The Consideration of Tau-Charm Factory Construction in China

ZHENG Zhipeng

IHEP, Beijing

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1. Review of history of HEP in China.
2. BES results.
3. Consideration of τcF construction in China.
4. Possible schedule.
5. Summary

1. The review of the development of HEP (High Energy Physics) in China:

1) Milestones

- In 1973, under the concern of the former Premier Zhou EnLai, IHEP (Institute of High Energy Physics) of CAS (Chinese Academy of Sciences) was founded.

- In 1978, a plan of building a 50 GeV proton accelerator was put forward, which however was stopped in 1980.

- In 1981, Profs. T.D.Lee and Panofsky suggested to construct a 5 GeV electron positron collider in China, which was actively responsed by Chinese physicists.

- In 1982, the proposal of BEPC (Beijing Electron Positron Collider) construction was approved.

- In Oct. of 1984, BEPC started its ground breaking. Mr. Den XiaoPing was on the scence.

- In Oct. 0f 1988, the BEPC construction was completed and the e^+e^- beams successfully collided.

- In the Summer of 1989, BES (Beijing Spectrometer), the single detector on BEPC was moved to the interaction point of the collider.

- In the Spring of 1991, about 20 American physicists from 6 institutions and universities of USA participated the BES collaboration. Now the number has been increased to 40 physicists from 10 units.

- In 1992, the precise measurement of Tau mass was accomplished on BEPC/BES.

2) Why could China build the good quality BEPC/BES in 4 years short time, and soon after that, achieve the significant physics results? There are reasons for the success:

- The HEP in China was strongly supported by the leaders at the top level, such as the former Premiers Zhou and Den. Since in the meantime HEP was opposed by many people in and outside the Chinese scientific community, this support was particularly important in such a developing country as China.

- Actually the HEP in China was not started from BEPC construction. In the field of advanced physics, such as atomic, nuclear, cosmic ray and theoretical physics, several generations of Chinese physicists had made continuous efforts for decades of years.

- In China there has been a team of scientists on HEP accelerator and detector. They experienced strict training and they are willing to devote to scientific research.

Also they are good and quick in learning from the Western science and technology.

- We have been efficiently helped by international HEP community. The special help and achievement from US physicists, especially Profs. T.D. Lee and Panofsky, US-China HEP joint committee meeting, and BES collaboration should be emphasized.

- The plenty of potential in Tau, Charm, and Charmonium field has always attracted physicists of the world.

2. The main physics results achieved at BEPC/BES in the past 3 running years:

- BEPC

  E_{cm} = 3 - 5.6 GeV

  Peak luminosity = $6 \times 10^{30} cm^{-2} s^{-1}$ (at E_{cm}=4GeV)

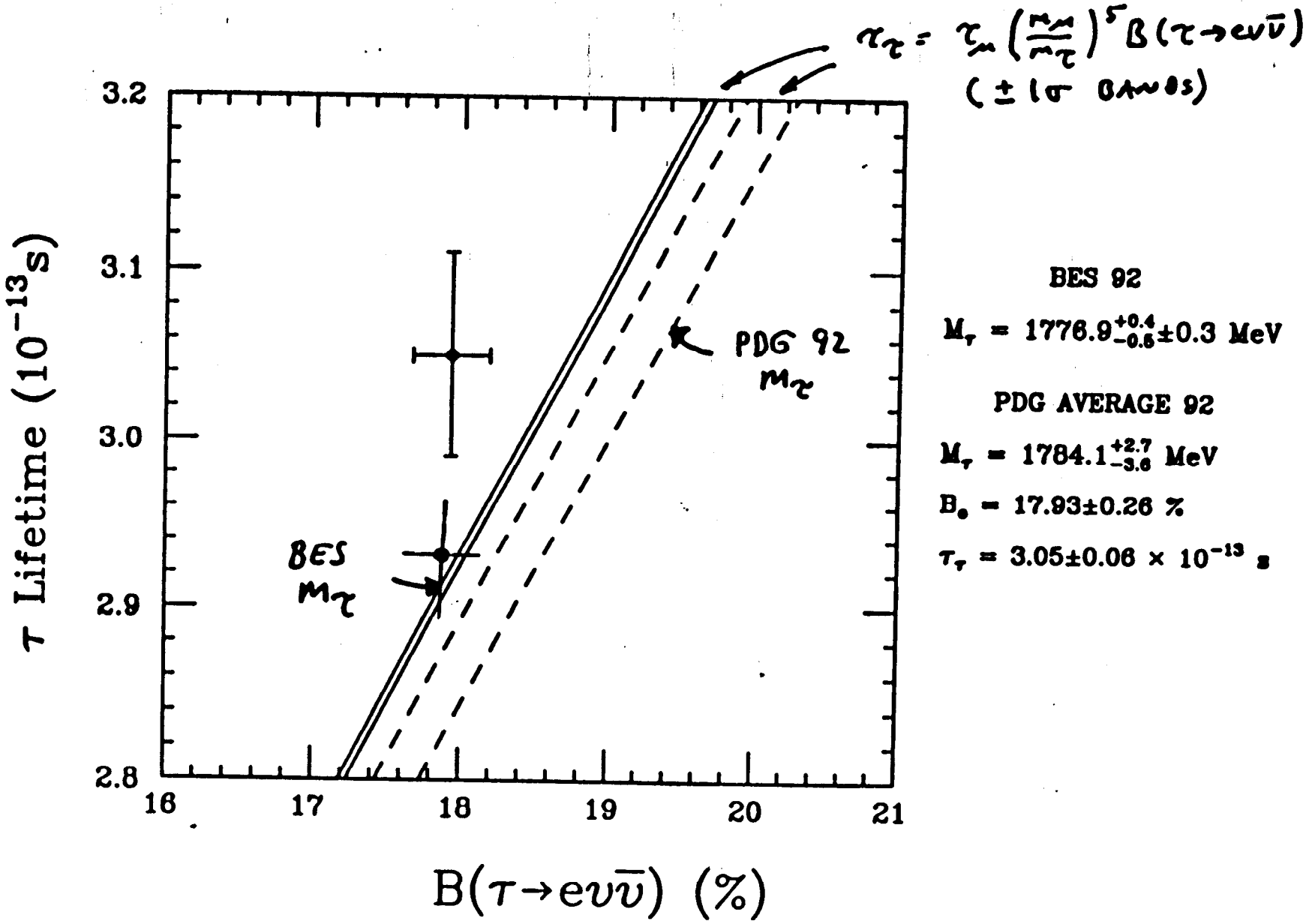
- The following data have been collected:

  $9 \times 10^6 J/\psi$ events,
  $1.4 \times 10^6 \psi'$ events, and
  25 pb^{-1} (at Ecm=4.03GeV) Ds & τ data.

- The precise tau mass measurement:

$$M_\tau = 1776.9 \pm 0.2 \pm 0.2 MeV$$

  Since the method of energy scanning at the tau pair production threshold (about 3.5 - 3.6 GeV) was used, only $5pb^{-1}$ of $\tau^+\tau^-$ data were collected, and high precision obtained. Comparing with the previous experiments at $\sqrt{s}$ ~10GeV, there were great advantages:


$\tau_\tau = \tau_\mu \left(\frac{m_\mu}{m_\tau}\right)^5 B(\tau \to e\nu\bar{\nu})$
($\pm 1\sigma$ BANDS)
3.2
3.1
3.0
2.9
2.8
16
17
18
19
20
21
τ Lifetime (10^{-13}s)
$B(\tau \to e\nu\bar{\nu})$ (%)
PDG 92
m_τ
BES
m_τ
BES 92
$M_\tau = 1776.9^{+0.4}_{-0.5} \pm 0.3$ MeV
PDG AVERAGE 92
$M_\tau = 1784.1^{+2.7}_{-3.6}$ MeV
$B_e = 17.93 \pm 0.26$ %
$\tau_\tau = 3.05 \pm 0.06 \times 10^{-13}$ s

ARGUS $M_\tau = 1776.3 \pm 2.8 MeV$, 341 pb^{-1} of data collected.

CLEO $M_\tau = 1777.6 \pm 1.7 MeV$, 1400 pb^{-1} of data collected.

BES $M_\tau = 1776.9 \pm 0.2 \pm 0.2 MeV$, $5pb^{-1}$ of data collected.

- Three pure leptonic decay events of D_s were observed. The weak decay constant f_{D_s} and the absolute branch ratio of $D_s \to \phi\pi$ were obtained:

  $f_{D_s} = 434 \pm^{153}_{133} \pm^{35}_{33}$ MeV
  $\mathrm{Br}(D_s \to \phi\pi) = (4.2 \pm^{9.0}_{1.5} \pm^{1.7}_{0.0} \pm 0.5)\%$

- The branch ratio of $\psi' \to \tau^+\tau^-$ was firstly measured.

- For the suppressed decay channel of $\psi' \to \rho\pi$, its new upper limit was given. And the preliminary analyses showed the decay channel of $\psi' \to \omega f_2$ is also suppressed.

D_s Pure Leptonic Decay Event Display

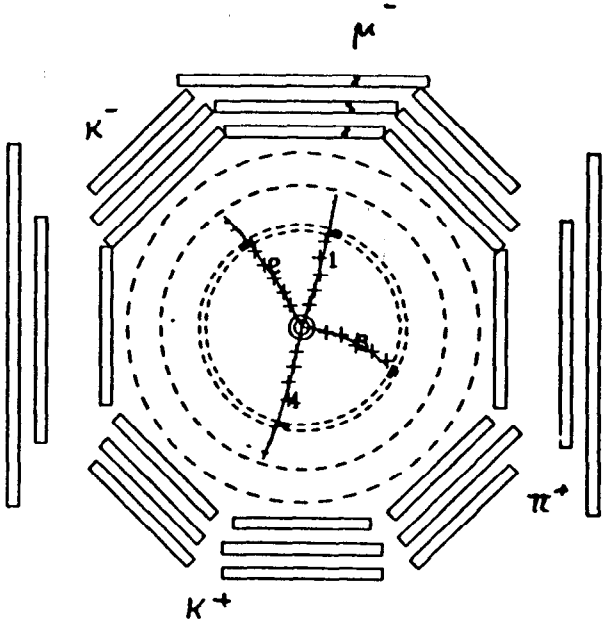
BES RECORD: 14523.RUN: 3273.CM ENERGY: 4.03GeV

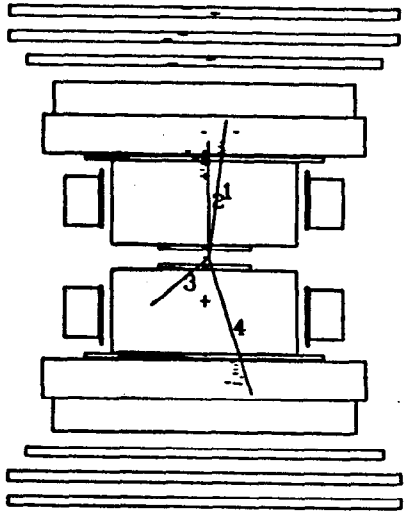
$e^+ e^- \rightarrow D_s^+ D_s^-$

$D_s^- \rightarrow \mu^- \nu$

$D_s^+ \rightarrow K^{*0} K^+$

$K^{*0} \rightarrow K^- \pi^+$





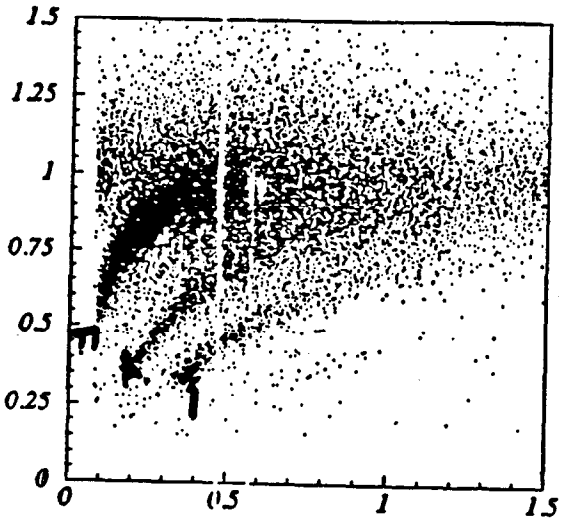
Beam Constrained Mass of $KK\pi$ = 1.971GeV/c^2

Square of Missing Mass = −0.1122 GeV^2/c^4

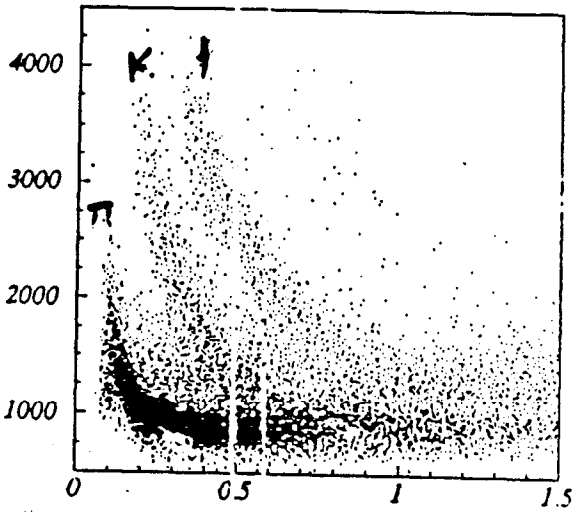
Comparison of Different Energy Collider

for f_{D_s} measurement

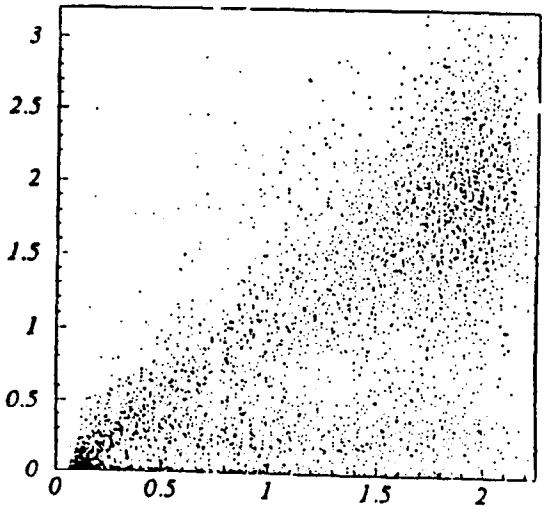
	$\sqrt{S} > 10GeV$	$\sqrt{S} \sim 4$ GeV
Br($\phi\pi$) dependent	yes	no
Model dependent	yes	no
D_s identification	can't tag	single tag
D_s^*	yes	no
b $\rightarrow$ c decay	yes	no
Mode	relative	absolute



BETA VS MOMENTUM



PHMP VS MOMENTUM



P vs E

- At the energy of $\sqrt{s}$=4.03GeV, the upper limit of ν_τ mass was determined from the decay channel of $\tau^- \to K^+K^-\pi^-\nu_\tau$,

  The comparison with another channel of $\tau \to 5\pi\nu_\tau$ is as following:

	$\tau^- \to K^+K^-\pi^-\nu_\tau$	$\tau \to 5\pi\nu_\tau$
Br	$(2.2\pm1.7)\times10^{-3}$	$(5.6\pm1.6)\times10^{-4}$
$Q = m_\tau - m_{had}$	0.6 GeV	1.0 GeV
$\bar{P}(\sqrt{s} \sim 10GeV)$	1.3 GeV	0.8 GeV
$\bar{P}(\sqrt{s} \sim 4GeV)$	0.5 GeV	0.3 GeV

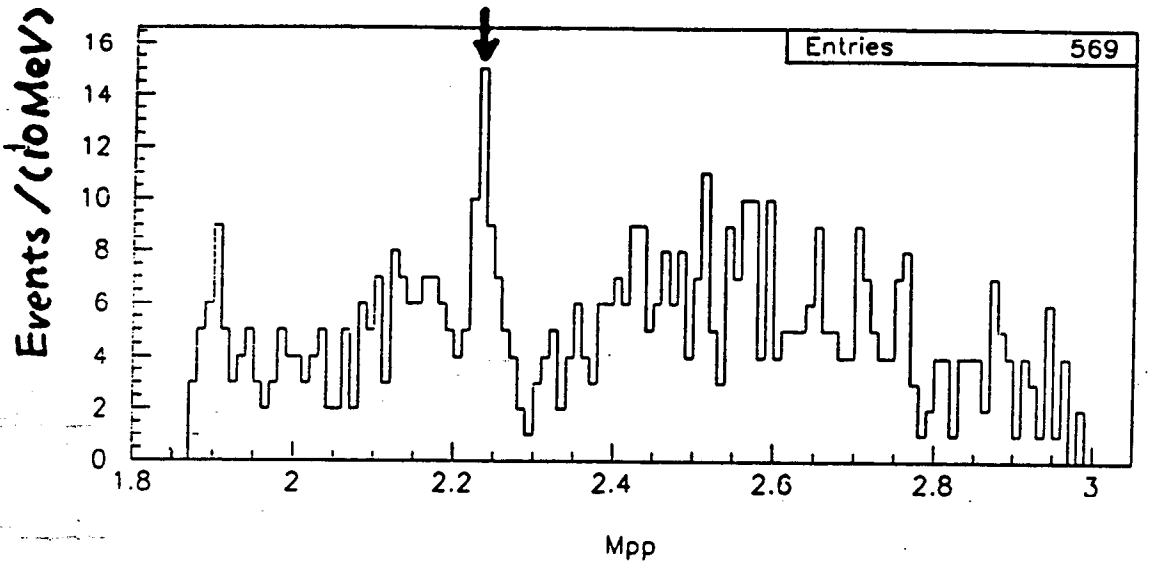
- J/ψ

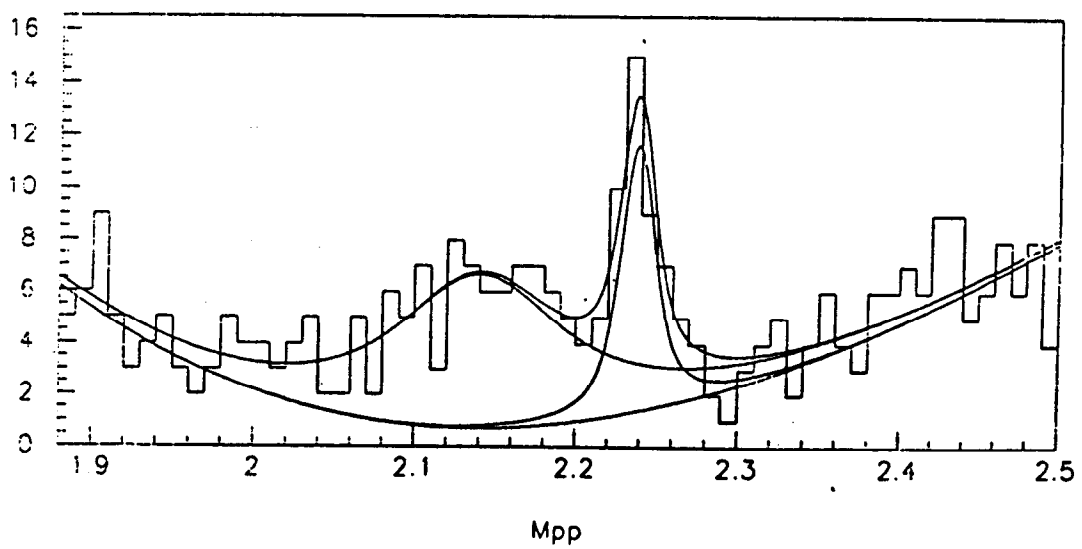
  The existance of $\xi(2230)$ was confirmed, and addition to the channel of J/$\psi \to \gamma K^+K^-$ and J/$\psi \to \gamma K_s^0 K_s^0$, and ξ was also observed in the channel of J/$\psi \to \gamma P\bar{P}$.

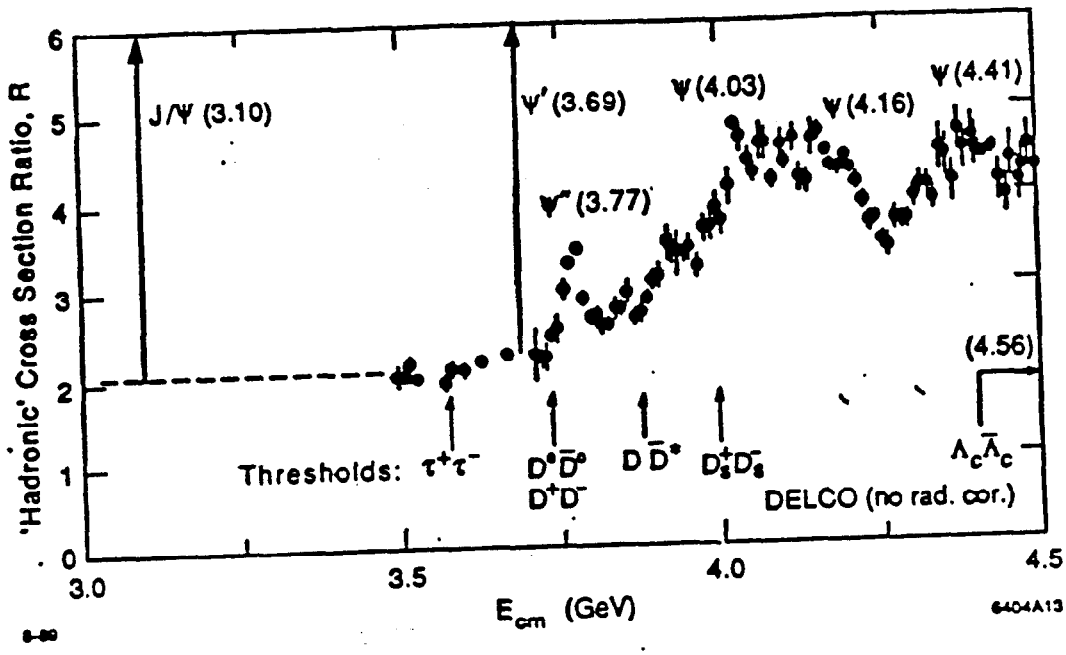
  The J^{pc} analyses suggested that $\theta(1720)$ has some structure.

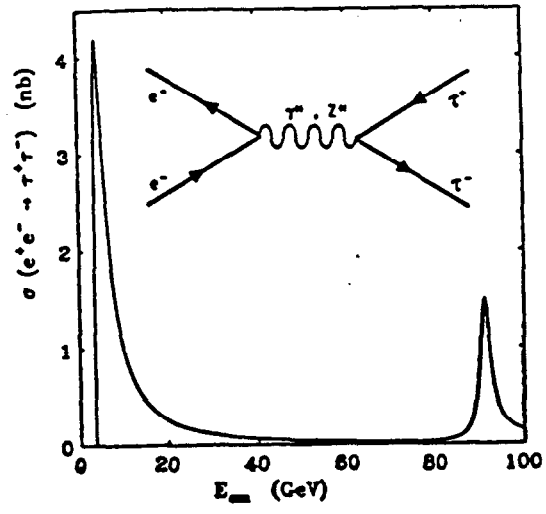
$J/\psi \to \gamma\, \xi(2230)$

$\hookrightarrow p\bar{p}$






'Hadronic' Cross Section Ratio, R
J/Ψ (3.10)
Ψ' (3.69)
Ψ (4.03)
Ψ (4.16)
Ψ (4.41)
Ψ'' (3.77)
(4.56)
Thresholds: τ+τ−
D°D̄°
D+D−
D D̄*
D+s D−s
ΛcΛ̄c
DELCO (no rad. cor.)
E_cm (GeV)
6404A13


σ (e+e− → τ+τ−) (nb)
e−
e−
γ*, Z*
τ−
τ−
E_cm (GeV)

- Although the above results were preliminary, they have shown the Tau, Charm and charmonium physics are so interesting and have advantages.

- Especially at the energy region of $\sqrt{s} = 3$ - 5 GeV, there are the resonance peaks of J/ψ, ψ', and ψ", the production threshold of $\tau^{\pm}$, D^0, $D^{\pm}$, and $D_s^{\pm}$, and the maximum production cross section of Tau and Charm.

- Operating near threshold compeletely excludes backgrounds from b quark.

- Backgrounds can be directly measured above or below threshold.

- The method of single tag could be used to reduce the background and biases.

- The small Lorentz boost would make the π/k/p seperation easier.

- J/ψ for calibration

- Above advantages are not available on the fix target experiment and the e^+e^- collider at high energy region ($\sqrt{s} \sim 10$GeV).

- To continue the research in the Tau, Charm, and Charmonium, τcF (Tau-Charm Factory) is a natural extension of BEPC, which meets the following requirements:

Precise test of Standard Model:

$$\sigma^2_{total} = \sigma^2_{stat} + \sigma^2_{sys}$$

1) Increase the machine luminosity so to decrease the statistical error,

2) Improve the performance of the machine and detector, so to decrease the systematic error.

Table 1: Mark III (J.Drinkard Ph.d.thesis)

J^{PC}	intermediate state	Mass (MeV)	Width (MeV)	B.R. (10^{-4})
0^{-+}	$a_0\pi$	1424 ± 10	39 ± 7	$6.8 \pm 0.8 \pm 1.4$
0^{-+}	K^*K	1476 ± 11	77 ± 23	$11.0 \pm 1.7 \pm 2.2$
1^{++}	K^*K	1445 ± 7	90 ± 27	$9.5 \pm 1.2 \pm 1.9$

Table 2: DM2 (G.Szklarz at HADRON 89)

J^{PC}	Intermediate state	Mass (MeV)	Width (MeV)	B.R. (10^{-4})
0^{-+}	K^*K	1421 ± 14	63 ± 18	$8.3 \pm 1.3 \pm 1.8$
0^{-+}	$a_0\pi$	1459 ± 5	75 ± 9	$18 \pm 2 \pm 3$
1^{++}	K^*K	1462 ± 20	129 ± 41	$7.6 \pm 1.5 \pm 2.1$

BES observed 3 states from 1.42 – 1.46 GeV.

Comparison between BES and τcF

	BES	τcF
σ_{m_τ} (MeV)	$\sim$ 0.3 MeV	$<$ 0.1 MeV
U.L. of m_{ν_τ} (MeV)	$\sim$ 31 MeV	$\sim$ 3 MeV
$\sigma_{f_{D_s}}$ (%)	$\sim$ 30%	1 $\sim$ 2%
σ_{f_D} (%)	-	1 $\sim$ 2%
σ_ρ (%)	-	$\sim$ 0.5%

3. The Consideration of the τcF Construction at IHEP

The physics goals of τcF:

$$\begin{pmatrix}\nu_e\\ e\end{pmatrix}\ \begin{pmatrix}\nu_\mu\\ \mu\end{pmatrix}\ \begin{pmatrix}\nu_\tau\\ \tau\end{pmatrix}$$

$$\begin{pmatrix}u\\ d\end{pmatrix}\ \begin{pmatrix}c\\ s\end{pmatrix}\ \begin{pmatrix}t\\ b\end{pmatrix}$$

- τ and ν_τ leptons.
- Charm hadrons ($D^0, D^\pm, D_s^\pm, \Lambda_c^\pm, \Sigma_c, \Xi_c, \Omega_c$, etc.).
- Charmonium ($J/\psi, \psi', \eta_c, \chi_c$, etc.).

1. Precision Tests of the Standard Model

Charm decays provide a unique laboratory to probe QCD quantitatively at the interface between the perturbative and non-perturbative regimes.

CKM matrix elements V_{cs}, V_{cd}.
m_τ, m_{ν_τ}, Michel parameter, f_D, f_{D_s}.
Light quark and gluonium spectroscopy.

2. New Physics Discovery Potential.

- $D^0 - \bar{D}^0$ mixing, CP violation in D decays.
- Rare $\tau, D, J/\psi$ decays, searches for decays outside the Standard Model.
- Evidences of glueballs and hybrid states.

Search for glueball and hybrid

BES	TCF
1×10^7 J/ψ	10^9 J/ψ
more knowledge on some Candidates of glueball	confirmation of glueball need much better statistic mass resolution particle ID Clear quantitative Criterion

$\theta(1720)$ two states 2^+, 0^+

$L(1440)$ tree states

$\xi(2230)$ $J/\psi \to \gamma \xi$
$\hookrightarrow K^+K^-$
$\{ K_S^0 K_S^0$
$p\bar{p}$

$J^{PC} = 4^+$

$G(1590)$

$X(1500)$ no observed in BES yet

The principle of τcF design:

1. The existing Spanish design (two rings + multi-bunches) is considered as valuable reference.

2. $E_{cm} = 3 - 6^{*}GeV, L = 1 \times 10^{33} cm^{-2} s^{-1}$.

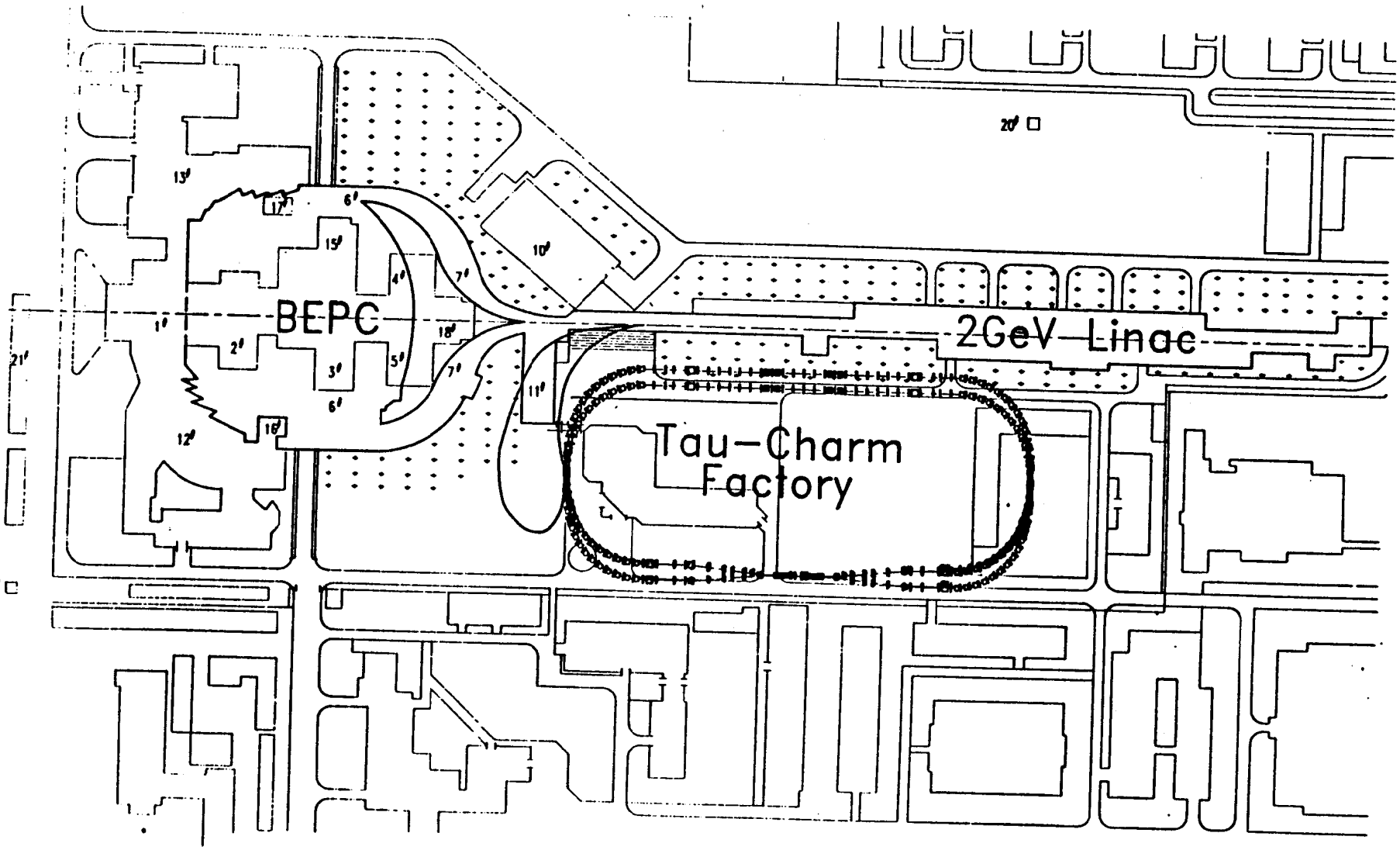
3. Using the monochromator scheme, beam energy spread = 0.1 MeV. (m_τ).

4. The requested circumference of τcF ring would be larger than that of the BEPC storage ring, so it must be re-constructed. (long straight section)

5. The BEPC LINAC can be used as the injector.

6. Consideration of polarized beam.

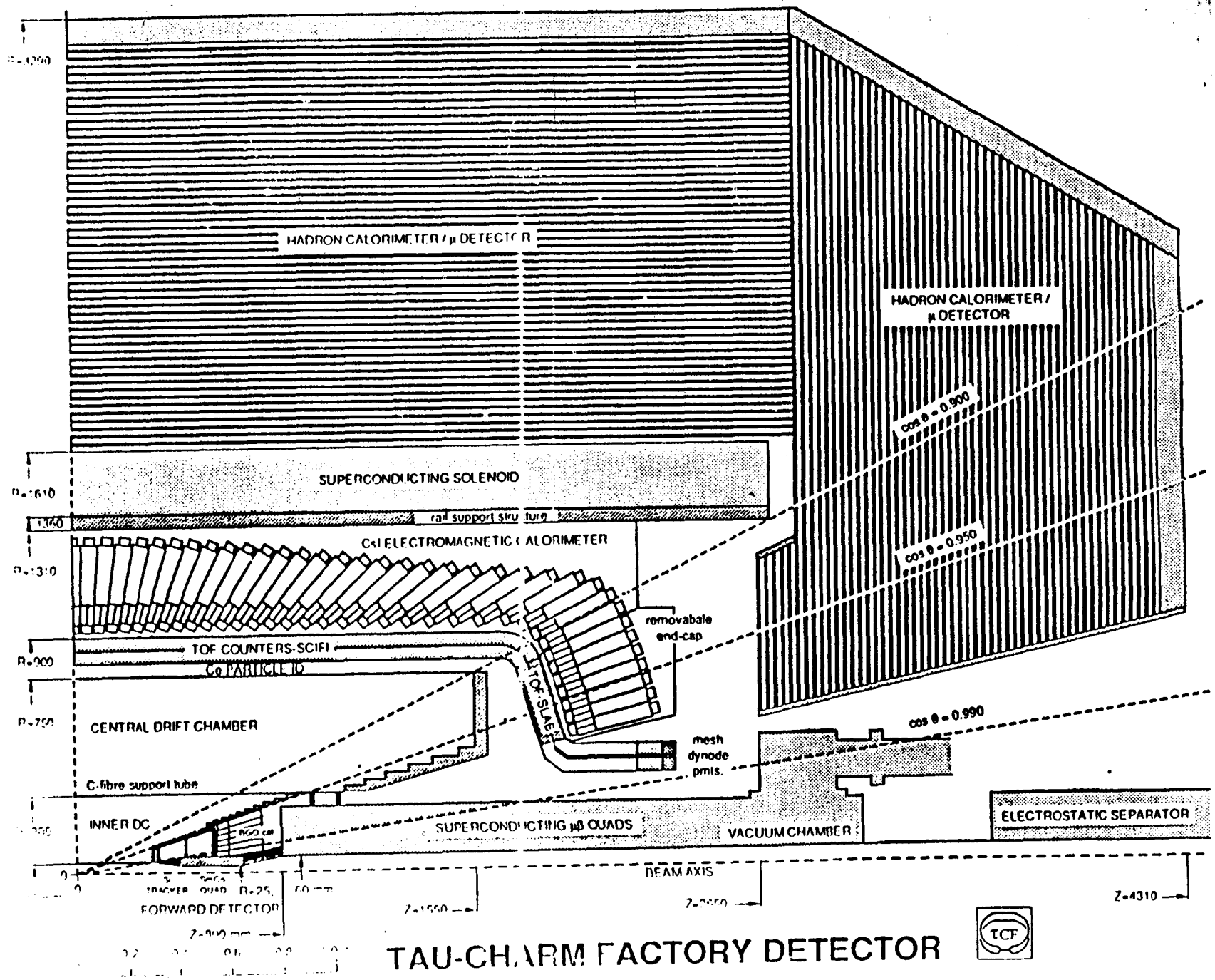
* 6 GeV is for production of heavy charmed baryon masses ($m_{\Omega_c} = 2.74 GeV$).



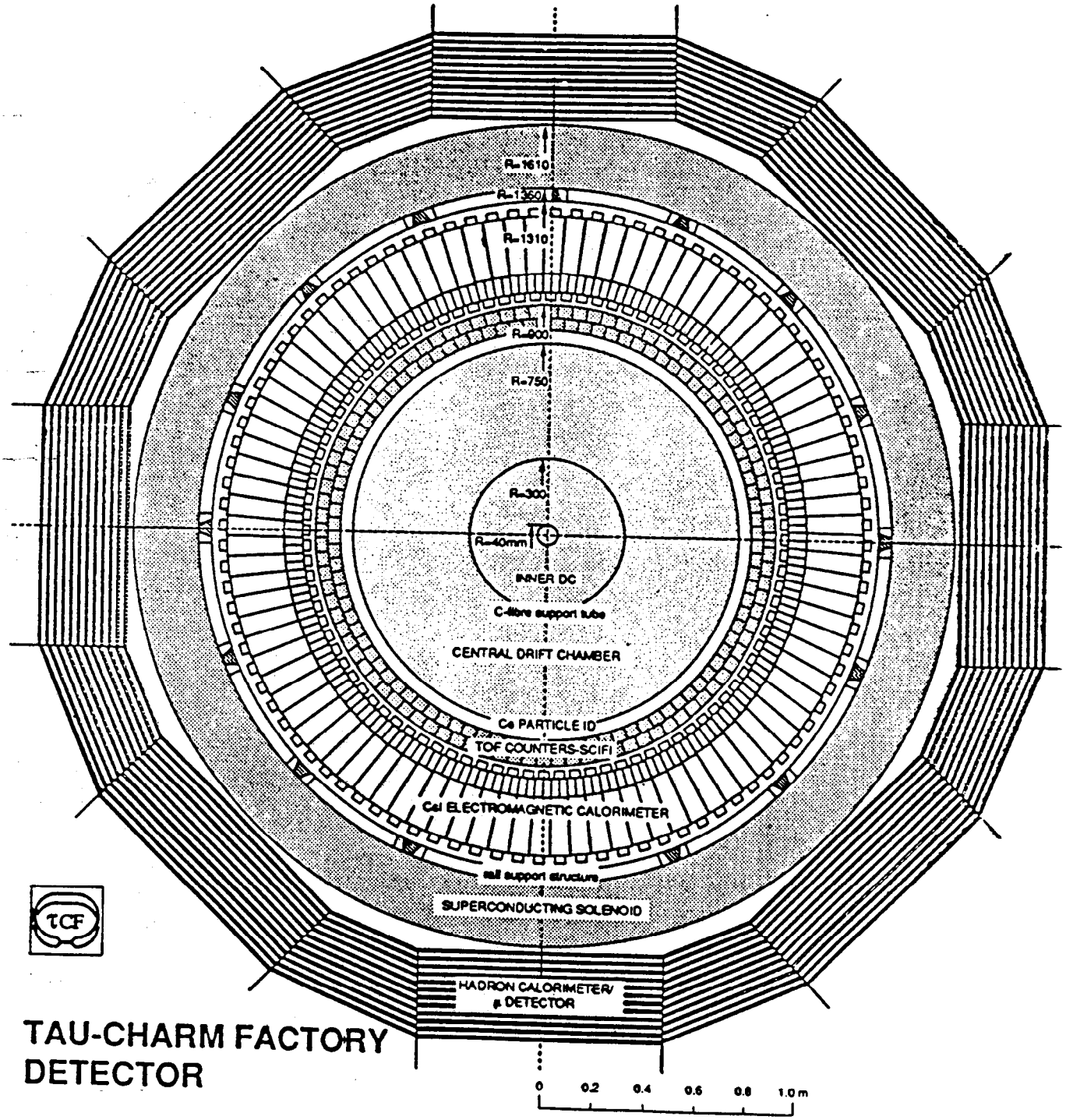
General layout of the TcF on BEPC site

The preliminary designed parameters of the τcF in Beijing:

Beam Energy:	E = 2.0 - 3.0 GeV
Circumference:	C = 367.5 m
β fuction at IP:	β_x^*/β_y^* = 0.2m / 0.01m
Dispersion at IP:	D_y^* = 0.0 m
Natural emittance:	e_x = 251 nm
RF frequency:	f_{RF} = 499.58 MHz
RF volage:	V_{Rf} = 9.00 MV
Number of banches:	k_b = 32
Bunch spacing:	S_b = 11.5 m
Total current/beam:	I = 500 mA
Luminosity:	L = $1 \times 10^{33} cm^{-2} s^{-1}$
CM energy spread:	σ_w = 1.53 MeV



TAU-CHARM FACTORY DETECTOR



TAU-CHARM FACTORY DETECTOR

Detector

1. Excellent Performance

- Momentum resolution: $0.4\% p \oplus 0.4\%/\beta$. Low material, 1.2T superconducting solenoid. (2%, BES)
- Energy (4K) resolution (CsI(Tl)): $2\%/E^{-\frac{1}{4}} \oplus 1\%$. (2%, BES
- Time resolution: 120ps. (330ps, BES

2. Full Solid Angle Acceptance and Good Hermeticity.

Barrel + forward detector $\Rightarrow$ 99% $\times$ 4π str.
EM + Hadron Calorimeter $\Rightarrow$ detectoion of neutral hadrons (K_L^0, n).

3. Excellent Particle Identification.

For π, K, P, TOF + dE/dX + RICH.
For e and μ, EM + Hadron Calorimeter. (μ detector)

4. High Rates Data Acquisition.

- Event rate 2 - 10 KHZ.
- Level 3 trigger.
- 2×10^4 MIPS to process a 2KHZ input event rate.
- 2×10^4 MIPS, offline processor.

- The preliminary cost estimation for the τcF in Beijing:

Civil construction (RMB):	170M
Storage Ring (RMB):	363 M
LINAC upgrade (RMB):	35 M
Detector (RMB):	300 M
Contigency (RMB):	100 M

Total cost: 968M RMB, or $109M.

Comparing the similar estimated cost from SLAC ($108M) and ANL ($125M).

- The proposal for τcF construction in China was already put forward to CAS at the beginning of this year.

  Created a research group — accelerator, detector, Monte Carlo

- There are favourable factors:

  1) We have had BEPC, the experimental HEP base in China, it's achievements are recognized by international HEP community.

  2) We have already a team on accelerator, experimental and theoretical physics. Their ability has shown in the smooth machine running, data analyzing, and BEPC/BES upgrading.

  3) Some of the existing linac, magnets, power supplys and test facilities can be used for τcF.

- There are also disadvantages:

1) The cost of 109 MUSD is a too big amount for China.

2) Generally to say, people in other scientific field don't support τcF. After the termination of the SSC, Some people said "Since the SSC has been killed even in the richest country as US, China has no reason to do HEP any more".

3) There are scientists, some of them are influential, consider that the work of τcF could actually done on B-Factory. Since two B-Factories are in construction, the necessity of τcF building needs to be proved.

- In the situation, what we'd do may follow such a strategy:

  1. The τcF construction had better be an international cooperation (e.g. a coo.-perative project in the Asia-pacific region). Then the cost could be shared by more than one side. And it'll be easier for Chinese goverment to agree to bear the expense.

  2. The Chinese scientists and leaders who make policy must be convinced. And the significance of HEP research should be further explained. HEP'll not only deepen people's fundamental knowledge to nature, but also promote the development of the whole science and technology, which has been proved by numerous facts in history and the time (e.g. the synchrotron radiation application).

  3. The reason for SSC termination should be correctly interpreted as to be due to the situation of USA, rather than any

meaning of HEP dead way. High luminosity machines are still under construction in the world, and to be the promising tendency of HEP development.

4. The B-Factory can't replace τcF, which I have commented in previous pages of the report. Especially it can't cover τcF's advantages in Tau Charm physics. B-Factory has of course its own merit. They are complementary rather than replaceble each other.

- The possible schedule for τcF construction in China is:

  1994-96 BEPC upgrading, to the luminosity of $1.5 \times 10^{31} cm^{-2} s^{-1}$ (near 3 times of the present $6 \times 10^{30} cm^{-2} s^{-1}$).

  1997-99 τcF R & D

  2000-04 τcF construction, to the luminosity of $1 \times 10^{33} cm^{-2} s^{-1}$.

Upgrade II

BEPC

- $L = 1 \times 10^{32} cm^{-2} s^{-1}$.
- One ring.
- Mini-β + multi-bunches + new lattices.

BES

- CsI(Tl) (or BGO) calorimeter.
- New TOF.

Advantages:

More practical, it is easier to be accepted by the government.

Disadvantages:

Less competitive.

IHEP Tau-charm Factory R&D plan
accelerator aspect
1995 - ?

Some key points:

Theoretical issues

- single-bunch and multi-bunch instabilities
- beam-beam effects with a large dispersion at IP
- possibility of the Crab-crossing scheme

Hardware issues

- superconducting magnet
- superconducting RF cavity (including HOM-damper and feedback system)
- specific wiggler (Robinson wiggler)
- separator and fast kicker
- high precision survey & alignment
- impedance control

Summary

- BEPC/BES has progress since 1988.
- Construction of τ-Charm Factory in China is a logic extension of BEPC.
- τ-Charm physics is a very important field in HEP.
- τ-Charm Factory is a best facility to study τ-Charm physics. It has many advantages: there are resonances and thresholds to make systematic error small. B Factory and τ-Charm Factory are complementary rather than replaceable each other.
- International cooperation is one of the key points to increase the possibility of τcF projects to be approved.
- Need more efforts for τcF project.