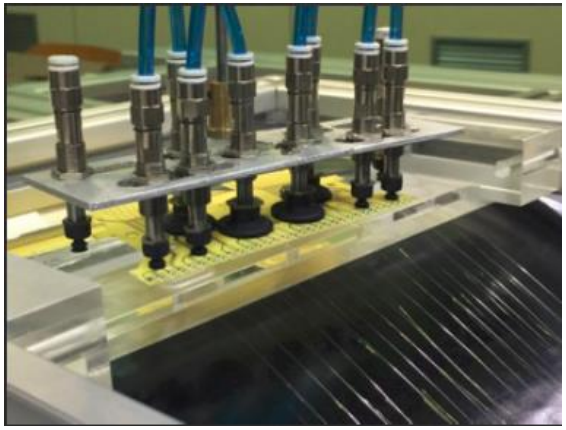
Measurement of individual clusters improves time and dE/dx resolution

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

≈0.2% at 1 GeV

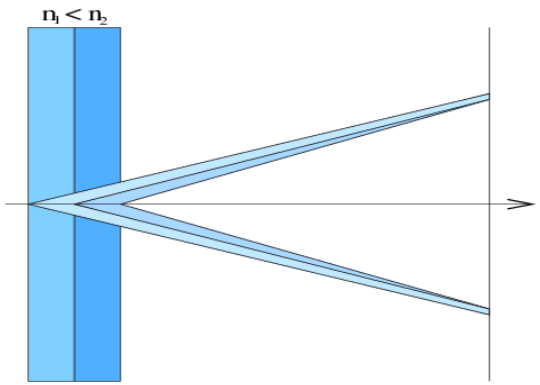
$$\frac{\sigma_{dE/dx}}{dE/dx} \approx 3.6\%$$

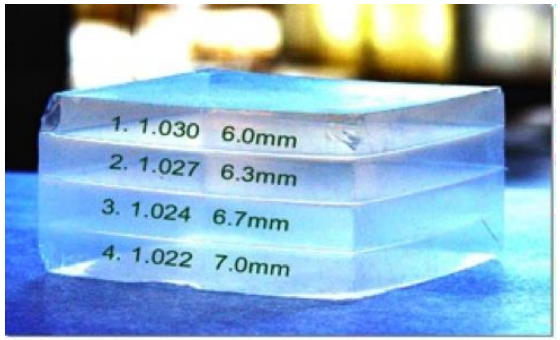
With room for improvement!



Robotic wiring

PID options

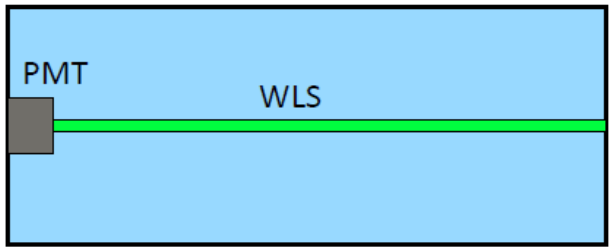




FARICH: focusing aerogel

O(10^6) readout channels!
Test beam:

π/K: 7.6σ at 4 GeV/c
μ/π: 5.3σ at 1 GeV/c



ASHIPH: threshold Cherenkov counter with WLS+PMT readout

Two n values
Low cost:
30000 readout channels
π/K from 0.5 to 2 GeV/c
μ/π from 0.4 to 0.9 GeV/c

dE/dx + TOF for lower momenta, muon system for higher momenta

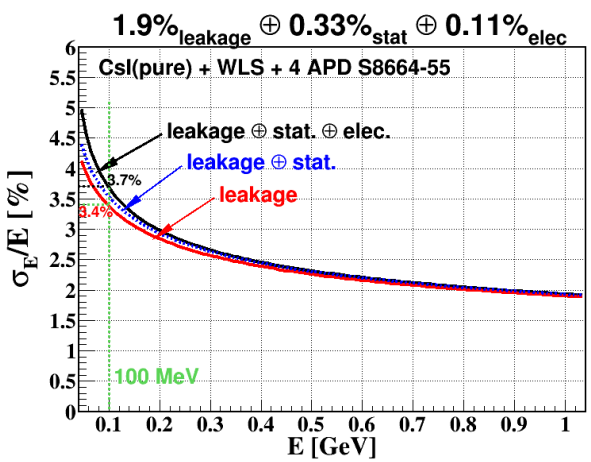
TOF (TOP) counters, $\sigma_t \approx 30$ ps:

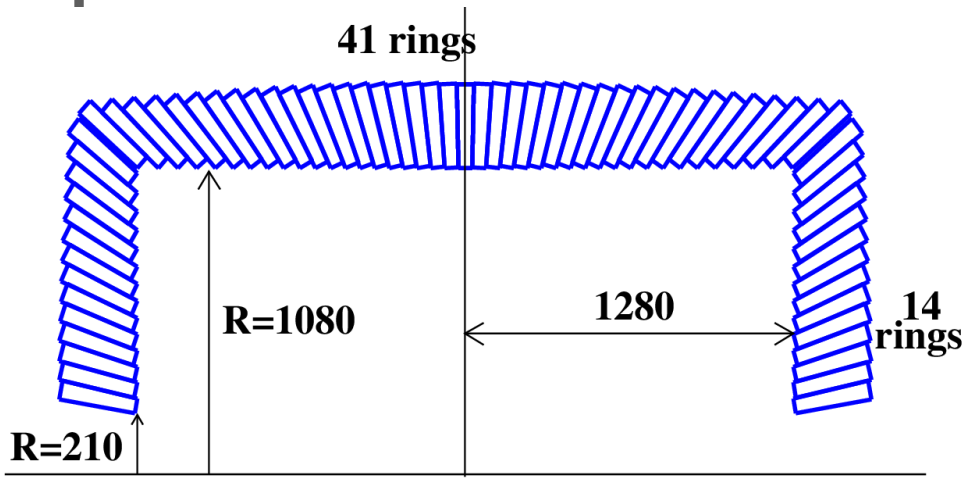
π/K up to 2.5 GeV/c
μ/π from 0.25 to 0.5 GeV/c

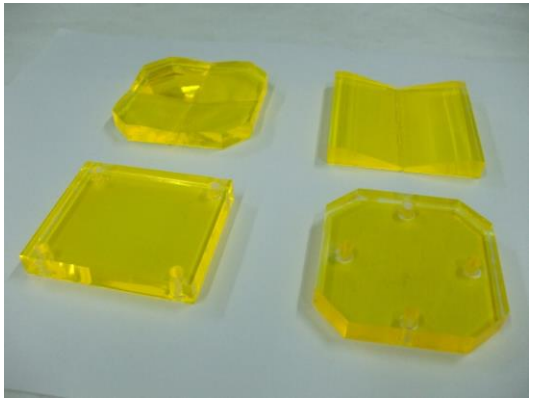
Calorimeter: pCsI option

- 7424 crystals
  - 5248 in barrel
  - 2176 in endcap
- 5.5 x 5.5 x 30(34) cm
- pCsI+WLS+4 APD

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







This option is being prototyped and optimized