τ-c COLLIDER - PROPERTIES - PROSPECTS

SLAC - MAR 6-9 '99

INTRO.

- τ-CF HISTORY > DECADE → many interesting ideas. WILL NOT REVIEW DEVT.

- MOST new IDEAS INCORP. IN "REFERENCE DESIGN" of 1996 = "BTCF FEASIBILITY STUDY"

- THIS REVIEW BASED ON '96 STUDY: IF START TODAY ?? "DREAM" OF FUTURE ??

BASICS

- e^+e^- SR COLLIDER : VERY E SPECIFIC (RADIATION) → E_{opr}. $E(\hat{\mathcal{L}})$ - Ref. Des. - ~2 GeV/bm. [atten' paid to 1.5 GeV oper as well] $\hat{E} \gtrsim 2.5$

- $\mathcal{L} \propto \frac{\xi \cdot E \cdot I}{\beta^*}$; E (specified), ξ ("constant" of Nat.)

  β^* (technology, physics constr - some variability)

  $I = k N_b e f_0$; N_b limited, f_0 heavy constraints,

  → go for big k (# bunches)

- BIG k → small S_B → fast separation at IP to avoid sacrifice ξ uselessly → separate rings → constrained IR

②

<u>REF. DES.</u>

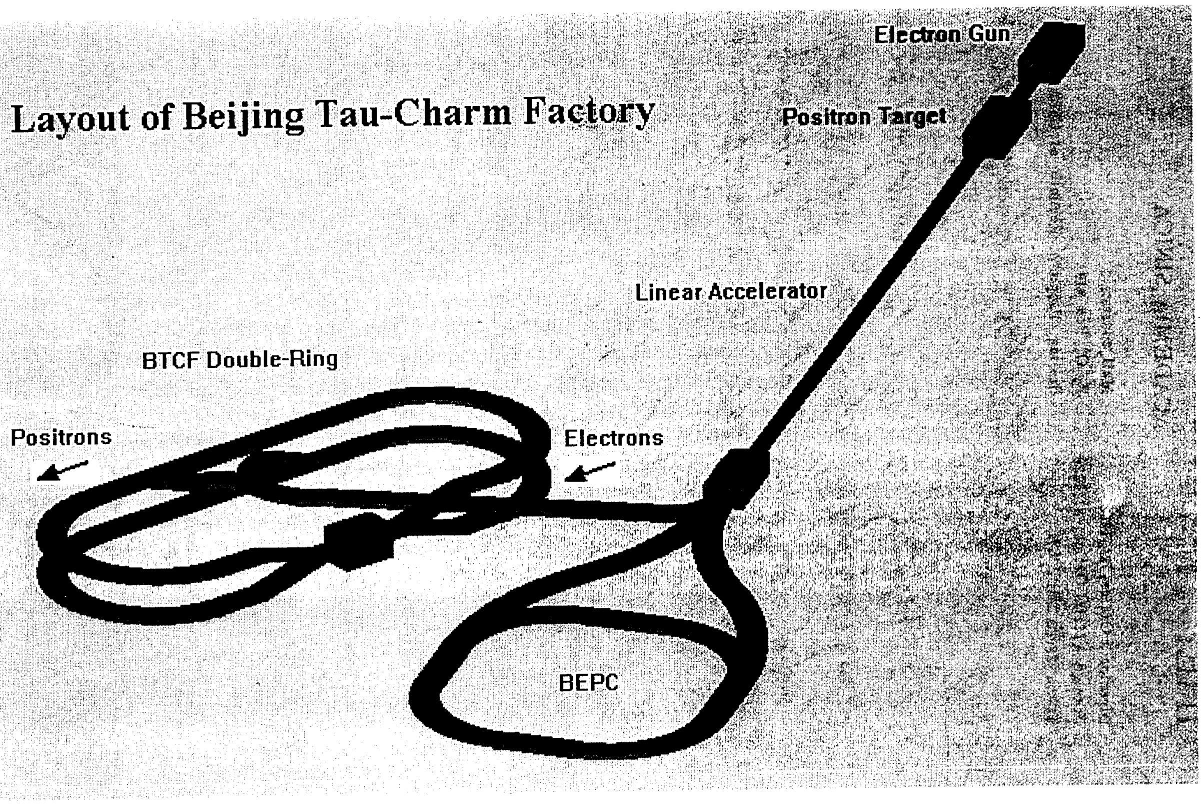
- ≥2 MODES, e.g. Hi $\mathcal{L}$, $\vec{n}$, mono …
  CONDENSE TO 2: (Hi $\mathcal{L}$, $\vec{n}$, 26eV); (mono, 1.55GeV)

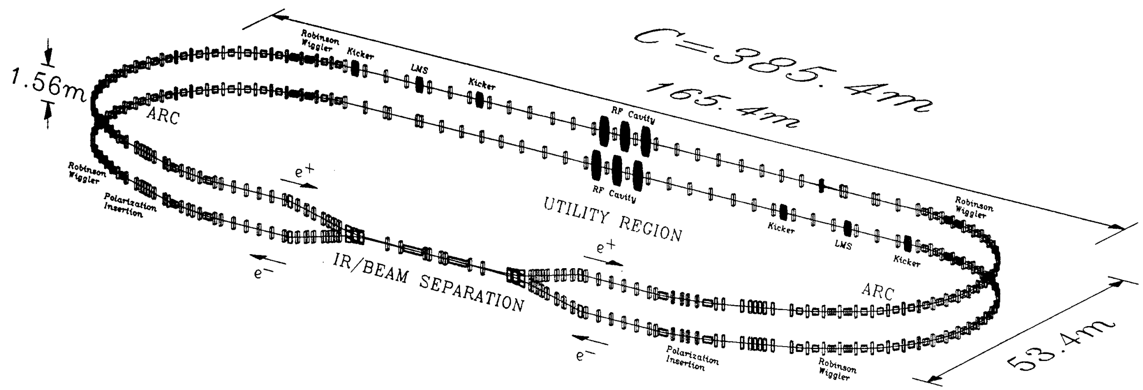
- See Layouts
  - ✓ 2 RINGS (2)
  - ✓ IR (3)

- Hi $\mathcal{L}$, $\vec{n}$ (See Param List)
  ($X \cdot \mathcal{L}$??)

- Monochromator - $D_y \rightarrow \Delta y_\epsilon \gg \Delta y_\beta$
  (See Param List) ($X \cdot \mathcal{L}$??)

The Layout of Beijing Tau-Charm Factory




C=385.4m
165.4m
1.56m
ARC
Robinson Wiggler
Kicker
LWS
RF Cavity
Polarization Insertion
e+
e−
UTILITY REGION
IR/BEAM SEPARATION
53.4m

CHALLENGES IN IR - DETECTOR / ACC. INTERFACE peculiar to τ-cF (w.r.t. B-fac)

- ✓ Hi B-sol / Bρ ; Compensation Steals fac. sp.
- ✓ Pol'n adds some constraints (maybe not hard-v)
- ✓ SR less than B-fac
- ✓ BEAM-GAS (Brems + Coulomb) ≈ same [DETAILS]
- ✓ TOUSCHEK MUCH worse (STUDY ESSENTIAL!!)

e.g. BTCF: $\tau_{Tk} < \frac{1}{2}\tau_{BG}$ — gas can be pumped; Touschek trickier?

(See Prelim Bkgnd Calcs - Zhang Dehong)

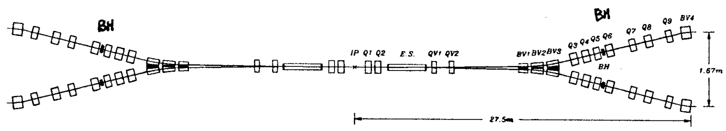
THEN

(See POLARIZATION - Wang Dong's wk)

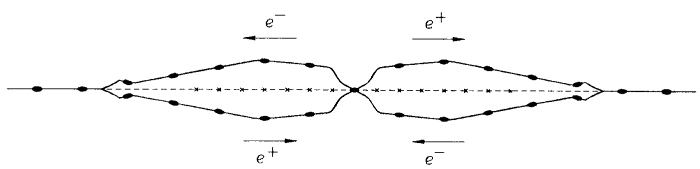
(3) Compatibility for Different Modes

a) The crossing angle collision optics

- The crossing angle by a pair of horizontal dipoles BHs.



Side View



Top View

- *Bunch*
- × *Parasitic Crossing Point*

- Main parameter choice

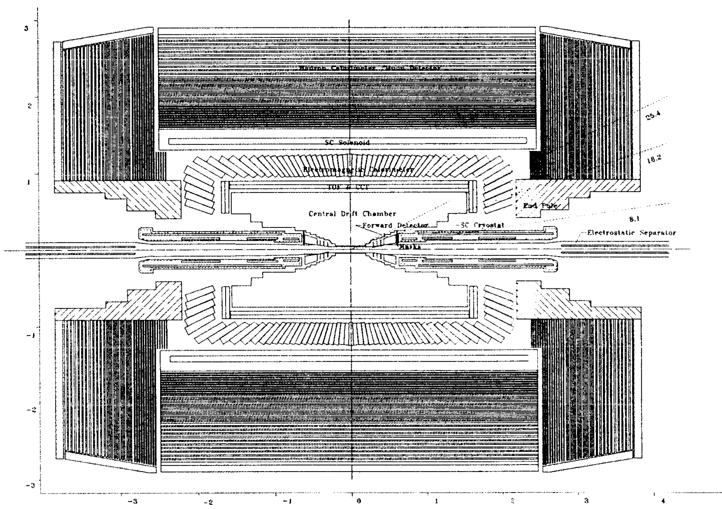
crossing angle	$2\phi_c = 2.6 \times 2$ mrad
bunch spacing	3.78 m
bunch number	86
natural emittance	ε_{xo}=140nmrad
beam current	570 mA
$\beta_x^* \ / \ \beta_y^*$	0.65 m / 0.01 m

(1) Interaction Region

a) Detector boundary conditions

- The accelerator components must fit within a conical space with an opening angle of 18.2°, and must be located beyond 0.6m from the IP.

- The superconducting solenoid of the detector has a field strength of 1.0 T over a distance of ±2.65 m around the IP.

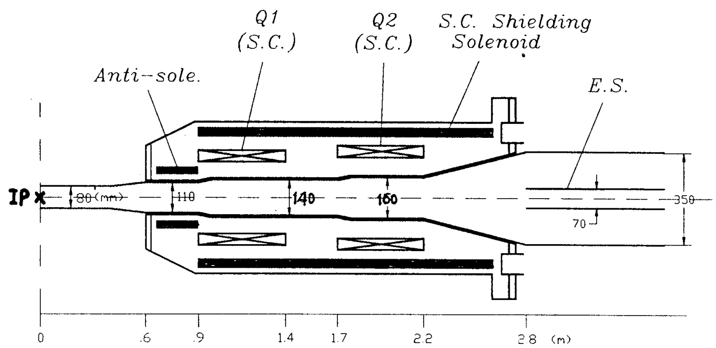


Schematic layout of the detector facilities
and IR accelerator components

c) Compensation Solenoids and IR Aperture

- Anti-solenoid with -3.0 T, 0.3 m long to cancel the detector solenoid field between IP and Q1.

  Shielding solenoid to eliminate the detector solenoid field in the Q1, Q2 region.



Vacuum chamber and cryostat in the IR

- All the aperture in the IR are designed for a beam with at least 14σ in detector .

- The inside diameter of the vacuum chamber in IR is 80 mm at the IP, 140 mm at Q1 and 160 mm at Q2; the vacuum chamber with 0.8 m long at the IP will be made of pure beryllium.

Table 3.1 Machine parameters for high luminosity mode with a horizontal crossing angl

Beam energy E (GeV)	2.0
Circumference C (m)	385.447
Revolution frequency f_0 (MHz)	0.778
Crossing angle at IP $2\phi_c$ (mrad)	5.2
β-function at IP $\beta_x^*/\beta_y^*(m)$	0.65/0.01
Dispersion at IP D_x^*/D_y^* (m)	0.0 /0.0
Betatron tunes Q_x/Q_y	11.8/12.6
Momentum compaction α_p	0.014
Synch. rad. loss/turn U_0 (keV)	172
Damping time $\tau_x/\tau_y/\tau_\epsilon$ (ms)	30/30/15
Natural emittance ϵ_{x0} (nm)	153
Vertical emittance ϵ_y (nm)	2.3
Momentum spread σ_ϵ	5.84×10^{-4}
Synchrotron tune Q_s	0.068
Natural chromaticity Q_x'/Q_y'	-20/-36
Total current per beam I (A)	0.57
Number of bunches k_b	86
Particles per bunch $N_b(10^{11})$	0.54
RF frequency f_{rf} (MHz)	476
RF voltage V_{rf} (MV)	6.8
Natural bunch length σ_l (cm)	0.76
Beam-beam effect ξ_x/ξ_y	0.04/0.04
Luminosity L ($cm^{-2}s^{-1}$)	1×10^{33}
CM energy spread σ_ω (MeV)	1.7

c) Monochromator scheme

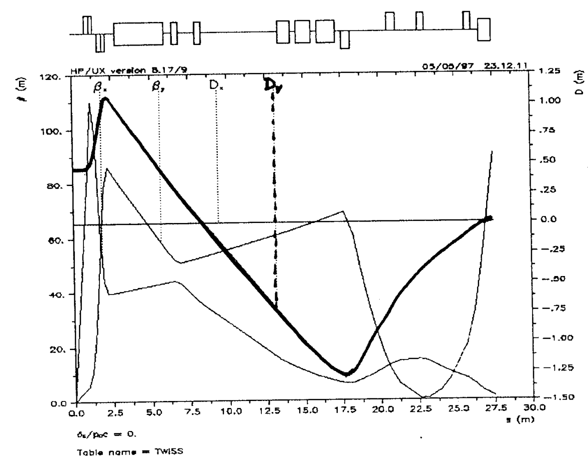
- Polarity change: Q1, Q2, Q6, QV2;

  switching off: Q4, Q8, BH.

- Using Robinson wigglers to adjust the emittance and the energy spread.

- The main parameters:

β_x^*	1cm	β_y^*	15cm	D_y^*	±0.45 m
ε_{x0}	35nmrad	L	$2\times10^{32}cm^{-2}s^{-1}$		



IR for monochromator scheme

- The machine studies about beam-beam interaction when η^* is lager will be arranged at BEPC.

Table 3.14 Machine parameters of the monochromator mode

Beam energy E (GeV)	1.55
Circumference C (m)	385.447
Revolution frequency f_0 (MHz)	0.778
Crossing angle at IP $2\phi_c$ (mrad)	0.0
β-function at IP β_x^*/β_y^* (m)	0.01/0.15
Dispersion at IP D_x^*/D_y^*(m)	0.0/0.35
Betatron tunes Q_x/Q_y	13.08/11.11
Momentum compaction α_p	0.0115
Synch. rad. loss/turn U_0 (keV)	71
Damping time $\tau_x/\tau_y/\tau_\epsilon$ (ms)	25/59/95 (with wig.)
Natural emittance ϵ_{x0} (nm)	48 (with wigglers, Jx=2.37)
Vertical emittance ϵ_y (nm)	4.0
Momentum spread σ_p	8.0×10^{-4}(with wigglers)
Synchrotron tune Q_s	0.057
Natural chromaticity Q'_x/Q'_y	-37/-29
Total current per beam I(A)	0.2
Number of bunches k_b	29
particle per bunch $N_b(10^{11})$	0.57
Bunch space S_b (m)	11.97
RF frequency f_{rf} (MHz)	476
RF voltage V_{rf} (MV)	4.4
Bunch length σ_l (cm)	1.0
Beam-Beam effect ξ_x/ξ_y	0.014/0.015
Beam life time τ (hrs)	$\geq$1
Luminosity L (cm^{-2}s^{-1})	1×10^{32}
CM energy spread σ_ω (MeV)	0.12

Table 3.15 Touschek lifetime of the monochromator mode

Energy acceptance 10^{-3}	Emittance x/y (nm)	Touschek lifetime hours
8	13/2	0.5
8	48/4	1.7
9	13/2	0.7
9	48/4	2.2

Charmonium Summary

Walter Toki

The charmonium section of the tau charm workshop included talks by Yifan Gu (ψ' physics), Kam Seth (charmonium results from $p\bar{p}$ gas jet experiments) and Walter Toki (topics in J/ψ and ψ' decays). This summary will discuss (1) the existing data, (2) the expected rates at a tau charm factory,(3) a survey of the physics topics, and (4) calibration procedures.

CHARMONIUM EXPERIMENTS

The previous e^+e^- experiments on J/ψ and ψ' physics include the Mark II, Crystal Ball, Mark III, and DM2 and the only running experimeint is BES. The existing data sets are listed below.

Table 1. J/ψ and ψ' Data Sets		
Experiment	J/ψ data	ψ' data
Mark II	1.3M	1M
Crystal Ball	2M	1.3M
MarkIII	5.8M	.3M
DM2	8M	-
BES	9M	1.5M

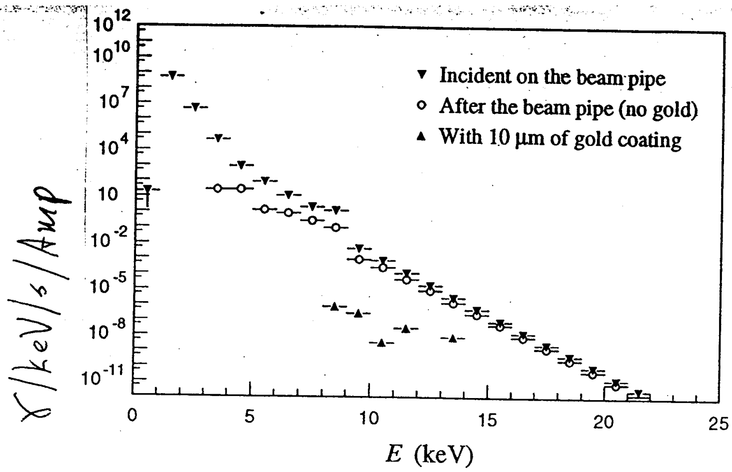
Another important charmonium experiment is the antiproton experiment[1], E760, with a proton gas jet target in the FNAL antiproton accumulator. This experiment has produced in $p\bar{p}$ collisions the J/ψ, ψ', χ_c, η_c and recently the $^1P_1$. The experiment can measure very precisely the masses and widths by using a cooled antiproton beam whose momentum spread is very small. Typically the center of mass energy spread is 0.5 KeV (full width). The widths have been measured for several resonances. The experiment has been approved for another fixed target run in 1995 (E835).

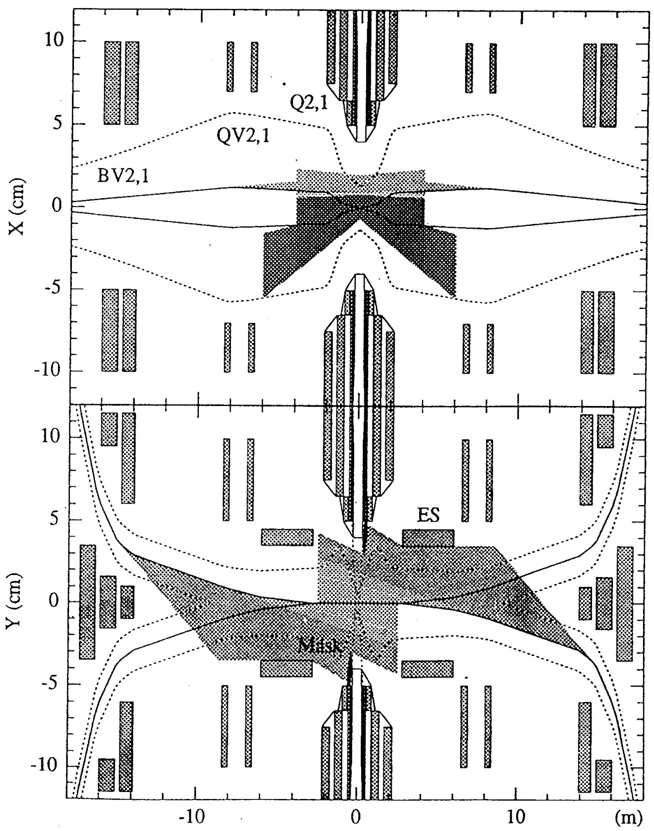
TAU CHARM FACTORY RATES

In a tau charm factory. the projected luminosity is 10^{33} cm^{-2}sec^{-1} with a energy spread of ~1 MeV. With a monochrometer. the energy spread can be reduced to 0.14 MeV to increase the peak luminosity for narrow resonances. Using the particle data book values for the Γ(hadron) and Γ(ee) for the J/ψ and ψ', we can estimate the peak luminosity.[2]

Table 2.			
Resonance	peak cross section	instantaneous rate at 10^{33} cm^{-2}sec^{-1}	number of events per day(50% efficiency)
J/ψ	~2600 nb	2.6 Khz	112×10^6
ψ'	~800 nb	0.8 Khz	34×10^6
J/ψ with mono-chrometer	~16000 nb	16 Khz	688×10^6
ψ' with mono-chrometer	~5000 nb	5 Khz	215×10^6

[1] Kam Seth talk. this workshop.
[2] D. Yennie. Phys. Rev. Lett.. 34.239(1975)


γ/keV/s/Amp
Incident on the beam pipe
After the beam pipe (no gold)
With 10 μm of gold coating
E (keV)


Q2,1
QV2,1
BV2,1
X (cm)
ES
Mask
Y (cm)
(m)

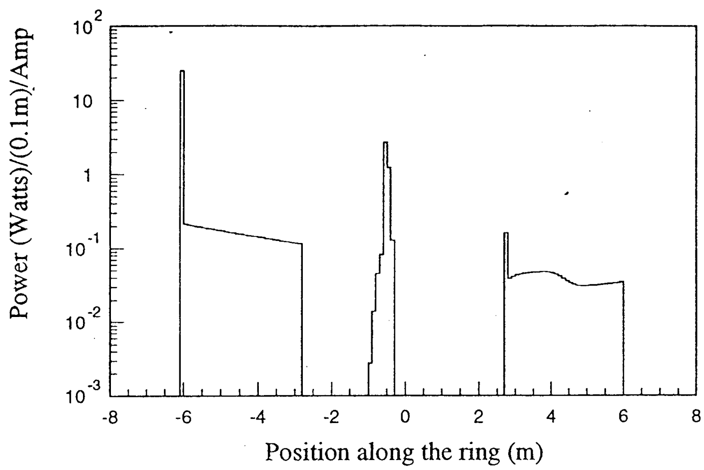


Figure 3.17 SR power deposited by the electron beam into the vacuum chamber wall within ±8 m of the IP.

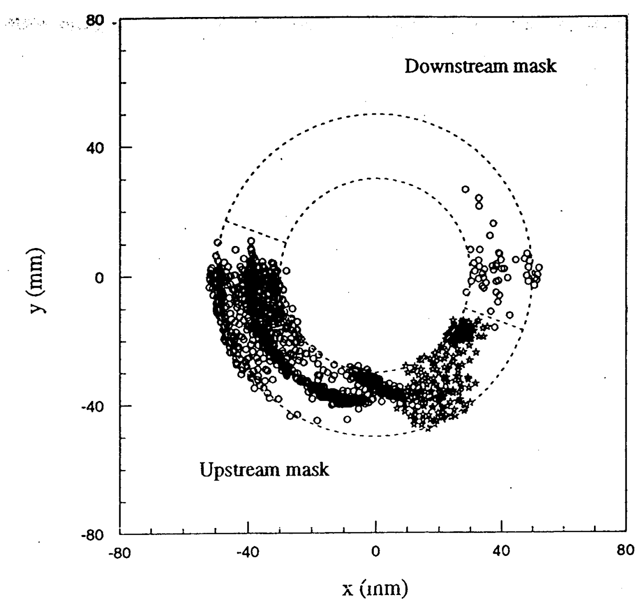
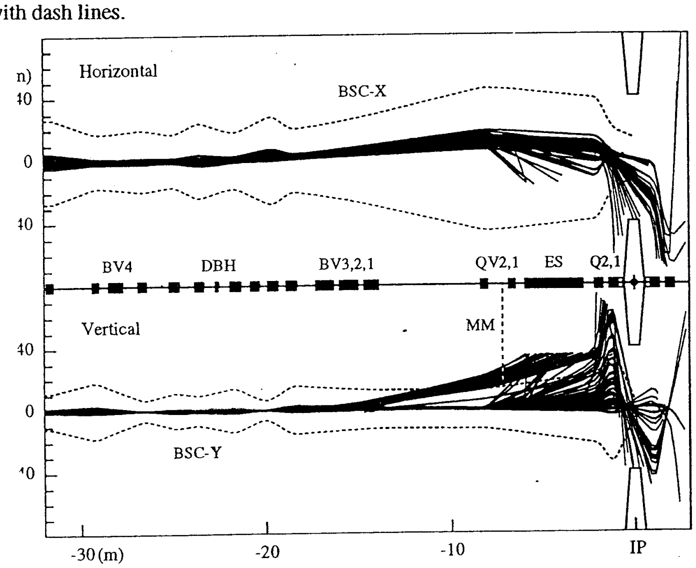


Figure 3.21 Spatial distribution for bremsstrahlung particles (circles) and photons (stars) when they hit the upstream mask and the beam pipe. The half-circle shaped masks are shown with dash lines.



3.19 Typical trajectories for bremsstrahlung particles which hit the vacuum chamber the IP. Also shown is the position to place a movable mask (MM).

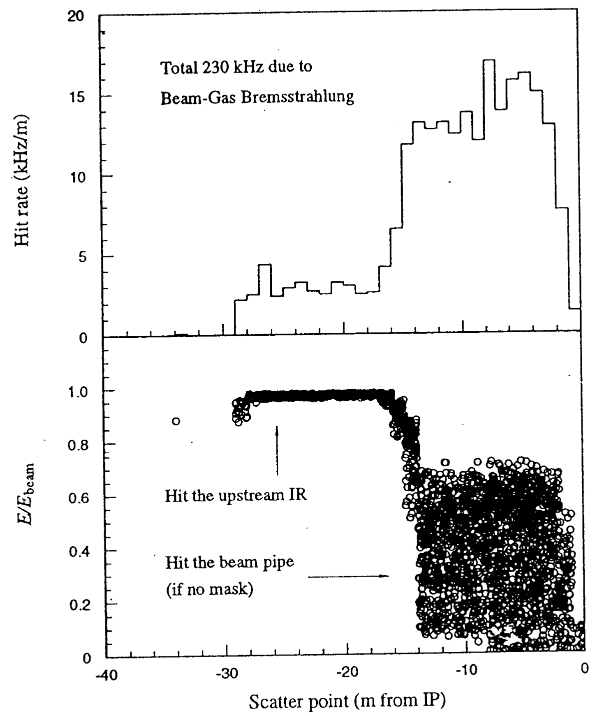


Figure 3.20 Hit rate as a function of the bremsstrahlung point for one beam (top) and the correlation between energy and the scatter point (bottom).

Longitudinal Polarization in a Tau-charm Factory

Dong Wang

Accelerator Center
Institute of High Energy Physics

December 10, 1998

I

Longitudinal Polarization in BTCF
— Definitions:

1, Energies preferred:

So far, 1.8436 GeV is most wanted

If possible: around 2.0 GeV, 1.55 GeV

2, Must both beams be polarized?

Single beam polarized: OK

Both beams polarized: perfect

3, How frequently must helicity be reversed?

Once a week or so

4, Must polarization be available at the start?

If possible

5, Polarization level

Nobody sets a quantity for BTCF, up to now

Mostly depends on the possiblity

1990: Soergel limit for HERA: 50%

Electron polarization in strorage rings

Table 1: The history of spin polarization in storage rings.

Name	Year	Polarization	Energy
VEPP	1970	80% vert	0.65 GeV
ACO	1970	90% vert	0.53 GeV
VEPP–2M	1974	90% vert	0.65 GeV
VEPP–3	1976	80% vert	2 GeV
SPEAR	1975	90% vert	3.7 GeV
VEPP–4	1982	80% vert	5 GeV
CESR	1983	30% vert	5 GeV
DORIS	1983	80% vert	5 GeV
PETRA	1982	70% vert	16.5 GeV
LEP	1993	57% vert	47 GeV
HERA	1993	60% vert	26.7 GeV
HERA	1994	70% long	27.5 GeV
Amps+BIVP	1996	~ long	0.6–0.9 GeV (Shatunov)

Longitudinal polarization:

1, Get beam polarized similiar to transverse case

2, Spin rotator: layout

3, Depolarization effects

Sokolov-Ternov polarization time(hour) vs. bending radius in BTCF

E(GeV)	1.55	1.77	1.84	2.0	2.5	3.0
ρ = 6m	6.8	3.5	2.9	1.9	0.6	0.2
ρ = 7m	9.2	4.6	3.9	3.7	0.8	0.3
ρ = 8m	12.0	6.2	5.1	3.4	1.1	0.4
ρ = 9m	15.2	7.8	6.5	4.3	1.4	0.6
ρ = 10m	18.8	9.7	8.0	5.2	1.7	0.7
ρ = 12m	27.1	14.0	11.5	7.6	2.5	1.0
ρ = 15m	42.3	21.8	18.0	11.8	3.9	1.6

$$\rho(\mathrm{m}) = \frac{\mathrm{E(GeV)}}{0.3\mathrm{B(Tesla)}}$$

BTCF:

E_{max} = 3.0 GeV

B_{max} = 1.2 Tesla

$\Downarrow$

ρ = 8.3 m

Sokolov-Ternov effect on BTCF

E(GeV)	1.3	1.55	1.77	1.84	2.0	2.8
τ_p (hour	30.2	12.5	6.5	5.3	3.5	0.65

Too long!

SLC polarized electron gun

Main parameters	Achieved level
Electron polarization	~ 80 %
Electrons/bunch peak	9×10^{10}
operation	7×10^{10}
Availability	~ 99 %
Repetition rate	120 Hz
Kinetic energy of e-	120 KeV
Pause width (FWHM)	2 ns

Fufill the requirement of BTCF e- injection

BTCF e- source: Similar scheme as SLC

- Thermal gun for positron production;
- Polarized gun for polarized e- injection

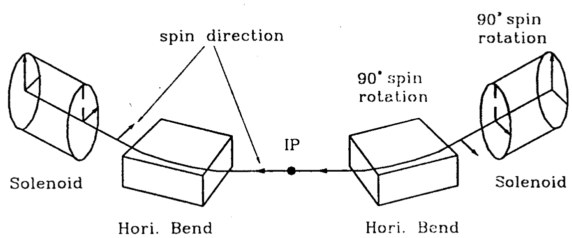
Compact pre-polarization ring(C=96m) with s.c. dipoles

Polarization time: a few minutes

Refresh(top-up) 1/4 of e+(or e-) bunches each time

Efficient enough?

Symmetric dipole solenoid spin rotator



Dipole-solenoid spin rotators in τ-charm factory

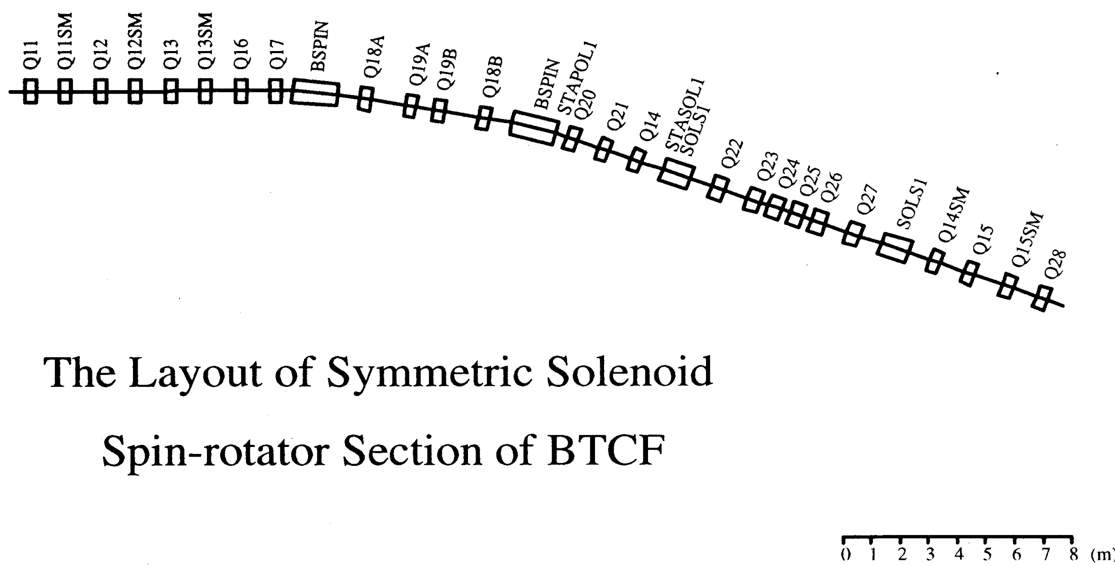
Energy	1.55 GeV	1.84 GeV	2.0 GeV
Solenid field	8.1 T·m	9.7 T·m	10.5 T·m
Bend angle	25.6°	21.5°	19.8°

Longitudinal field(L=1.5m)

Energy	1.55 GeV	1.84 GeV	2.0 GeV
Field strength	5.4 T	6.5 T	7.0 T

Quadrupole for coupling compensation

quadrpoles	length	strength
SQ1A skew quad.	0.1 m	-0.2610876 1/m^2
SQ1B skew quad.	0.1 m	0.2610876 1/m^2
SQ2A skew quad.	0.2 m	-1.112822 1/m^2
SQ2B skew quad.	0.2 m	1.112822 1/m^2
QSOL normal quad.	0.4 m	1.167048 1/m^2



The Layout of Symmetric Solenoid

Spin-rotator Section of BTCF

WGDONG@SOLAR03, OCT18/20:34

Depolarization effects and spin matching studies

The presence of **spin rotators can cause** strong diffusive depolarization, even for perfect machine.

BTCF, 1995, calculated with SLIM by Chao, Minty, Nosochkov. (Rotators on, no spin matching)

Less than 10% !

Derbenev-Kondratenko formula (1973)

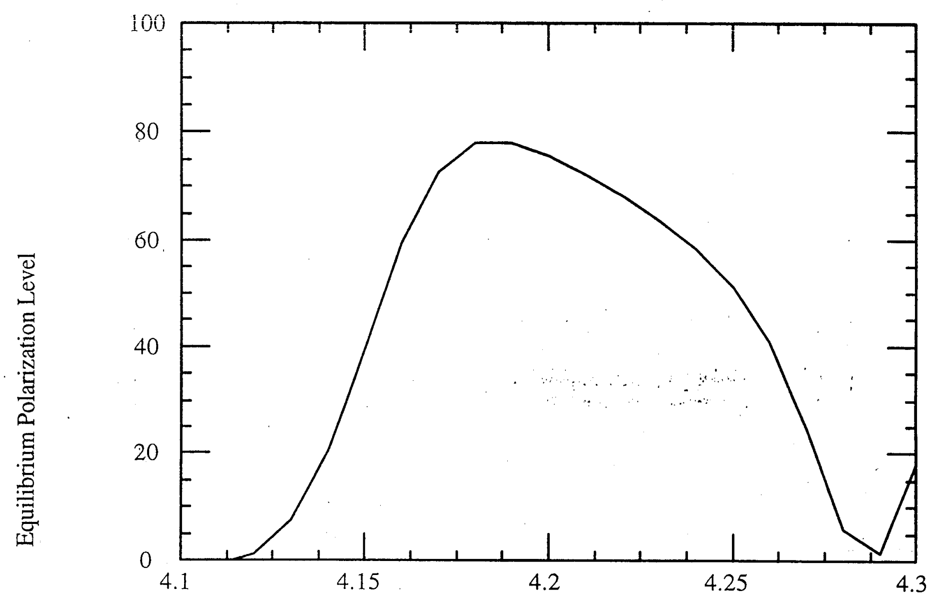
$$P_{eff} = P_{ST} \frac{\left\langle \oint \frac{ds}{|\rho(s)|^3} \vec{b} \cdot \left[\vec{n} - \gamma \frac{\partial \vec{n}}{\partial \gamma} \right] \right\rangle}{\left\langle \oint \frac{ds}{|\rho(s)|^3} \left[1 - \frac{2}{9} (\vec{n} \cdot \vec{v})^2 + \frac{11}{18} \left| \gamma \frac{\partial \vec{n}}{\partial \gamma} \right|^2 \right] \right\rangle}$$

minimize spin-orbit coupling term by

Spin-matching

Chao, Yokoya(1981)

BTCF Spin-matching at γa=4.184



• CONVERSION OF REF. DES. to WORKING DES.

✓ RETHINK ENTIRE DESIGN i.l.of. progress:
✓✓ BEGIN W. IR & WORK OUTWARDS i.l.of:
- BACKGROUND - INCL. TOUSCHEK - from start
- DYNAMIC APERTURE*
- POLARIZATION CONSTRAINTS
- POSSIBILITY OF "MONO" W. PLANAR RINGS
- DIFFICULTIES OF VERTICAL SEPARATION
- UPGRADE POTENTIAL
- - -

✓✓ REVIEW ARC DESIGN
- DYNAMIC APERTURE / TOUSCHEK AMELIORATION
- PEI
- POLARIZATION CONTROL
- - - - -

✓✓ INJECTION SCHEMES & INJECTORS
- REEXAMINE ALTERNATIVES FOR SIMPLICITY
- - - - -

* INTERPLAY OF SOLENOID COMPENSATION AND L^*

TECHNICAL PROSPECTS (10^{33}, 2GeV, $\vec{n}$ e^-)

✓ PRETTY GOOD: WILL LEARN A GREAT DEAL FROM CURRENT GENERATION + THEIR BUILDERS WILL BE AVAILABLE TO HELP:

FACILITY	Knowledge useful for τCF
BEPC	Background Studies - Touschek + PEI & Ion
CESR	Möbius; L-Xing
DAΦNE	Large XL, σ_z(nat) ~ 5mm, Hi Bat/Bp, Novel Sol. Comp., Heavy Touschek, PEI, Ions
KEK-B	Large XL, σ_z ~ 4mm, Crab Xing, Heavy Touschek, local ξ, PEI, ions, Super feedback
PEP-II	VERTICAL DISPOSITION, ion, PEI, Super feedback, LER Vac., Local ξ corr.

- TECHNICAL PROSPECTS ("Mono") ⑥
  - ✓ IDEA WILL WORK TO SOME EXTENT. Q: Optimum balance among Touschek life/bkgnd, $\mathcal{L}$ and σ_w (are cm)

    - ✓✓ small ε → small D → τ short owing to small beam size
    - ✓✓ small D → strong 6-pole → reduced dynamic aperture
    - ✓✓ Large D_x at IP compromises ΔE/p in IR → shorter life → higher background.

    ⇓

    ROUGH SLEDDING → MUCH TIME TO BRING UP.

- TECHNICAL PROSPECTS (5-10 x $\mathcal{L}_{33}$ "Dream") 2GeV
  - ✓ IF B-FACS → 10^{34}, τCF @ 5×10^{33} not crazy.
  - " " higher, so τCF: $\mathcal{L}\propto EI$

    - ✓✓ More q/bunch (optics, z)
    - ✓✓ more K_{IP}, bigger ξL from bunches
    - ✓✓ higher $\mathcal{L}/I$ ⇒ bk. har., mötius, phase conjugation ...

- TECHNICAL PROSPECTS (mono "Dream")
  - ✓ as never been done, no basis for upgrade discussion.