The 15th International Workshop on Tau Lepton Physics
24-28 September 2018, Vondelkerk, Amsterdam

Novosibirsk: tau-charm factory and di-muonium experiment

P.Piminov on behalf of
the Super Charm Tau Factory team,
Budker Institute of Nuclear Physics,
Novosibirsk, Russia

Martin Perl about Super Charm Tau Factory

SLAC NATIONAL ACCELERATOR LABORATORY

Martin L. Perl, Nobel Laureate in Physics
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Re: Super Tau/Charm Project at Novosibirsk

July 10, 2011

Professor Andrey A.Fursenko,
Minister of Education and Science of Russian Federation.
11 Tverskaya ul.
125903
Moscow,
Russian Federation

Dear Professor Fursenko:

It is an honor for me to write to you about the great importance and physics promise of the proposed Super Tau/Charm Project at Novosibirsk. I write about the importance of the project to tau physics, the importance of the project to charm physics, and the importance of continuing and expanding the many magnificent contributions of the Budker Institute of Nuclear Physics to experimental and theoretical particle accelerator physics.

The Super Tau/Charm Facility will produce 10^{10} tau lepton pairs, much larger than existing tau lepton data sets. This 10^{10} data set is also much larger than future data sets that might be produced in existing electron-positron colliders or in other proposed colliders such as Super-B factories. With this immense data set, physicists at the Super Tau/Charm Facility will explore the following areas in tau physics:

- lepton flavor violation decays,
- possible CP violation in tau decays,
- increased precision in the tau decay matrix elements,
- unforeseen new direction in tau physics.

The Super Tau/Charm Facility will offer unique advantages in studying charm physics because the charm particle pairs can be produced near the production threshold. Some of these unique advantages are:

- reduced particle multiplicity,
- much improved detection of charm particle pair production,
- precise , basic quantum-mechanical studies of quantum correlations,
- unforeseen new direction in charm physics.

In the fifty year history of the development, building and operation of electron-positron colliders, many laboratories have made contributions of inventions, basic theoretical understanding, and practical accelerator technology. However the two leading laboratories are the Budker Institute of Nuclear Physics and my institution, the SLAC National Accelerator Laboratory. The construction and operation of the Super Tau/Charm Facility will continue this Budker Institute of Nuclear Physics leadership.

I strongly support the initiation, construction and operation of the Super Tau/Charm Facility at the Budker Institute of Nuclear Physics.

Sincerely,

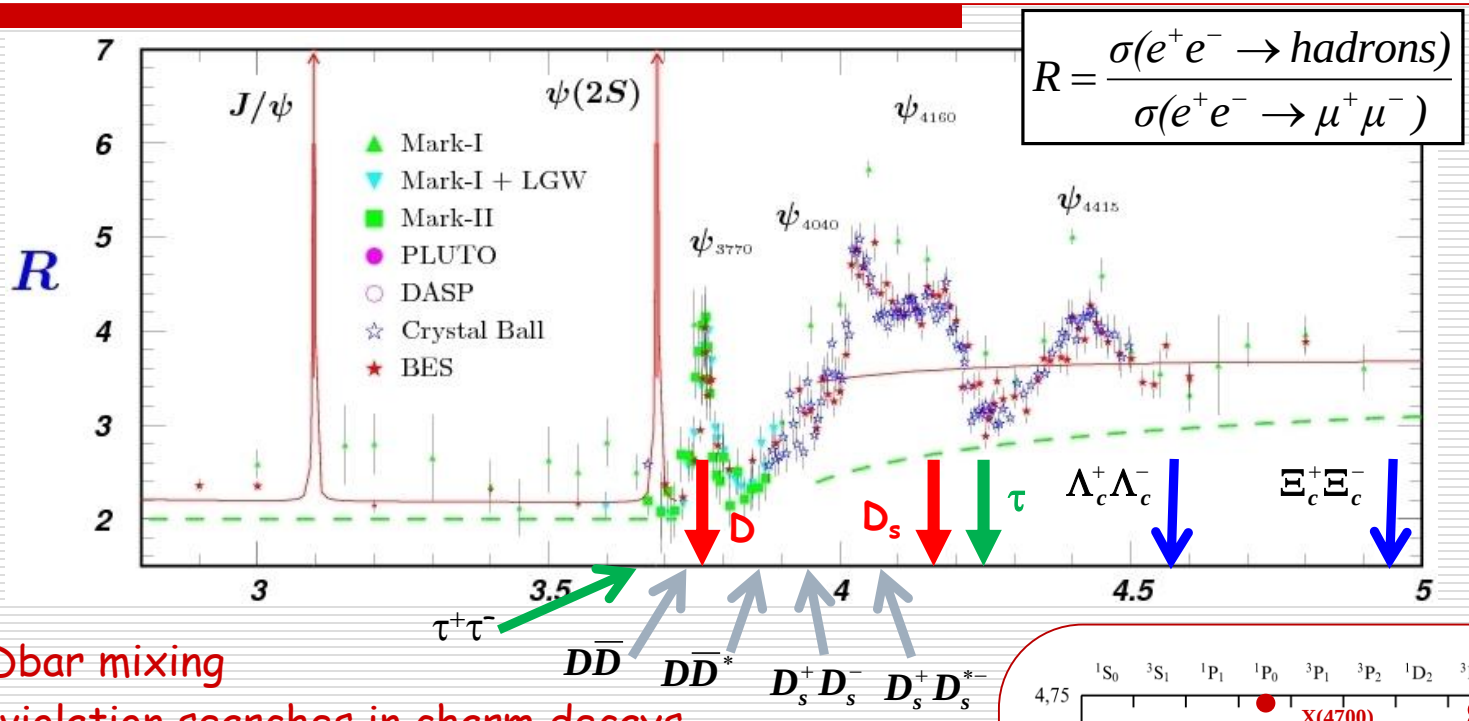
Martin L. Perl

Martin L. Perl

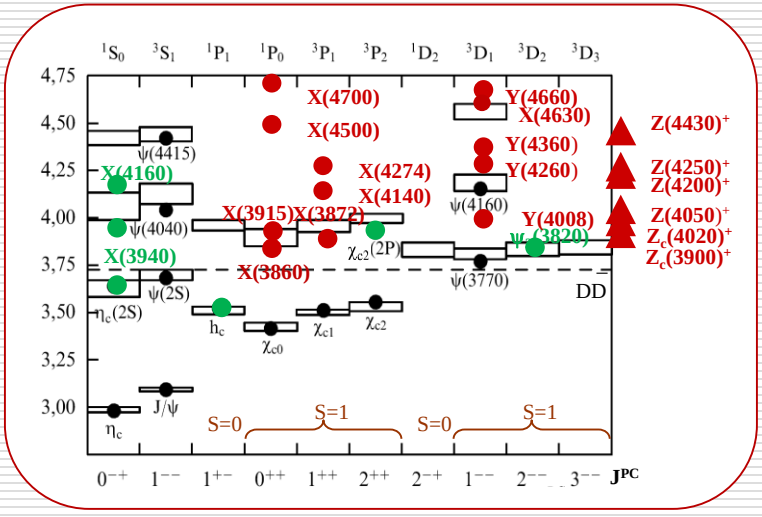
Nobel Laureate in Physics
Professor in Stanford University

P.Piminov, Novosibirsk: tau-charm factory and di-muonium experiment

Physics program



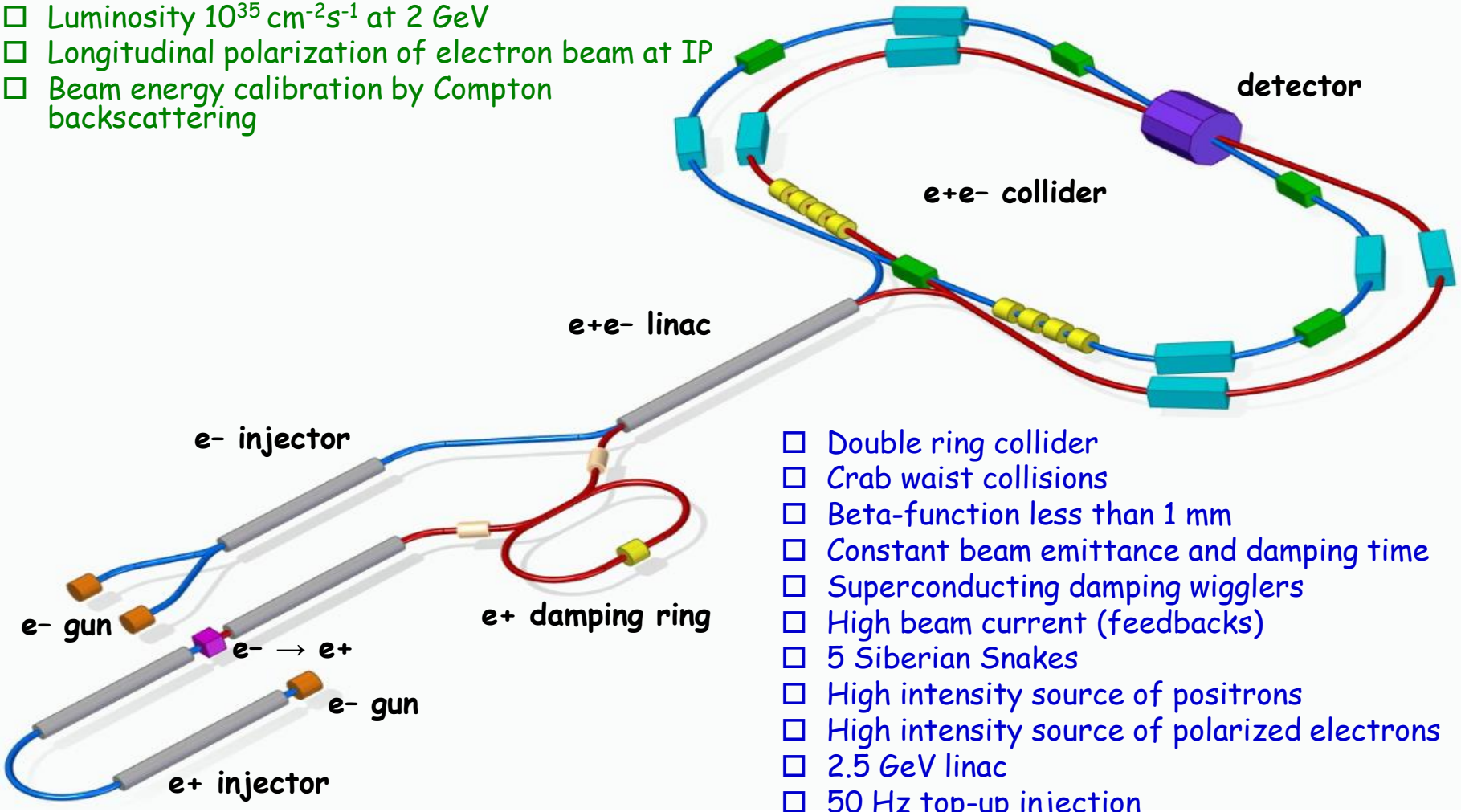
- ✓ D-Dbar mixing
- ✓ CP violation searches in charm decays
- ✓ Rare and forbidden charm decays
- ✓ Standard Model tests in τ leptons decays
- ✓ Searches for lepton flavor violation τ→μγ
- ✓ CP/T violation searches in τ leptons decays
- ✓ Exotics
- ✓ Production of the polarized anti-nucleons @ E=1 GeV



P.Piminov, Novosibirsk: tau-charm factory and di-muonium experiment

Layout

- Beam energy from 1.0 to 2.5 GeV (3.5 GeV !?)
- Luminosity 10^{35} $cm^{-2}s^{-1}$ at 2 GeV
- Longitudinal polarization of electron beam at IP
- Beam energy calibration by Compton backscattering

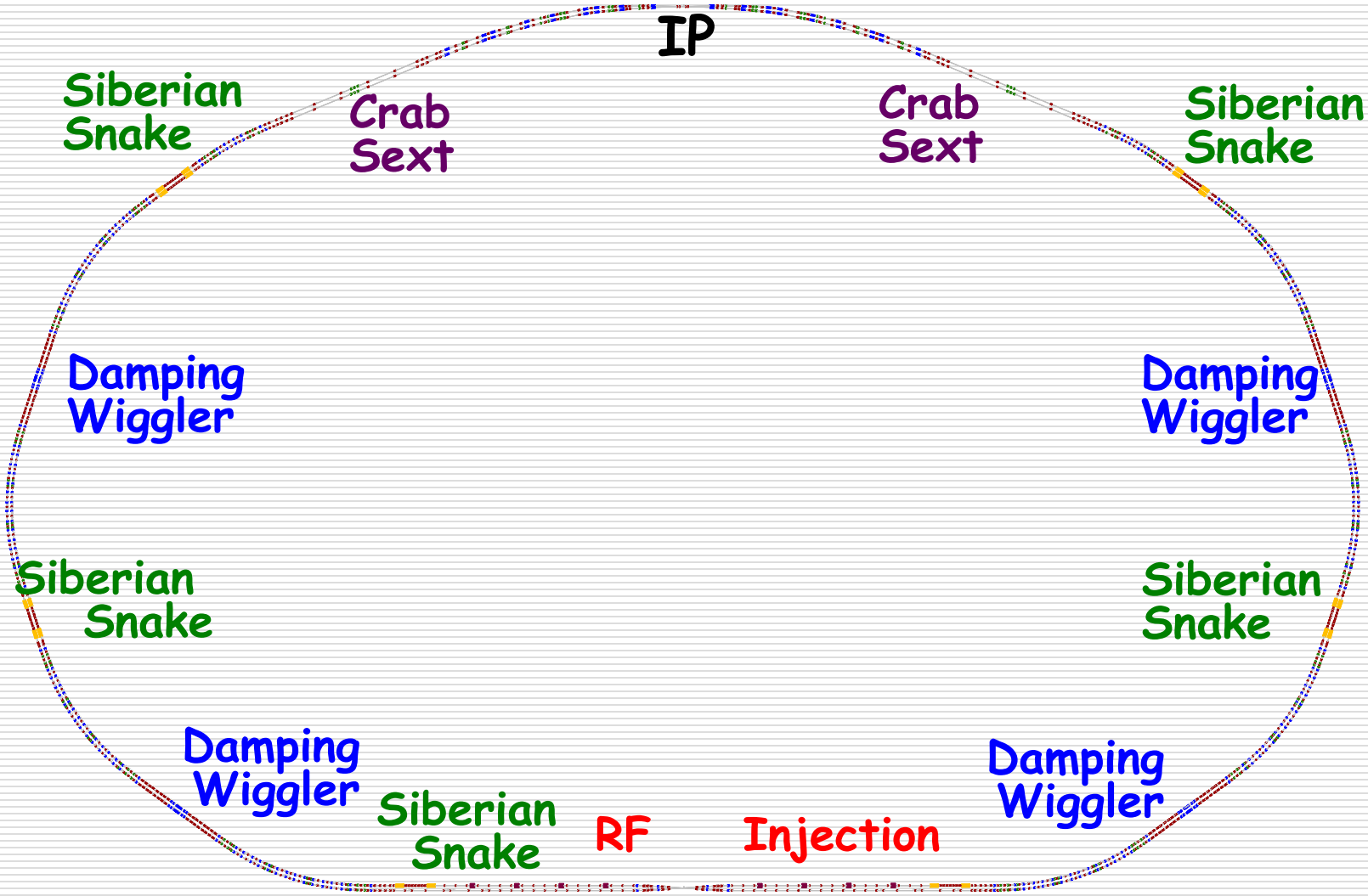


- Double ring collider
- Crab waist collisions
- Beta-function less than 1 mm
- Constant beam emittance and damping time
- Superconducting damping wigglers
- High beam current (feedbacks)
- 5 Siberian Snakes
- High intensity source of positrons
- High intensity source of polarized electrons
- 2.5 GeV linac
- 50 Hz top-up injection

Main parameters

Energy	1.0 GeV	1.5 GeV	2.0 GeV	2.5 GeV
Circumference	813.1 m			
Emittance hor/ver	8 nm/0.04 nm @ 0.5% coupling			
Damping time hor/ver/long	50/50/25 ms	30/30/15 ms		
Bunch length	21 mm	12 mm	10 mm	10 mm
Energy spread	$8.7 \cdot 10^{-4}$	$11 \cdot 10^{-4}$	$9.3 \cdot 10^{-4}$	$7.2 \cdot 10^{-4}$
Momentum compaction	$8.73 \cdot 10^{-4}$	$8.81 \cdot 10^{-4}$	$8.82 \cdot 10^{-4}$	$8.83 \cdot 10^{-4}$
Damping wiggler field	50 kGs	50 kGs	35 kGs	10 kGs
Synchrotron tune	0.007	0.012	0.009	0.008
RF frequency	499.95 MHz			
Harmonic number	1356			
Particles in bunch	$7 \cdot 10^{10}$			
Number of bunches	406 (10% gap)			
Bunch current	4.2 mA			
Total beam current	1.7 A			
Beam-beam parameter	0.135	0.135	0.121	0.097
Luminosity	$0.6 \cdot 10^{35}$	$0.9 \cdot 10^{35}$	$1.0 \cdot 10^{35}$	$1.0 \cdot 10^{35}$

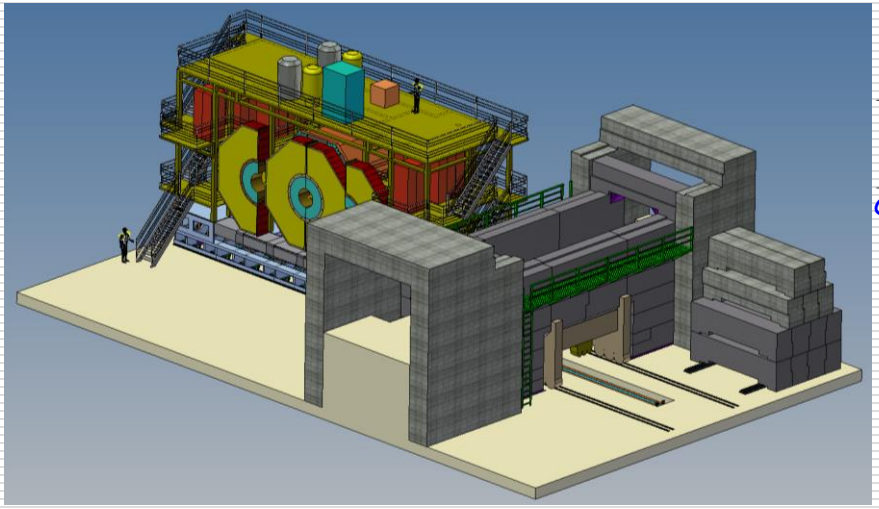
Collider

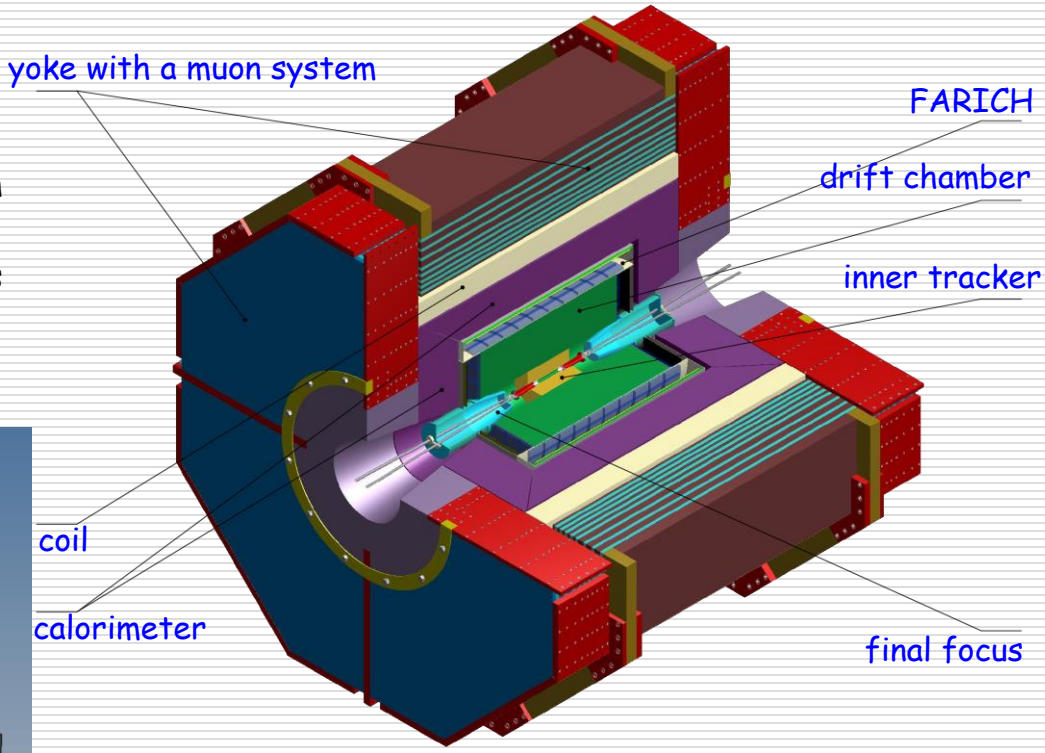

IP
Siberian Snake
Crab Sext
Crab Sext
Siberian Snake
Damping Wiggler
Damping Wiggler
Siberian Snake
Siberian Snake
Damping Wiggler
Damping Wiggler
Siberian Snake
RF
Injection

Detector

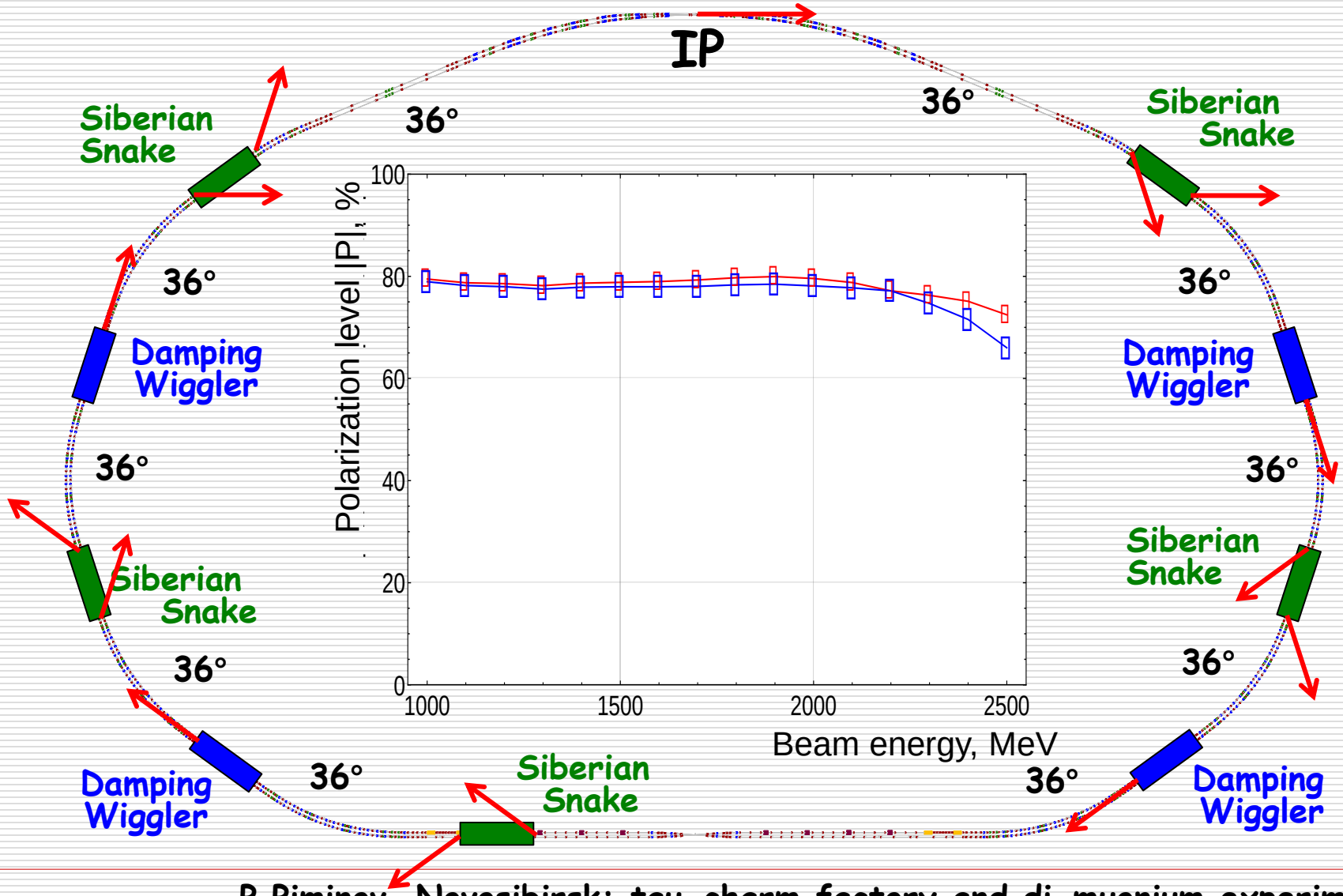
Universal magnetic detector with 1T longitudinal field

- an excellent momentum resolution for charged particles and a good energy resolution for photons;
- a particle identification system with nearly record parameters among existing detectors or those under construction;
- a digitizing hardware and data acquisition system, which is able to read events at a rate of 300 kHz with an average event length of about 30 kB;
- a unique trigger, which is able to select physics events and suppress background under a very high detector load.



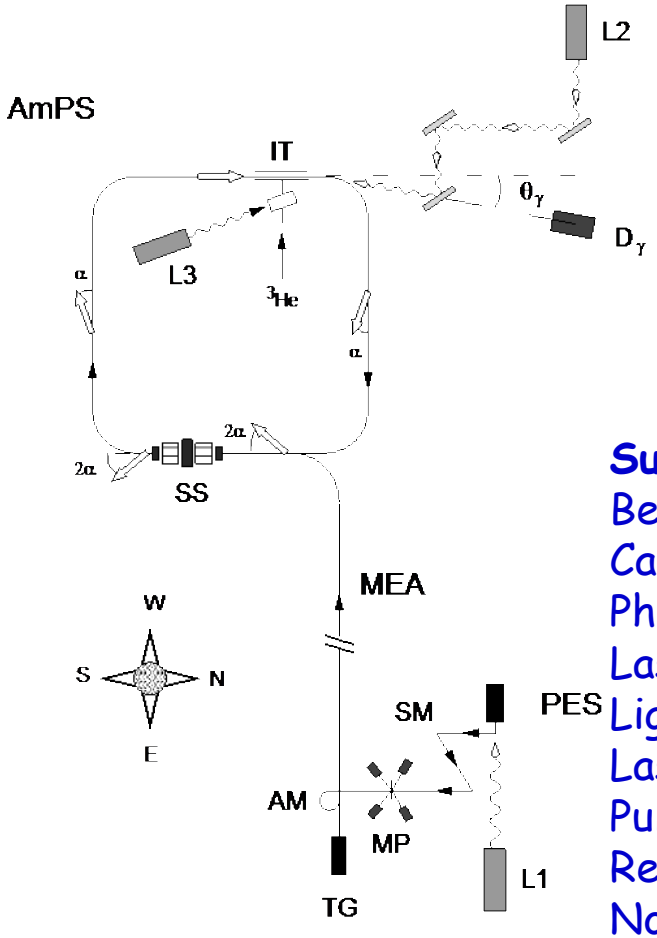


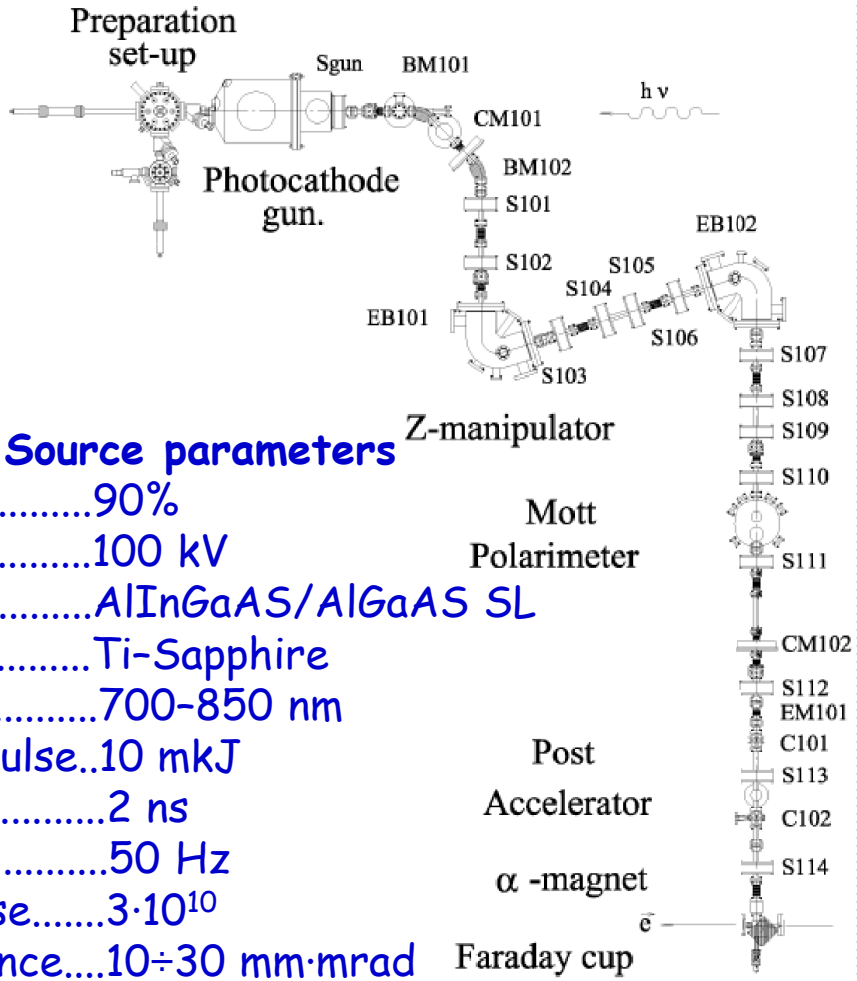
Polarization with 5 Siberian Snakes



Source of polarized electrons

Polarized electron source produced by BINP for AmPS in Nikhef





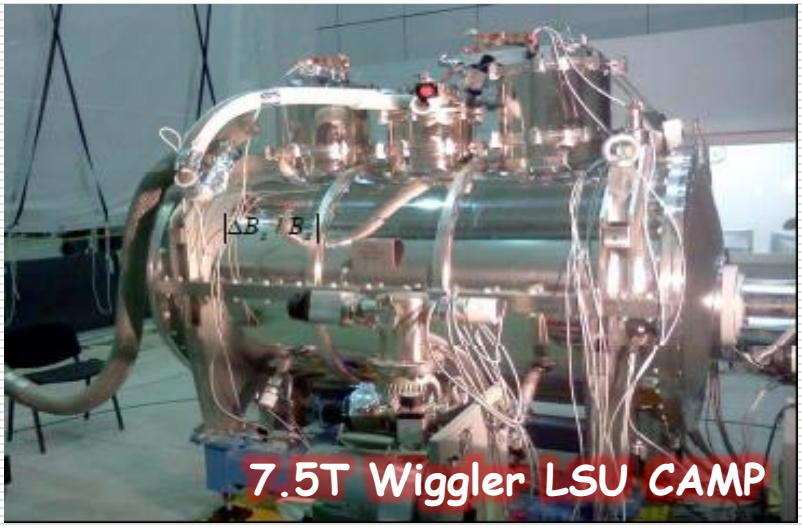
Super Charm Tau Source parameters

Beam polarization.....90%
Cathode voltage.....100 kV
Photocathode type.....AlInGaAS/AlGaAS SL
Laser type.....Ti-Sapphire
Light wavelength.....700-850 nm
Laser energy in a pulse..10 mkJ
Pulse duration.....2 ns
Repetition rate.....50 Hz
No. of e- per a pulse.....$3 \cdot 10^{10}$
Normalized emittance....10÷30 mm·mrad

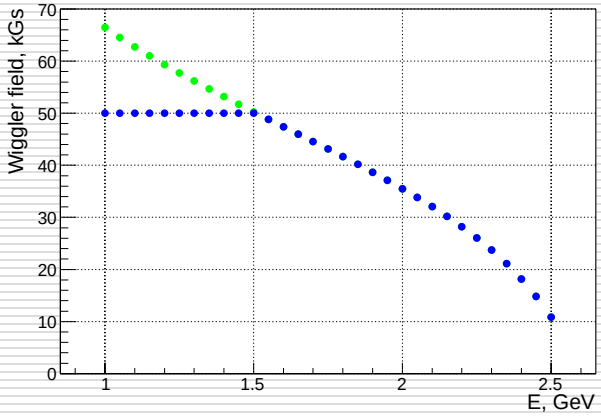
Superconducting damping wigglers

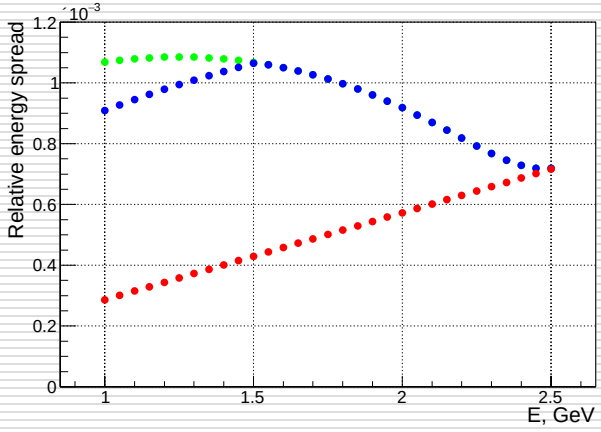
4 superconducting damping wigglers (50 kGs field, 25 cm period, 1.9 m length) keep the damping time (30 ms) in the beam energy range 1.5÷2.5 GeV and the horizontal emittance (8 nm) in all energy range.

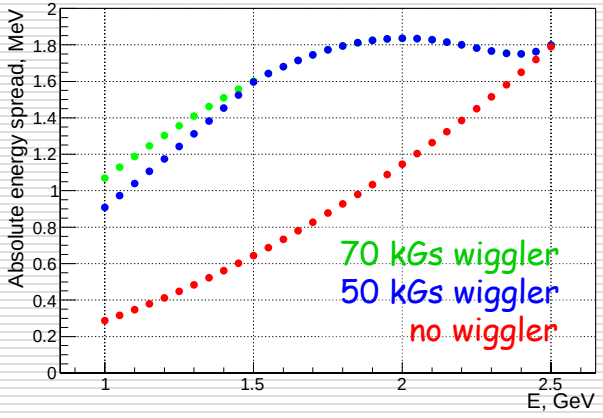
It allows to reduce IBS and Touschek effect and to obtain high luminosity at low beam energy.



Due to additional damping by wigglers beam energy spread is increased.







Energy & polarization measurement by Compton backscattering

- Maximum photon energy: $\omega_{max} = \frac{E_0 \kappa}{1+\kappa} \approx 4\,\omega_0 \gamma^2, \quad \kappa = \frac{4\,\omega_0 E_0}{m c^2}$
- Minimum electron energy: $E_{min} = E_0 - \omega_{max} = \frac{E_0}{1+\kappa}$
- Energy measurement below 2 GeV (precision~ $5 \cdot 10^{-5}$): ω_0 = 0.117 eV (CO_2 laser) → ω_{max} ~ 2…7 MeV. Maximum photon energy is measured by HPGe detector.
- Energy measurement above 2 GeV (precision ~ 10^{-4}): magnetic spectrometer + Compton scattering. ω_0 ~ 1…4 eV, two lasers. Coordinates of Compton photons, electrons beam are measured simultaneously; calibration at beam energy <2 GeV is required. Or beam position is also measured; precise positioning is required.
- If laser circular polarization is altered (left/right):

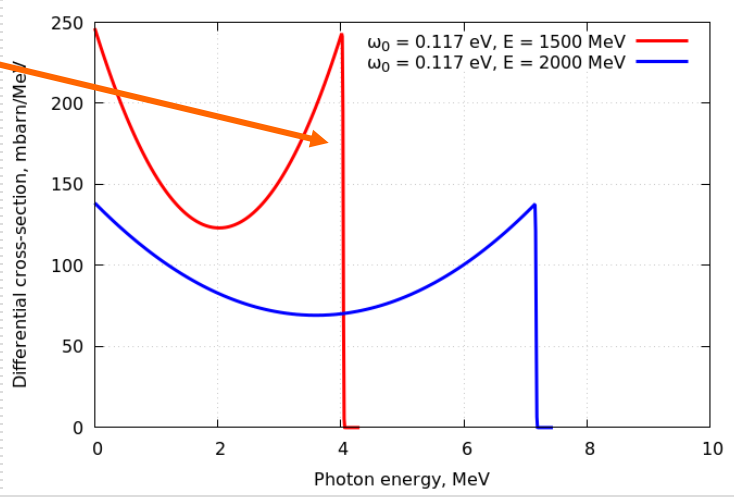
  -Longitudinal beam polarization leads to change in total cross-section (also in lower/upper parts of spectra).

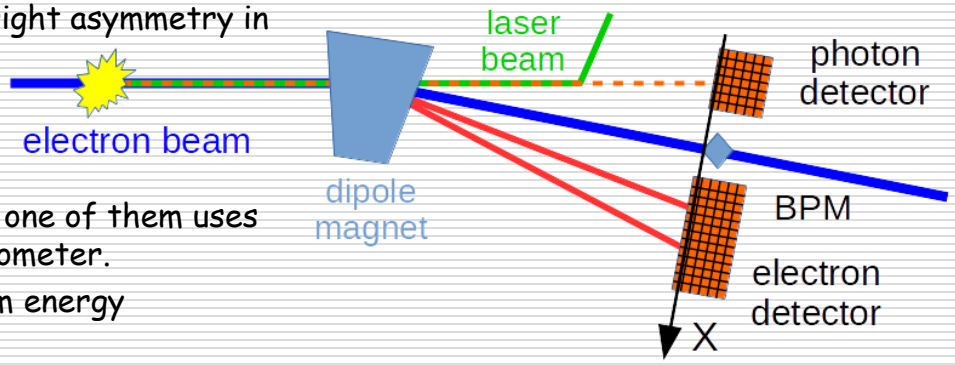
  -Transverse beam polarization leads to up/down or left/right asymmetry in photons and electrons angular distributions.
- Project:

  -2 beam energy systems with CO_2 lasers (e^-e^+).

  -2 combined photon/electron polarimeters near wigglers, one of them uses additional laser for beam energy measurement by spectrometer.

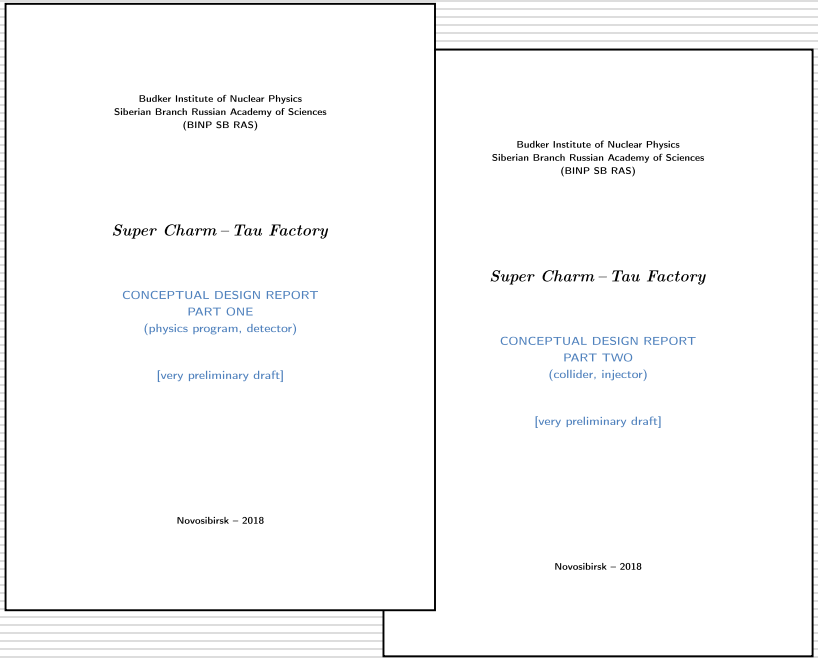
  -Compton spectrometer with two lasers for positron beam energy measurement.





Status

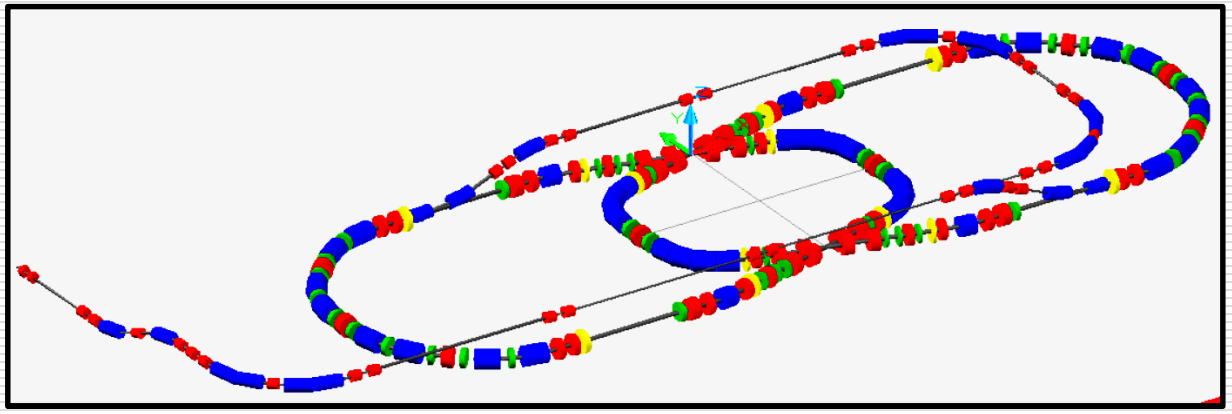
- ✓ Update of Conceptual Design Report of Super Charm Tau Factory is done
- ✓ 17-18 Dec 2017 – Super Tau Charm factory Physics program workshop
- ✓ 26-27 May 2018 – Super Tau Charm factory Satellite meeting at Charm-18 workshop and first International Advisory Committee
- ✓ Dec 2018 – Russian & Chinese Super Charm Tau Factory workshop in Orsay

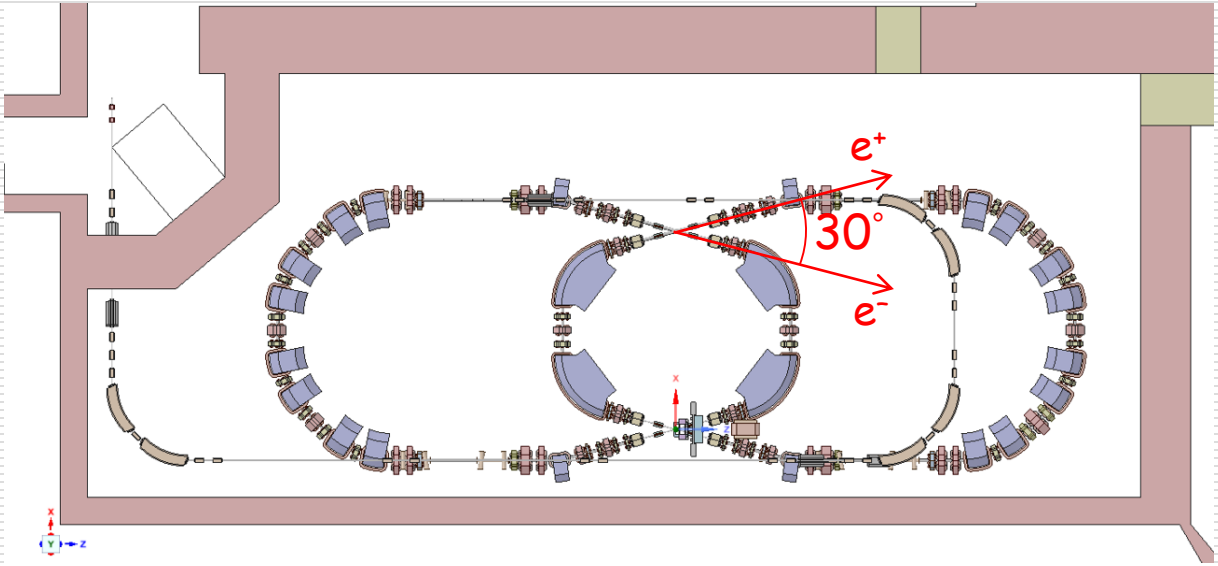


https://ctd.inp.nsk.su/wiki/index.php/CDR

μμtron is low energy e^+e^- collider

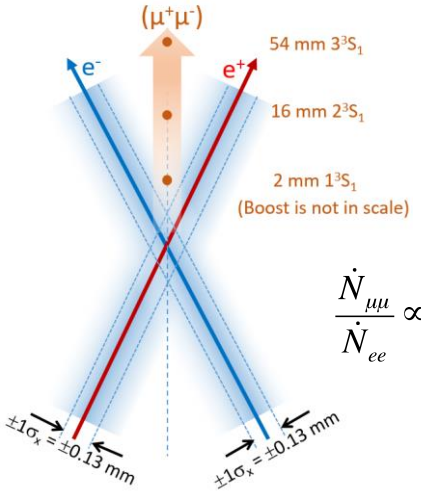
Beam energy	408 MeV
Circumference	29.35 m
Compaction factor	$5.8 \cdot 10^{-2}$
No particles	$3.5 \cdot 10^{10}$
Bunch current	57 mA
Bunch number	30
Total current	1.7 A
Coupling	0.5%
Emittance	30 nm 65 nm (IBS)
Energy spread	$3.7 \cdot 10^{-4}$ $8.7 \cdot 10^{-4}$ (IBS)
Horizontal beta	150 mm
Vertical beta	2 mm
Bunch luminosity	$2.8 \cdot 10^{31}$ $cm^{-2}s^{-1}$
Total luminosity	$8.3 \cdot 10^{31}$ $cm^{-2}s^{-1}$



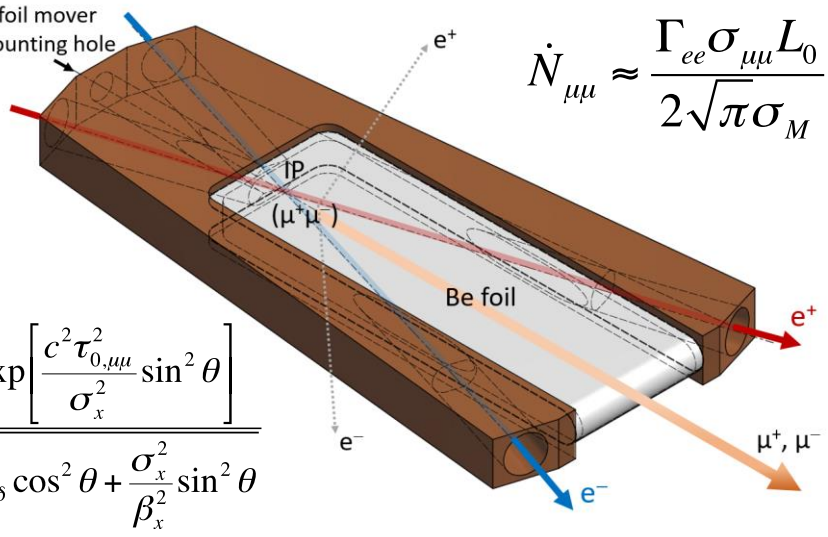


Dimuonium ($\mu^+\mu^-$) experiment

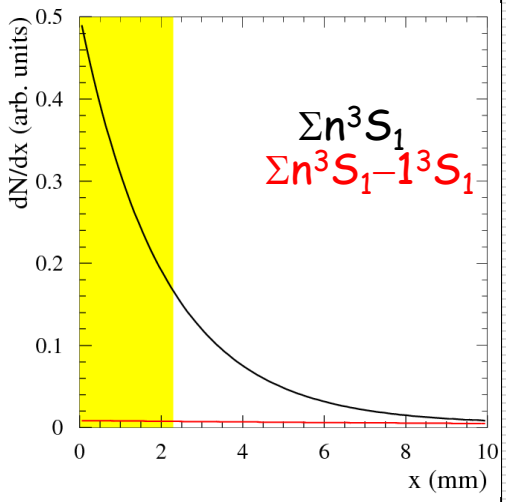
Dimuonium production rate (Γee) of 1S (1% for 10^7 s), 2S(5%), 3S(15%)
Dimuonium decay lengths with the same accuracy
Measurement of the breakup probability
Measurement 1S-2P transition probabilities
2P lifetime
Spectroscopy

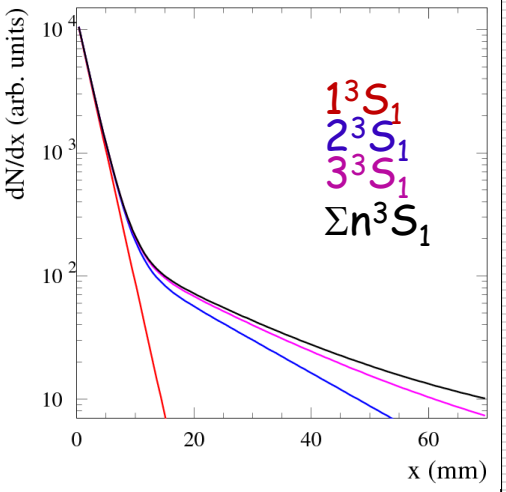


$$\frac{\dot{N}_{\mu\mu}}{\dot{N}_{ee}} \propto \frac{\exp\left[\frac{c^2\tau_{0,\mu\mu}^2}{\sigma_x^2}\sin^2\theta\right]}{\sqrt{\sigma_\delta\cos^2\theta + \frac{\sigma_x^2}{\beta_x^2}\sin^2\theta}}$$



$$\dot{N}_{\mu\mu} \approx \frac{\Gamma_{ee}\sigma_{\mu\mu}L_0}{2\sqrt{\pi}\sigma_M}$$





$\mu^+\mu^-$ rate (1S/2S/3S)	1 hour	4 months
Total	65/8.1/2.4	187k/23k/6.9k
x>2.3 mm	21/7/2.3	59k/20k/6.6k

Conclusion

- ✓ Conceptual Design Report of Super Charm Tau Factory is done
- ✓ 3.5 GeV mode is considering
- ✓ Super Charm Tau Factory is supported by Russian Government
- ✓ We are waiting funds for starting
- ✓ We invite you to our collaboration

Thank you for your attention