The project of Super-ct-factory with Crab Waist in Novosibirsk

E.Levichev

Budker Institute of Nuclear Physics, Novosibirsk

ICFA Workshop on Beam Dynamics in e^+e^- Factories, Novosibirsk, April 14-16, 2008

Contributors to the report

A.Blinov
A.Bondar
I.Koop
E.Levichev
S.Nikitin
V.M.Petrov
Yu.Pupkov
S.Sinyatkin
A.Skrinsky
A.Bogomyagkov
V.Kiselev
G.Kurkin
P.Logachev
I.Okunev
P.Piminov
D.Shatilov
V.Smaluk
P.Vobly

History

► E = 700 – 2500 MeV
► Round beams $L=10^{34}$ $cm^{-2}s^{-1}$
► Monochromatization $L\sim10^{32}$ $cm^{-2}s^{-1}$
► Long. Polarization $L\sim10^{34}$ $cm^{-2}s^{-1}$
► Transverse polarization for precise energy calibration

Rebirth

- ► Improvement of the economy situation in Russia
- ► Exciting results of B-factories
- ► Invention of the crab waist collision scheme

(P.Raimondi, March 2006)

Scientific case

- ► 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
- ► CP/T violation searches in t leptons decays

Requirements: L > 10^{34} cm^{-2} s^{-1}, longitudinal polarization

Specifications

► Variable energy E_{cm}= 3 – 4.5 GeV (from J/psi to charm baryons)

► $L = 1 \div 2 \times 10^{35}\ cm^{-2}s^{-1}$

► At least one beam (e^-) should be polarized longitudinally

► No energy asymmetry is needed

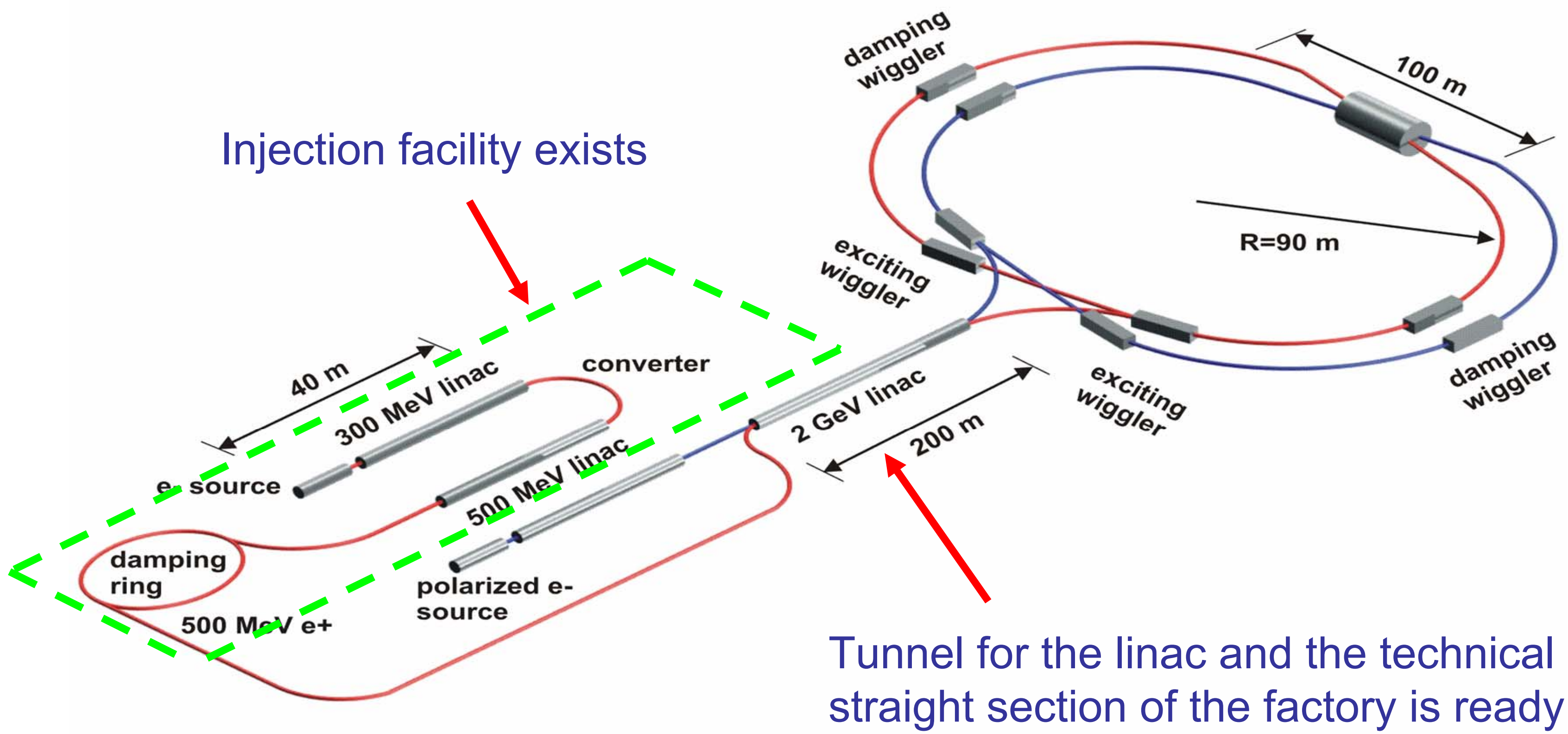
► No beam monochromatization is needed

► Energy calibration with medium accuracy (Compton backscattering) Talk by Nikolay Muchnoi

Facility key features and principles

► Two rings with a single interaction point
► Crab waist collision scheme $\rightarrow$ new FF design Talk by Anton Bogomyagkov
► Polarized e^- injector and spin gymnastics based on the Central Arc solution to get the longitudinally polarized electron beam at IP
► Wigglers to keep the same damping and emittance in the whole energy range (optimal luminosity)
► Modified FODO cell to obtain low emittance
► A wide adaptation of the existing injection complex, construction facilities (tunnels, halls, etc.) and elements (wigglers, etc.) for cost effectiveness

Layout



Injection facility exists
damping wiggler
100 m
R=90 m
exciting wiggler
exciting wiggler
damping wiggler
40 m
300 MeV linac
converter
e- source
500 MeV linac
2 GeV linac
200 m
damping ring
500 MeV e+
polarized e- source
Tunnel for the linac and the technical straight section of the factory is ready

Specification for the FF design

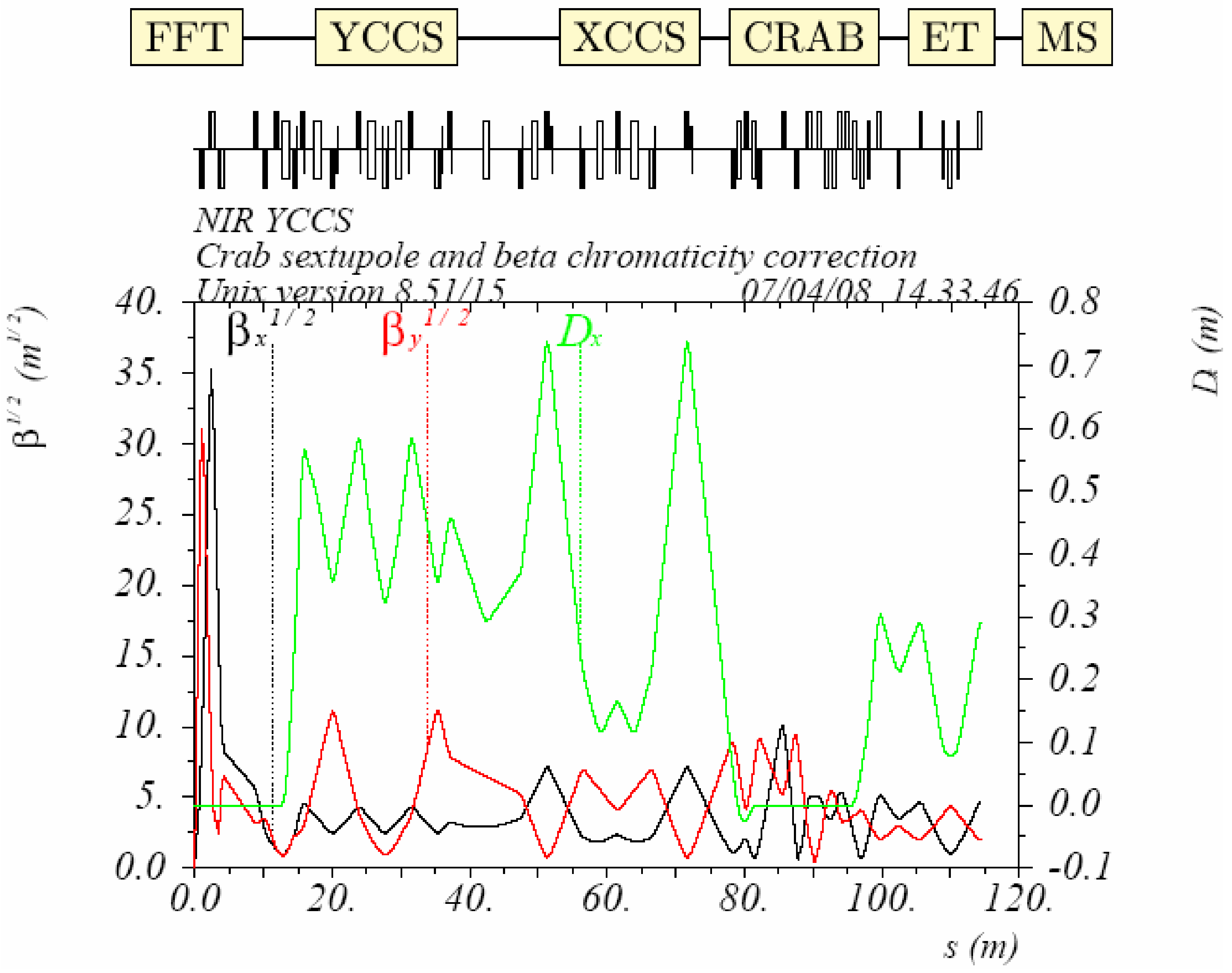
Energy, GeV	2
Beam current, A	1.36
Number of bunches	295
β_x, mm	20
β_y, mm	0.76
ε_x, nm rad	10
Coupling $\varepsilon_y/\varepsilon_x$, %	1
Beam length σ_z, cm	1
Crossing angle, mrad	34

Tune shift ξ_y	0.13
Particles per bunch	$7 \cdot 10^{10}$
Luminosity, $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$	$1 \cdot 10^{35}$
Hour glass $\frac{\sigma_x}{\theta\beta_y}$	1.095
Piwinski angle $\varphi = \frac{\sigma_z\theta}{\sigma_x}$	12.021

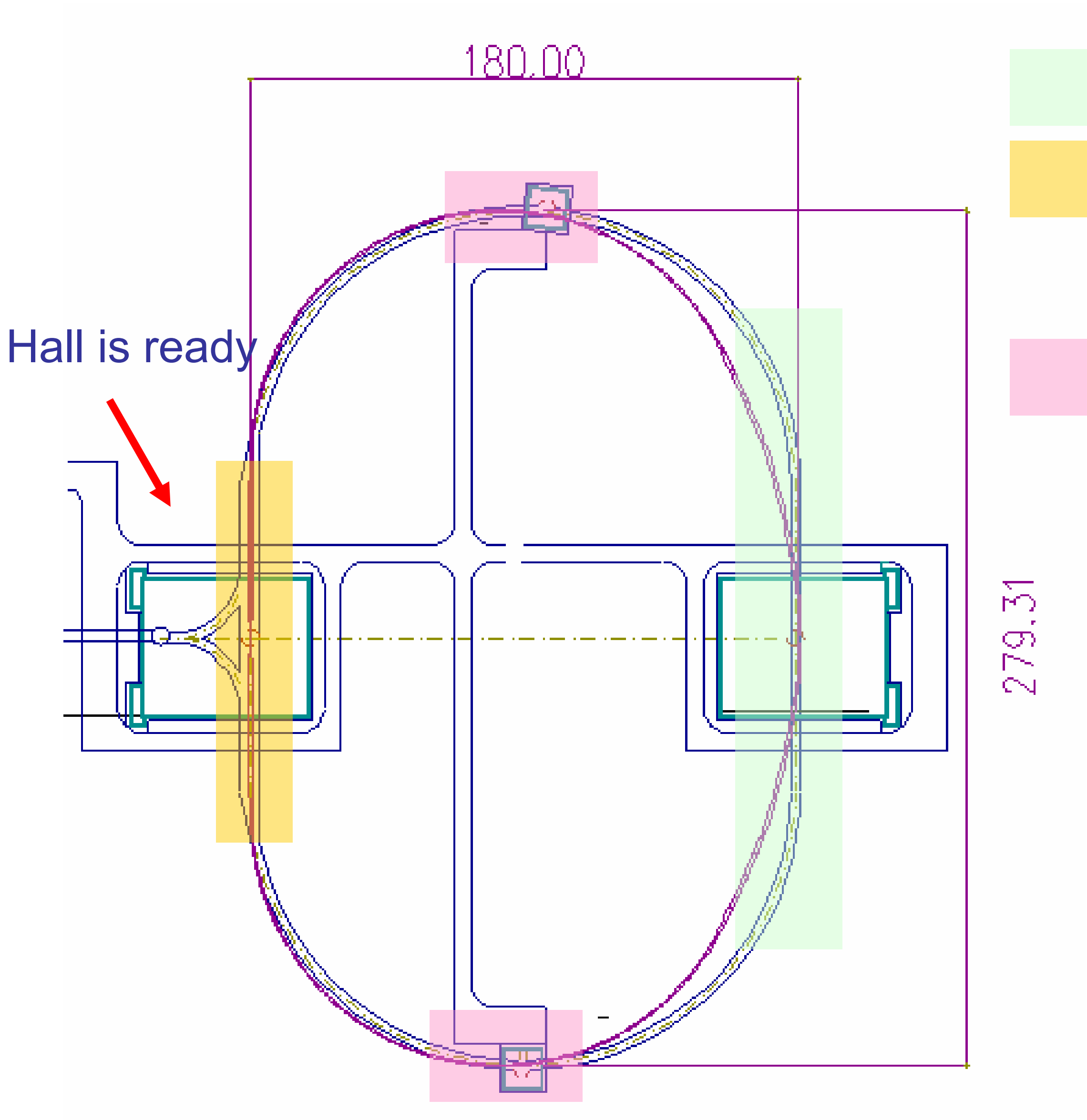
- No bend for incoming beam.
- No longitudinal field integral over each final focus lens.
- Longitudinal field is compensated before each final focus lens.
- Interaction region length less than 100 m.
- Place for CRAB sextupole.

From the talk by Anton Bogomyagkov

FF based on telescope design



SCT location



FF region (214 m)

Technical (RF and injection) region (100 m)

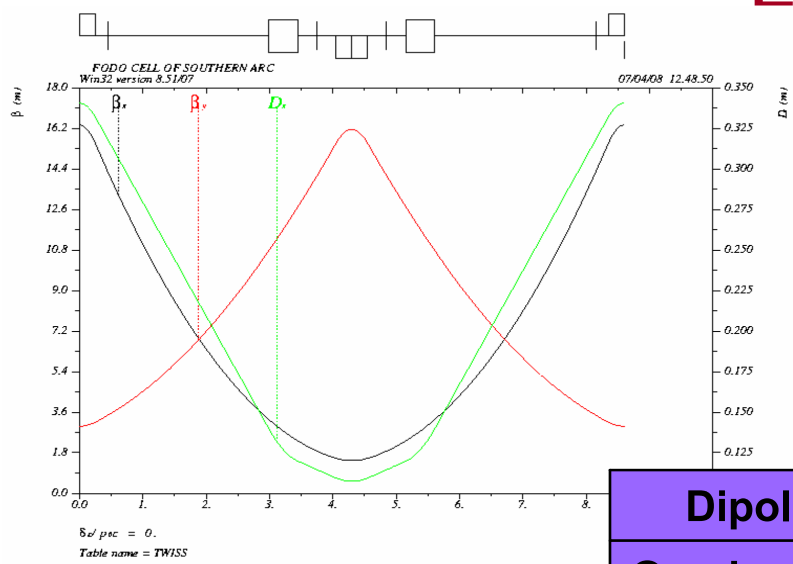
Damping wiggler sections

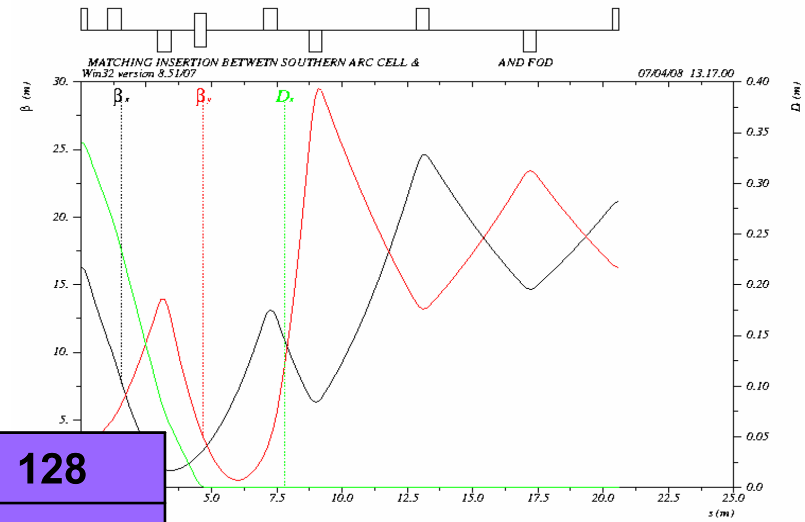
Arcs:
Small – 219 m
Large – 220.6 m

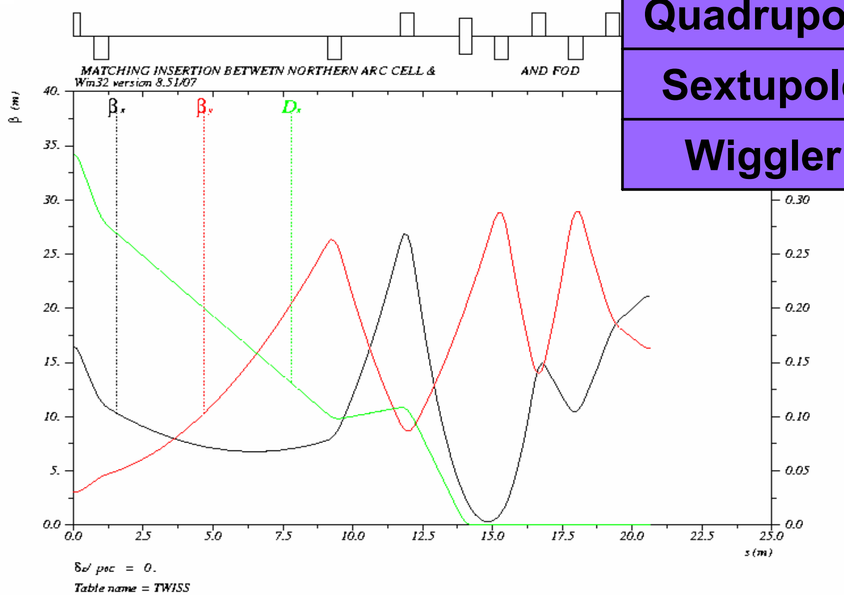
Main accelerator parameters

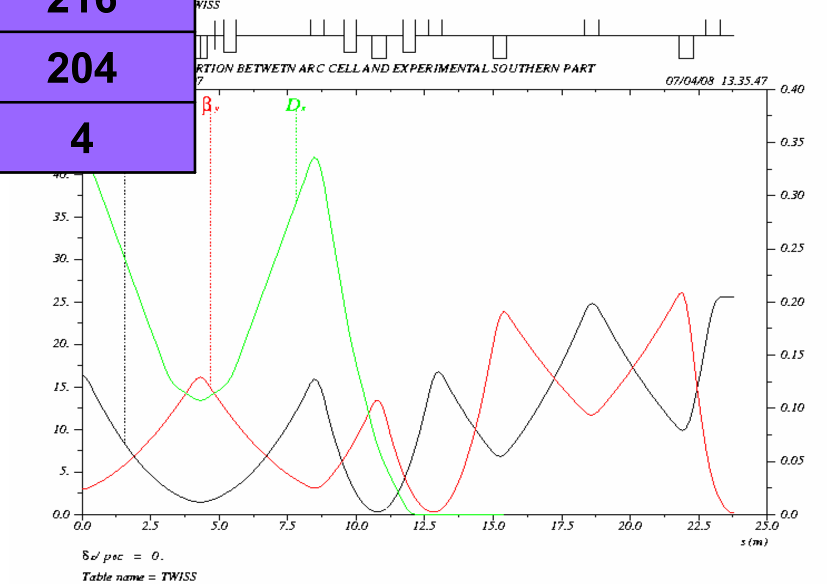
Energy, GeV	2.5
Circumference, m	749.48
Tunes x/y	26.53/19.57
Chromaticity x/y	-250/-320
Coupling factor	0.006
Emittance, nm	9.8
Bunch length, mm	10
dE/E*10^3	0.663
Tau_x, ms	30
Alfa*10^3	1
Energy loss/turn, MeV	0.418
Synchro-tune	0.0088
dE_acc_RF[%]	0.99
Urf, MV	1.05
q	1250
f_RF, MHz	500

Lattice







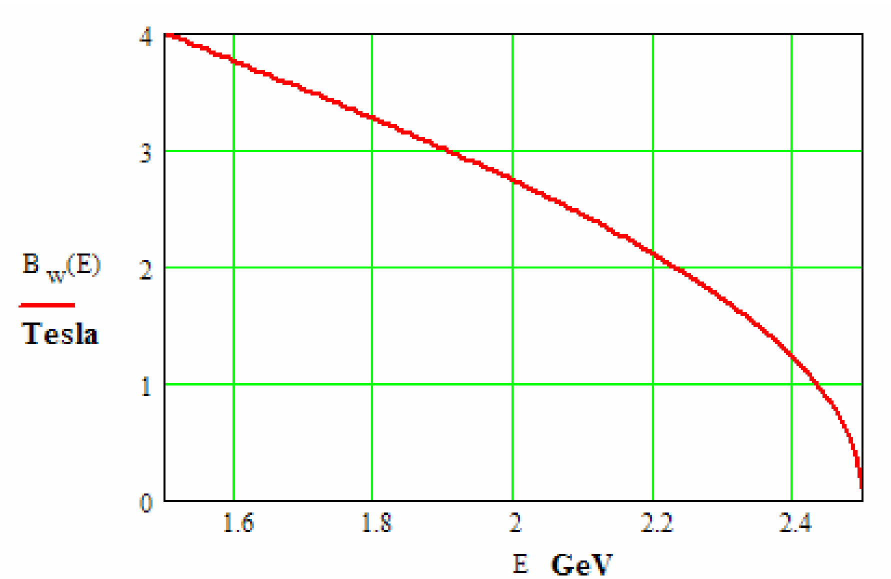


Dipole	128
Quadrupole	216
Sextupole	204
Wiggler	4

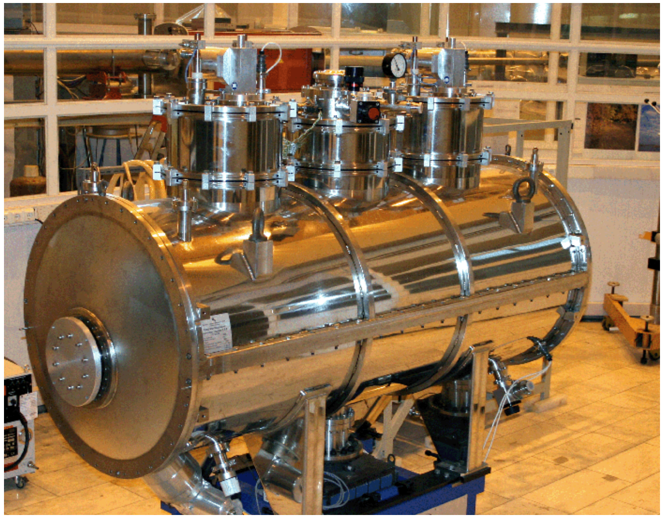
Damping wigglers

The damping wigglers keep the damping time Tau_x =30 ms and the horizontal emittance (10 nm) in the energy range 1.5 – 2.5 GeV

Field amplitude at 1.5 GeV	**4 T**
Period length	**0.23 m**
Total length	**8 m**
Damping integral i_2 at 1.5 GeV	**2.76 m^{-1}**
Excitation integral i_5 at 1.5 GeV	**0.01 m^{-1}**

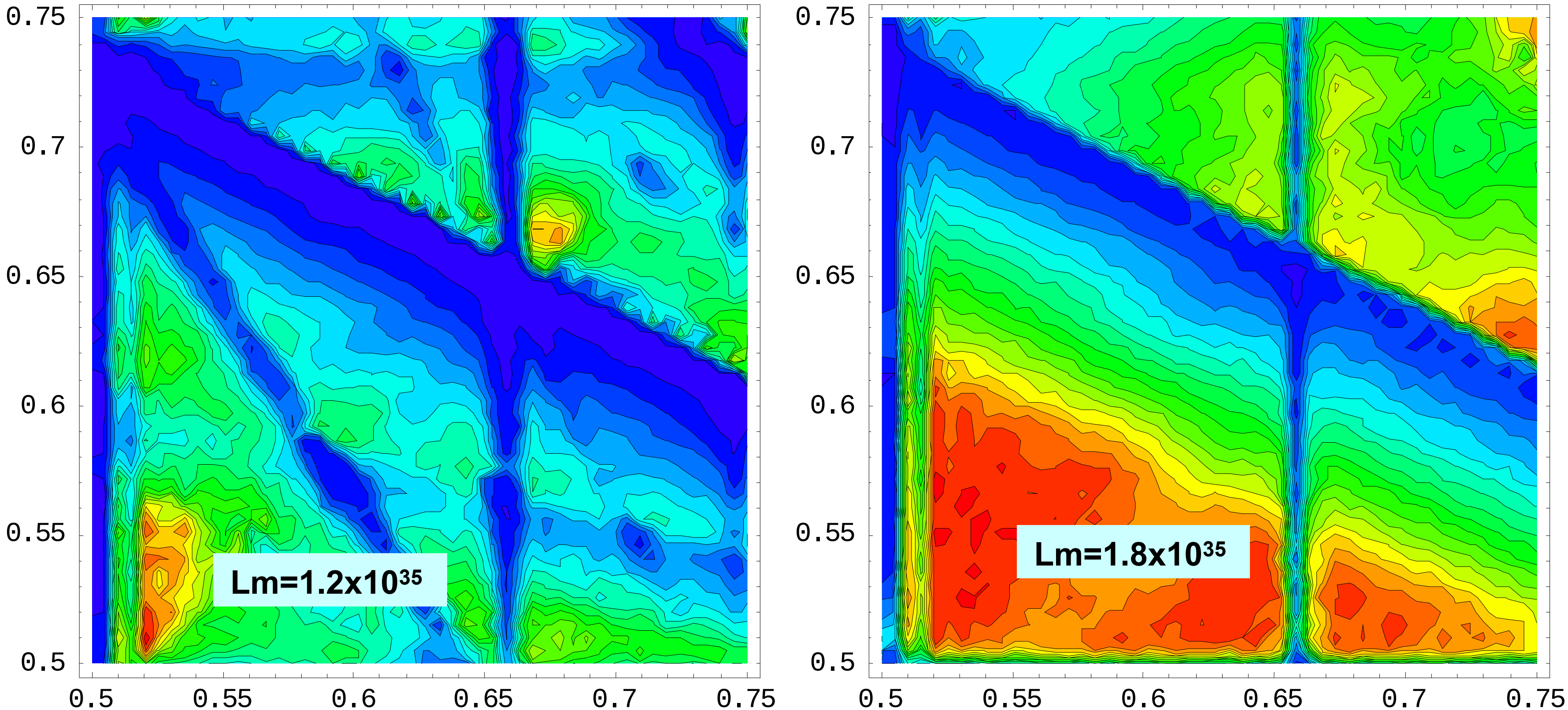


Wiggler field amplitude vs energy



Wiggler with similar parameters produced by BINP

Luminosity



Crab off

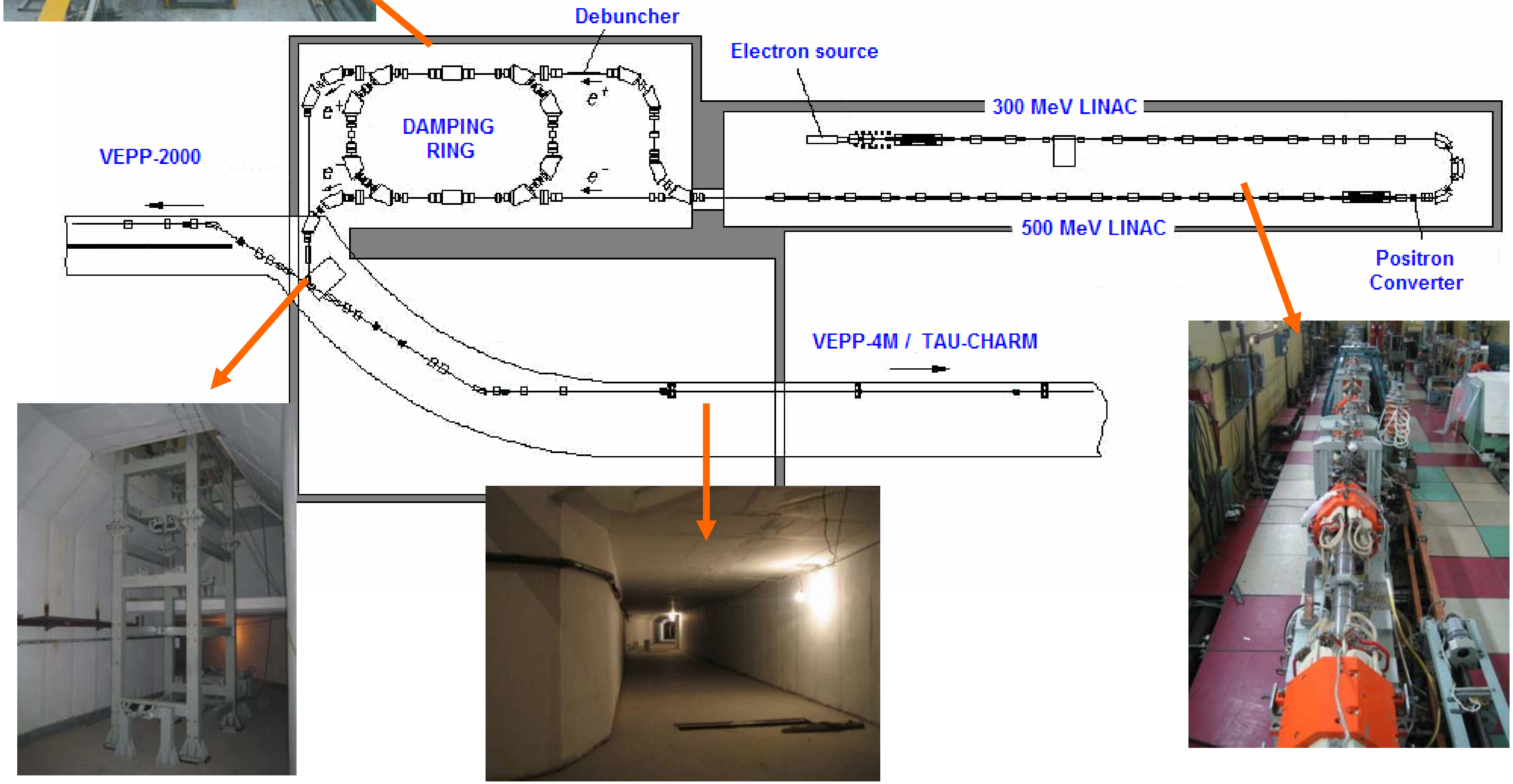
Crab on

Polarized electrons source

Polarized electron source produced by BINP for AmPS

• Beam polarization	90 %
• Cathode voltage	100 kV
• Photocathode type	Strained InGaAsP
• Laser type	Ti – Sapphire
• Light wavelength	700 – 850 nm
• Laser power in a pulse	200 W
• Pulse duration	2.1 μs
• Repetition rate	1 Hz
• Maximum current from a gun	150 mA
• Operational current	15 – 20 mA
• Photocathode lifetime	190 – 560 hours

Injection facility



Injection facility upgrade

- <u>Today:</u>
- 2×10^{10} e^-/pulse $\rightarrow$ (1.5% conversion) $\rightarrow$ 3×10^8 e^+/pulse
- $\times$ 50 Hz = 1.5×10^{10} e^+/s

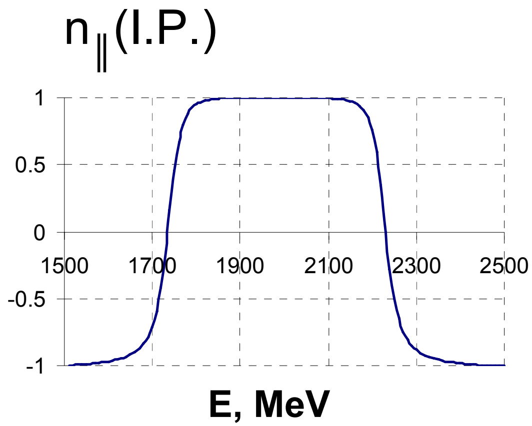
- <u>Upgrade:</u>
- e^- current increase ($\times$ 3)
- Better focusing in positron linac ($\times$ 1.5)
- Debuncher usage ($\times$ 2)
- = 1.35×10^{11} e^+/s

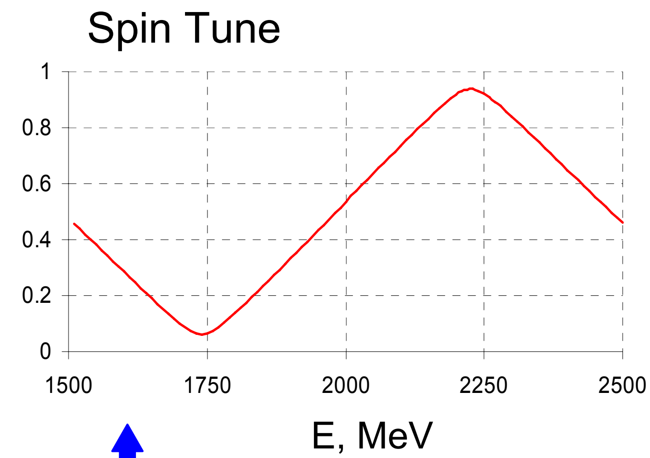
- Reserve: electron energy can be increased by 100 MeV ($\times$ 1.3)

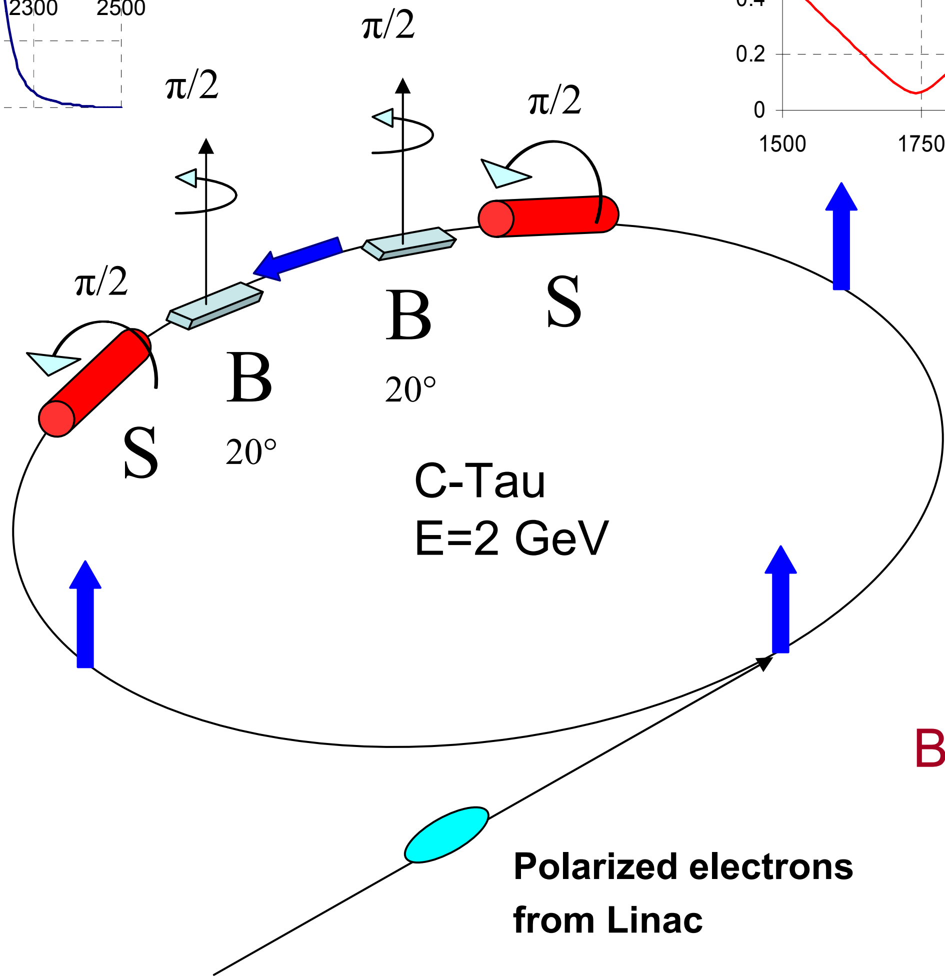
2.5 GeV linac

- ► Using the same accelerating structure as for the existing injection facility
- ► 13 accelerator modules (200 MeV, 16 m) each of 4 accelerator structures. Totally 208 m
- ► In a 1-m straight section between the accelerator structures there are two quadrupoles, BPM and vacuum valve
- ► Four accelerator structures (one module) are fed by one 5045 klystron (SLAC)
- ► Repetition frequency is 50 Hz

C-Tau Longitudinal polarization-1





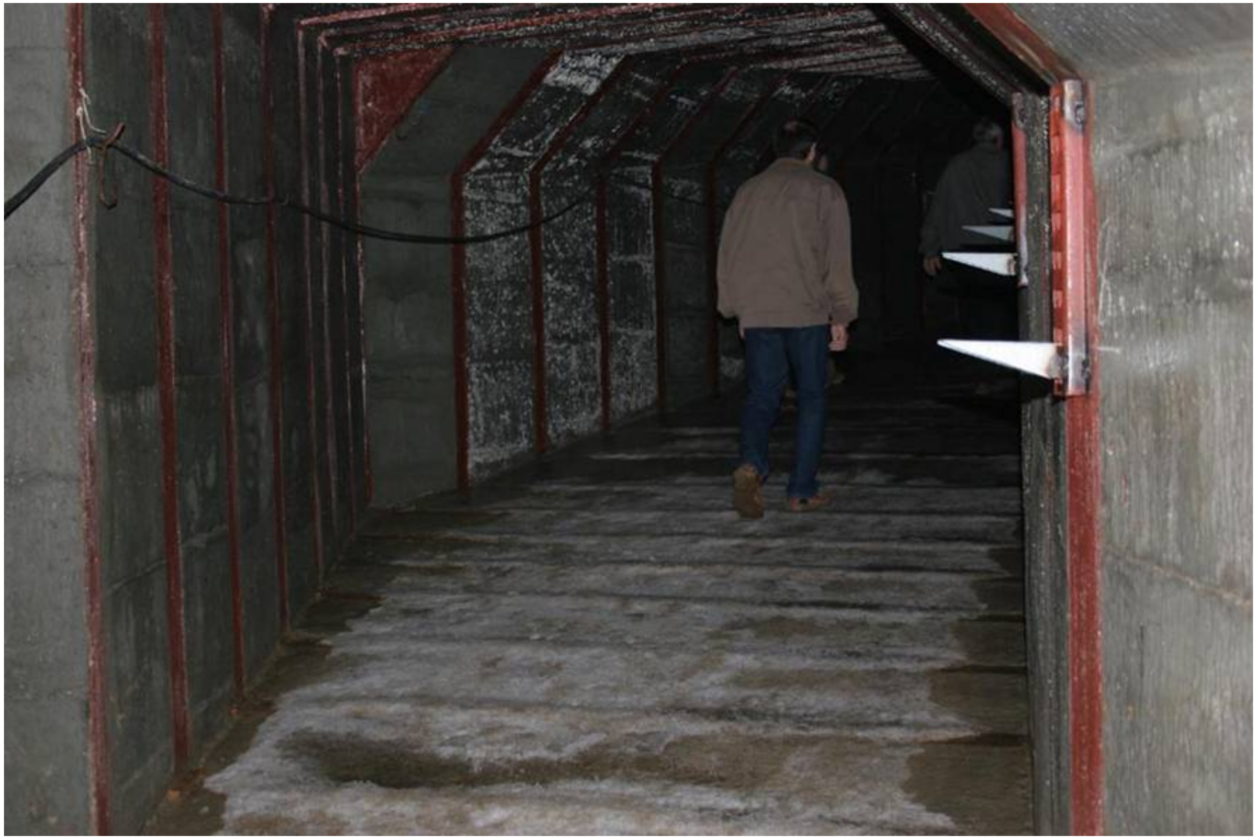


By Sergei Nikitin

C-Tau Longitudinal polarization-2

- Application of a Siberian snake scheme is not possible because of the small depolarization time (~2 min at 2.5 GeV)
- Central Arc scheme restoring the vertical polarization in the main arcs looks promising. The scheme includes two $\pi/2$-solenoid sections and two 20° bending magnets placed symmetrically around the IP
- SC solenoid section turns the spin around the velocity by $\pi/2$. Required longitudinal magnetic field integral in each section (which may be divided in two equal subsections) is $5.25 \cdot E$ [T-m] (E in GeV).
- Betatron coupling is compensated locally in the $\pi/2$-solenoid sections by skew quadrupoles.
- Relaxation time of radiative polarization without the solenoids is 7 hours at 2 GeV. Spin orbital coupling, which is not high for the Central Arc scheme, provides a vertical spin orientation in the main arcs. Expected spin relaxation time is ~1 hour at the energies where the longitudinal polarization at the IP is maximal (1.5, 2.0 and 2.5 GeV).

Long way to collision…



BB simulation expert D.Shatilov follows the electrons path in the C-Tau tunnel to the collision point…

Summary

- C-tau factory with $L = 10^{35}\ cm^{-2}\ s^{-1}$ seems to be an extremely attractive facility for HEP experiments.

- Crab-waist approach allows us to obtain such luminosity with achievable machine parameters: required beam intensity, low emittance, injection efficiency, polarization features have been already obtained in B- and Phi-factories, light sources, etc.

- At BINP we have an advantage-ground to start the C-Tau project: injection facility is under commissioning, tunnels for linac and injection lines are ready, a lot of the facility solutions are based on existing wares and technologies.

- Future plans for the project design: FF improvement, dynamic aperture optimization, BB study, Touschek lifetime increase, etc.

workers of all the world unite!

e^+e^- factories

workers of all the world unite!