Summary of the Marbella TCF Workshop

Jasper Kirkby
SLAC TCF Workshop
16 August 1994

- Third Workshop on the Tau-Charm Factory, Marbella, Spain, 1-6 June 1993:
  - Previous workshops in this series: SLAC 89, Sevilla 91.
  - 90 physicists from 12 countries.
  - Proc. (Editions Frontières, 1994): 65 papers / 850 p.

- Aims:
  - Thorough review of physics interest in light of recent theoretical and experimental progress.
  - Update designs of accelerators & detectors.
  - Discuss plans for realization of TCF.

Overall Marbella Conclusions

- The TCF is:
  - A vital machine to probe precision EW in τ decays.
  - The "QCD machine for the next decade".
- Physics strengths of the TCF:
  - Comprehensive precision study of τ and charm decays.
  - Potential exists for major discoveries.
- TCF and BF:
  - Similar statistics but TCF generally has lower backgrounds and systematic errors.
  - Complementary. Full exploitation of BF physics potential requires precision charm data from TCF.
  - Precision measurements are difficult and need confirmation by experiments with different systematics.
- Highly-flexible TCF collider is feasible: higher L, monochromator optics, longitudinal beam polarization.
- High-resolution detector is feasible and meets physics needs.

Progress in Particle Physics

Requires parallel experiments at:

I. High-energy frontier

- Search for new particles and interactions.

II. High-precision frontier

- CP violn. / precision studies of present quarks & leptons.
  - Strengthen experimental foundations underpinning SM
  - Search for rare processes / subtle deviations from SM

The SM needs both consolidation and extension.

Approved Next-Generation Accelerators (≥ 2000)

	DAΦNIA	TeV M.I.	KEK BF SLAC BF	RHIC	LHC	(TCF)
I. High-energy frontier						
1) Higgs + new particles	-	★	-	-	★★	-
2) Quark-gluon plasma	-	-	-	★★	★★	-
II. High-precision frontier						
1) CP violation: B	-	★	★★	-	★★	-
D	-	-	-	-	-	★
K	★★	★★	-	-	-	-
2) Precision electroweak & precision QCD:						
W,Z	-	★	-	-	★	-
b	-	-	★★	-	-	-
c	-	★	★	-	-	★★
τ	-	-	★	-	-	★★
g, u, d, s (spectr.)	-	-	-	-	-	★★
ν	-	★	★	-	★	★

Conclusions on Next-Generation Accelerators

- The TCF is:
  - Complementary to the approved accelerators.
  - An essential component of the next experimental tools required for the high-precision frontier of the SM.
  - Arguably the most important accelerator still to be approved (considering the LHC as approved).
- The key question:
  - ➢ Are the presently-approved accelerators (KEK BF, SLAC BF and TeV M.I.) ★ or ★★ for the important τ and c experiments?

TCF Physics Reach vs. Luminosity (1 y data)

- 10^{32}
  - ➤ glueballs, hybrids, uds & $c\bar{c}$ spectroscopy
  - ➤ semi-leptonic D decays ~1% precision
  - ➤ τ Br's ~0.1% precision
  - ➤ $\Lambda_c^{\pm}$, Ξ_c, Σ_c, Ω_c Br's ~5% precision
  - ➤ doub. Cab. sup. D^0, $D^{\pm}$, D_s decays ~1% precision
- 10^{33}
  - ➤ V-A structure in τ decays ≡ precision in μ decay
  - ➤ pure leptonic D decays, f_D & f_{Ds} ~2% precision
  - ➤ τ->eX limit ~10^{-5}, constraints on $m(\nu_\tau)$<1 MeV
  - ➤ $D^0\bar{D}^0$ mixing limit 2×10^{-5} (SM level?)
  - ➤ rare τ/D/J-ψ decays (LFV, FCNC, etc.) ~10^{-7}-10^{-8}
  - ➤ direct $m(\nu_\tau)$ limit ~2 MeV
  - ➤ CP violation in D decays at SM level
  - ➤ CP violation in Λ, Ξ decays at SM level
- 10^{34}
  - ➤ ??

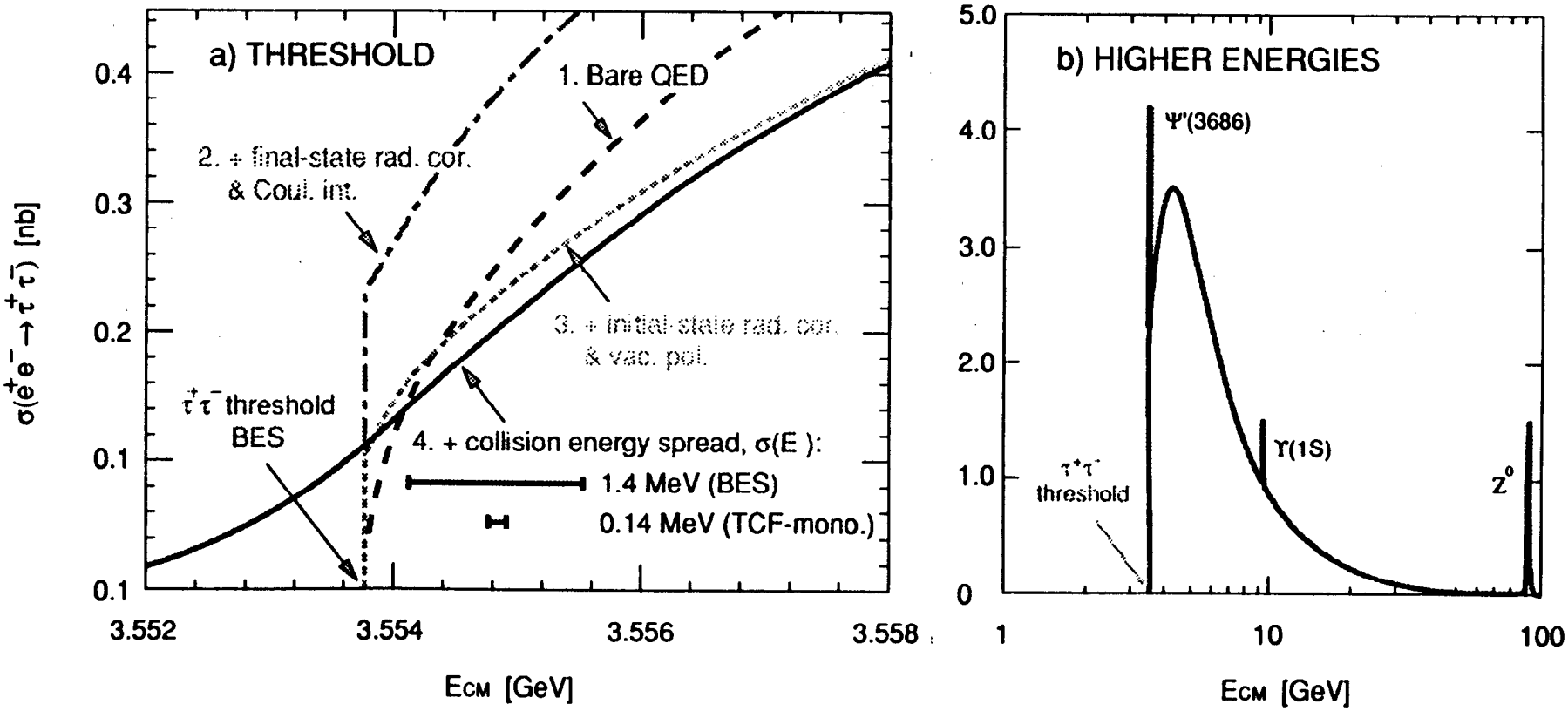
Interest in τ Physics

- Third generation lepton.
- Highest-mass lepton => highest sensitivity to New Physics
- Many decay channels; some can be calculated with high precision in SM.
- Only lepton heavy enough to decay to hadrons.
- Clean laboratory to test structure of the weak current.
- Properties of ν_τ are poorly known experimentally.

Experimental Environment for τ Physics

- Single-tagged samples (e.g. E_{miss} + e / monoch. π):
  - Reduced biases (no pre-selection of decay mode).
  - Exact flux normalization.
- Very small backgrounds (<0.1%) below c threshold.
- Backgrounds experimentally measured below τ thresh.
- Small Lorentz boost: monoch. 2-body, less overlap, etc
- High statistics (similar to BF with $L_{BF} = 3 \times L_{TCF}$):
  - 0.5×10^7 / yr at $\tau^+\tau^-$ threshold.
  - 2.4×10^7 / yr just below ψ' (zero charm background).
  - 10×10^7 / yr at ψ' (monoch. optics).
- High-resolution detector, with novel sensitivity to ν's.
- High-rate (~1kHz) det. calibration sources: J/ψ and ψ'.

The $\tau^+\tau^-$ cross section



Expected improvements for some τ parameters.

Parameter	Present accuracy	τcF sensitivity
m_τ	0.3 MeV	30 keV
m_{ν_τ}	< 31 MeV	2 MeV
$B_{e,\mu}$	1%	0.1%
B_π	3%	0.1%
B_K	34% (12%)	0.5%
$\lvert g_\tau/g_\mu \rvert$	0.6%	0.1%
$\lvert g_\mu/g_e \rvert$	0.6%	0.1%
$\rho_{e,\mu}$	$\pm 45 \times 10^{-3}$	$\pm 2 \times 10^{-3}$
ξ_l	$\pm 200 \times 10^{-3}$	$\pm 35 \times 10^{-3}$
h_{ν_τ}	22%	0.3%
η_μ	–	$\pm 4 \times 10^{-3}$
δ_l	–	$\pm 28 \times 10^{-3}$
ξ'_μ	–	15%
$B(\tau^- \to \pi^- \eta \nu_\tau)$	$< 3 \times 10^{-4}$	10^{-6}
$B(\tau^- \to l^- X)$	$< 2\%$	10^{-5}
$B(\tau^- \to 3l^\pm)$	$< 10^{-5}$	10^{-7}
$B(\tau^- \to \mu^- \gamma)$	$< 4 \times 10^{-6}$	10^{-7}
a_τ^γ	< 0.1	0.001
d_τ^γ	$< 6 \times 10^{-16}$ e cm	10^{-17} e cm

Michel parameters comparison: τ (τcF) vs. μ decay [$\times 10^{-3}$].
(W. Fetscher and A. Stahl.)

	$\tau^- \to e^- \bar{\nu}_e \nu_\tau$	$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$	$\mu^- \to e^- \bar{\nu}_e \nu_\mu$
ρ	± 2.2	± 2.3	751.8 ± 2.6
η	± 620	± 3.5	-7 ± 13
ξ	± 35	± 35	1003 ± 8
δ	± 27	± 28	749 ± 4

Precision Tau Branching Ratios

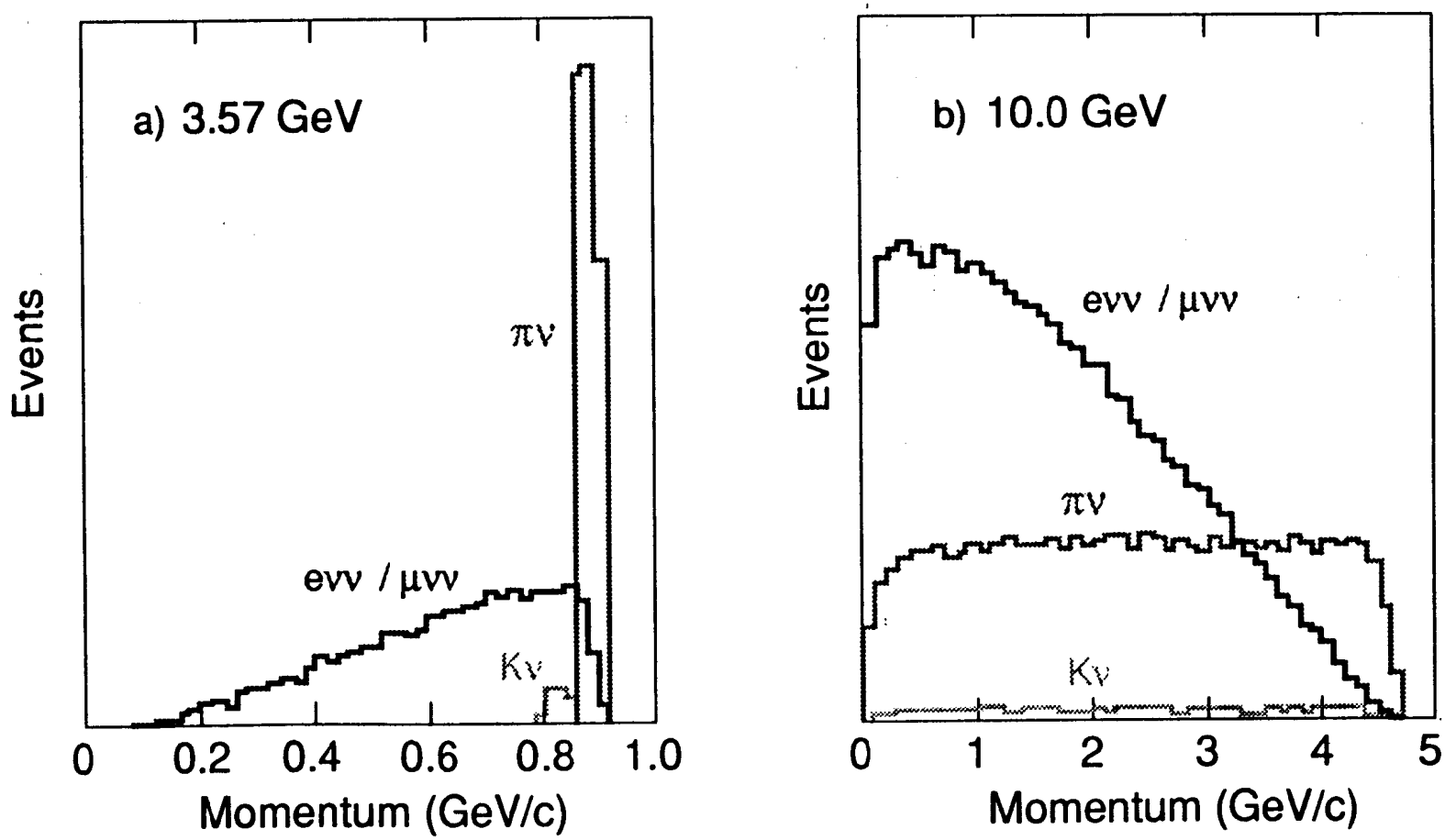
- Systematic errors are already dominating the main τ Br's, e.g. the $\rho\nu$ decay, Br($\tau \rightarrow h^{\pm}\pi^{0}\nu_{\tau}$):

	$\#\tau^{+}\tau^{-}$	Acc.	Bgd	Br	σ(stat.)	σ(syst.)
CLEO II	1.4 M	10%	5%	25.87±0.12±0.42%	0.5%	1.6%
OPAL	27 k	50%	6%	26.25±0.36±0.52%	1.4%	2.0%

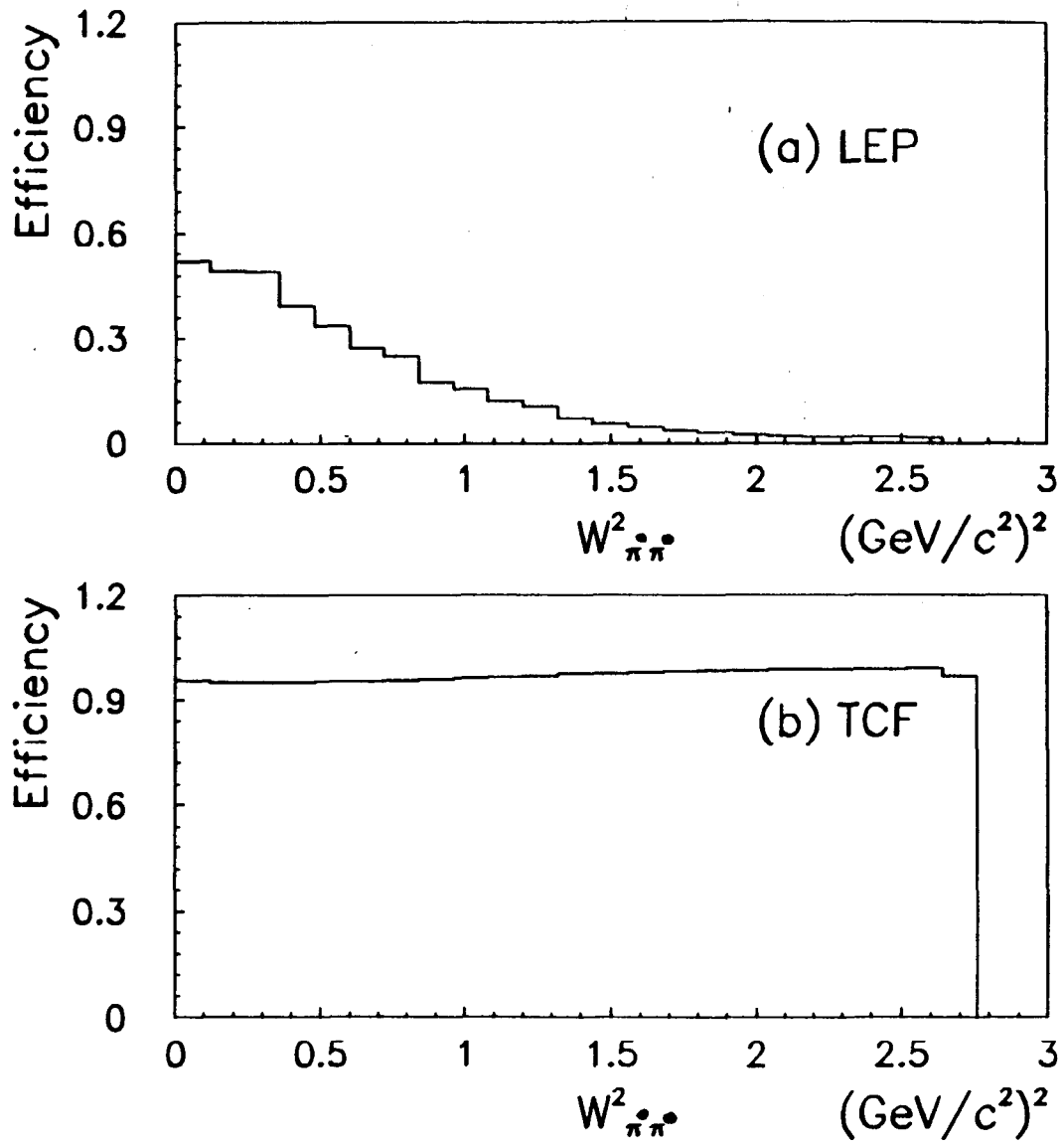
- TCF: estimated stat. & syst. errors ~0.1% for main τ decays:
  - Run exactly at $\tau^{+}\tau^{-}$ threshold—3.55 GeV.
    - ➢ Single-tag (E_{miss} + e / monoch.π):

      => No L error, no bias on τ decay mode.
  - One-prong decays separated kinematically.
  - High reconstruction efficiency.
  - Low feed-in corrections due to pileup.
  - Non-τ backgrounds measured experimentally at 3.54 GeV.
  - High resolution detector.
  - Direct, precision measurements of $\tau \rightarrow KX$ modes.

$\tau \rightarrow$ 1-prong + 0γ decays at a) TCF and b) BF.



Reconstruction efficiency as a function of the $\pi^0\pi^0$ invariant mass, for $\tau^\pm \to \nu_\tau \pi^\pm \pi^0 \pi^0$ events in (a) an idealized LEP experiment and (b) the τcF. (F. LeDiberder)



ν_τ Mass; Direct Measurement

(D.F Cowen, J.J. Gomez Cadenas)

- Measure end-points of $5\pi^\pm$, $3\pi^\pm 2\pi^0$, $K^+K^-\pi^-$ spectra.
- Statistical limit $\propto \sigma(5\pi) / \sqrt{N}$
  - $\sigma(5\pi)$ = 2 MeV (TCF); 3.5 MeV (BF).
  - $m(\nu_\tau)$ statistical limit ~ 2 MeV for both TCF and BF.
- Systematics - backgrounds - likely to dominate measurement:
  - Sensitive to bgd evs near end-point: lower limit / mask finite $m(\nu_\tau)$.
  - Before cuts: signal/bgd ~ 10^{-4}.
  - After cuts: signal/bgd ~ 10^4, i.e. ~10^{-8} $q\bar{q}$ rejection.
  - Reliability of M/C at 10^{-8} level?
- Most serious background is charm (~m_τ) with missing/misid. particles.
- CLEO:
  - 1.8M $\tau^+\tau^-$; $m(\nu_\tau)$<32.6 MeV based on 113 signal ev; ~1 charm bgd.
  - $5\pi^\pm$ acceptance= 7%
- TCF:
  - Zero charm background.
  - Backgrounds measured experimentally below $\tau^+\tau^-$ thresh

ν_τ Mass; Indirect Measurement

(J.J. Gomez Cadenas, C. Gonzalez-Garcia)

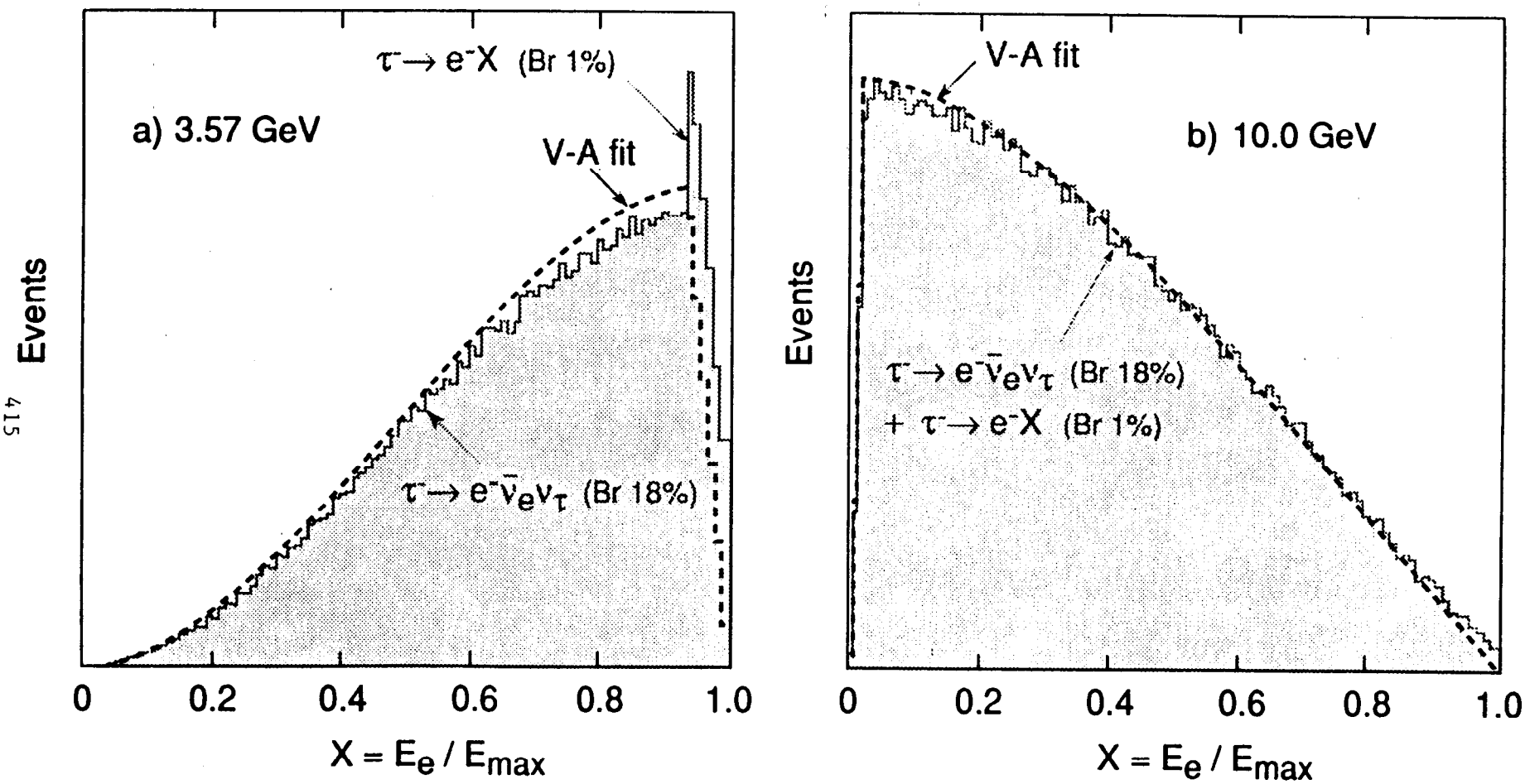
- If $m(\nu_\tau) > 100$ eV, ν_τ must be unstable.

- Possible decay:
  - $\nu_\tau \rightarrow \nu_e X$ => $\tau \rightarrow eX$ would also occur.
  - $Br(\tau \rightarrow eX)$ may be in the range $\leq 10^{-4}$.

- Experimental sensitivity:

	$Br(\tau \rightarrow eX)$ limit
BF:	5×10^{-3}
TCF: no monoch.	10^{-5}
with monoch.	10^{-6}

Rare τ decay, τ -> eX at a) TCF and b) BF.



Interest in Charm Physics

- Precision quantitative tests of QCD in a unique regime at interface of perturbative & non-perturbative regions:
  - Charm is tightly constrained in SM.
  - Quantitative theoretical treatments of charm decays are now possible (QCD sum rules, HQ expansions, QCD lattice).
- Input for precision beauty (and Z, etc.) analyses:
  - Test and calibrate theoretical tools, e.g. V_{td}/V_{ts} from $B \to \rho\gamma/K^*\gamma$ needs $D \to K^*\gamma$ (Br~10^{-5}) to measure non-penguin part.
  - Poor charm data (Br's, s.l. decay spectra,...) beginning to limit *present* precision LEP/CESR measurements.
- New physics discovery potential:
  - $D^0\bar{D}^0$ mixing*, CP violation, rare decays, etc.
  - Only heavy up-type quark accessible to precision experiments.
  - Rich variety of weak decays (CA,CS,DCS, 2nd-order W).

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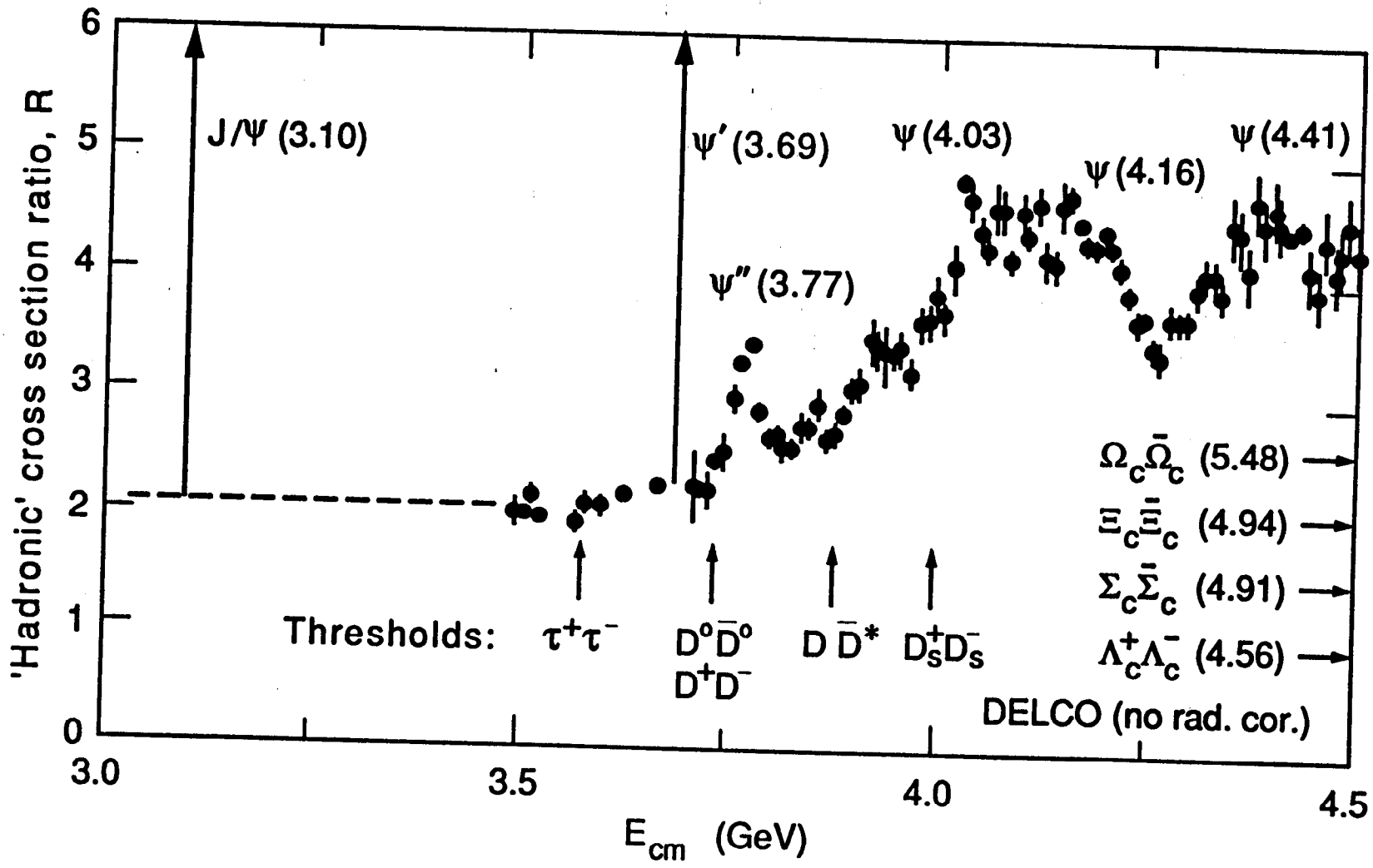
* New calc: small long-dist. contr. => D^0D^0 mixing v.sensitive to New Physics?

Experimental Environment for Charm Physics

- Tagged samples of D^0, $D^\pm$, $D_s^\pm$, $\Lambda_c^\pm$, Ξ_c, Σ_c, Ω_c:
  - Reduced biases (no pre-selection of decay mode).
  - Precise measurement of E (E_B) and $\vec{p}$.
  - Kinematic constraint on one missing particle (e.g. ν).
  - Reduced backgrounds:
    - Very clean tag.
    - Absence of additional jet particles / no combinatorial bgds).
  - Exact flux normalization (absolute Br's).
- Backgrounds experimentally measured by reducing E_B.
- High statistics: (TCF ~ 3 x BF *inclusive* with L_{BF}= 3 x L_{TCF}):
  - $D_s^\pm D_s^\pm$, $D^\pm D^\pm$, $D^0\bar{D}^0$ 10-30M / y
  - $\Sigma_c\Sigma_c$, $\Lambda_c^\pm\Lambda_c^\pm$ 1-3M / y
  - $\Xi_c\Xi_c$ 300k / y
  - $\Omega_c\,\Omega_c$ 30k / y

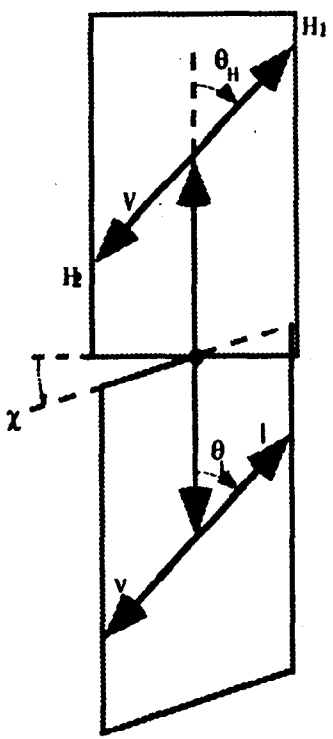
The energy range of the TCF



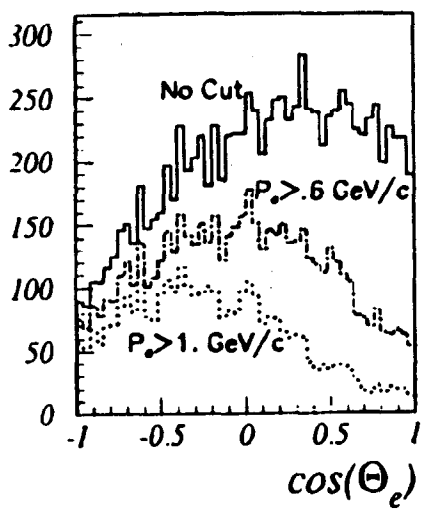
Expected improvements for some charm parameters.

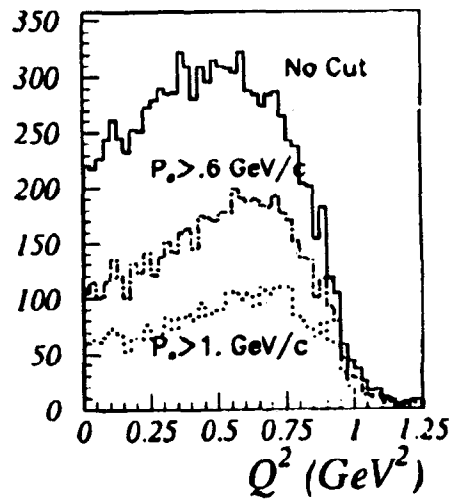
Parameter	Present accuracy	τcF sensitivity / 1 year's data
D^0, $D^\pm$, $D_s^\pm$ Br's	10%–30% (60%–80% observed)	0.1%–0.3% (~100% observed)
$\Lambda_c^\pm$ Br's	20%	1%
Σ_c, Ξ_c, Ω_c Br's	–	3–10%
D Br's (DCS)	30% ($D^0 \to K^+\pi^-$)	1%
Semileptonic D Br's (CA)	10%–20%	0.3%
Semileptonic D Br's (CS)	15%	1%
$\lvert V_{cd} \rvert / \lvert V_{cs} \rvert$	15%	1%
Pure leptonic Br's ($D \to \mu\nu, \tau\nu$); f_D, f_{D_s}	seen	2%
Rare D decay Br's	$< 10^{-5}$–10^{-4}	$< 10^{-7}$
$D^0\bar{D}^0$ mixing	$< 3 \times 10^{-3}$	2×10^{-5}
Direct CP violation in D decays	–	2×10^{-3} Br asym. (reaches SM level)

$D^0 \to K^* e\nu$ form factors, at a) BF and b) TCF (P. Roudeau)

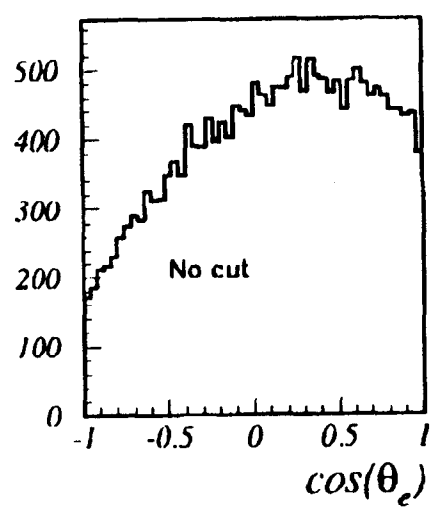


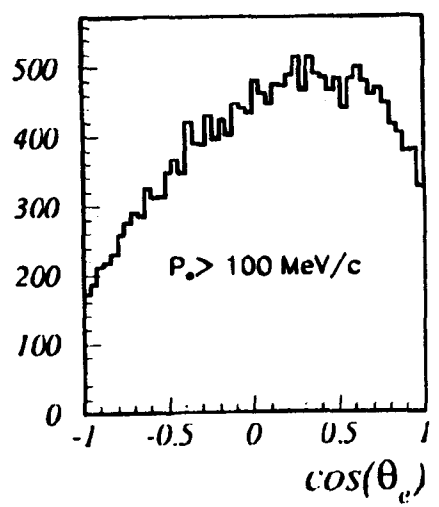
a) BF
(10 GeV)





a) TCF
(4 GeV)





Semileptonic D decays in different experiments.

Decay channel	Experiment	Technique	No. signal evts	Background	
$D^0 \to K^- \ell^+ \nu_\ell$	MARK III	$\bar{D}^0$ tag at $\psi''(3.77)$	55	1 %	MkIII
	E691	Secondary vertex	250	20 %	PHOTOPRODUCTION
	E687	Secondary vertex	1800	30 %	PHOTOPRODUCTION
	E653	Secondary vertex	80	20 %	HADROPRODUCTION
	CLEO	$D^{*+} \to D^0 \pi^+$ tag	800	70 %	CLEO
$D^0 \to \pi^- \ell^+ \nu_\ell$	MARK III	$\bar{D}^0$ tag at $\psi''(3.77)$	7	7 %	MkIII

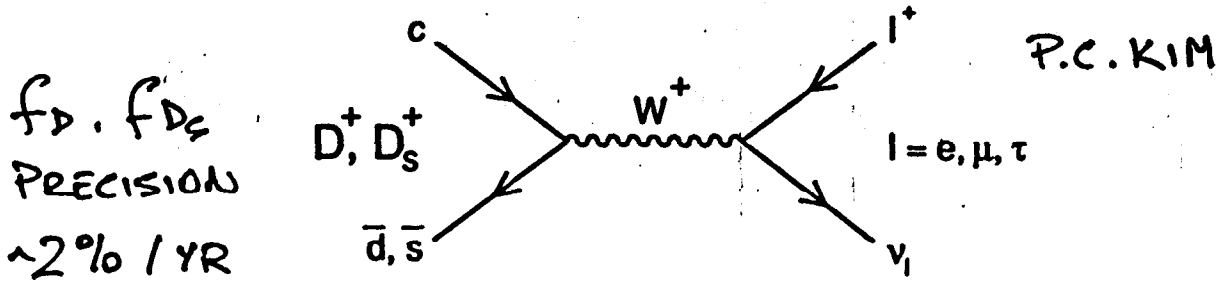


Figure 8: Pure leptonic $D^{\pm}$ or $D_s^{\pm}$ decay diagram.

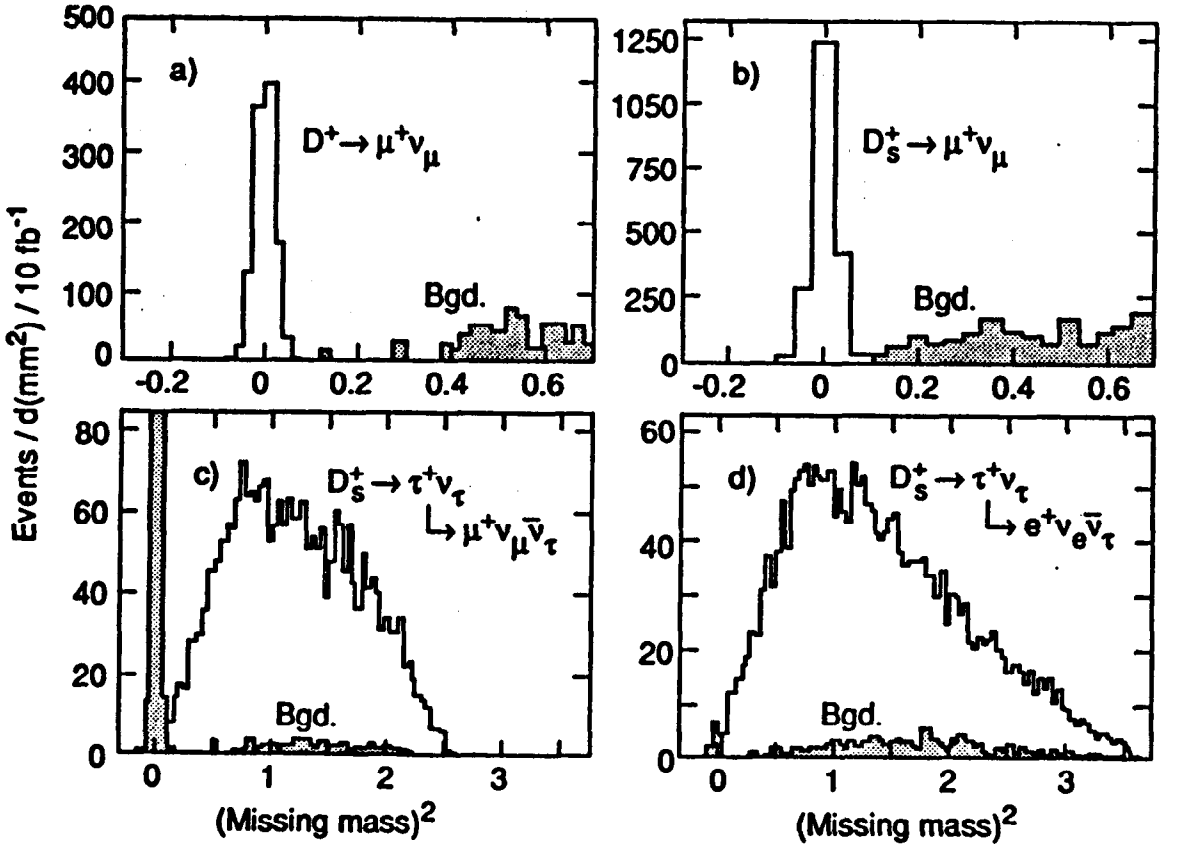


Figure 9: Measurement of pure leptonic D decays in the τcF detector[63]. Missing masses in single-tagged events are shown for: a)$D^+ \to \mu^+\nu_\mu$ ($\simeq$ 1100 events per year); b)$D_s^+ \to \mu^+\nu_\mu$ ($\simeq$ 2000 events per year); c)$D_s^+ \to \tau^+\nu_\tau$, $\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$ ($\simeq$ 2000 events per year); and, d)$D_s^+ \to \tau^+\nu_\tau$, $\tau^+ \to e^+\nu_e\bar{\nu}_\tau$ ($\simeq$ 2400 events per year). The indicated statistics correspond to 10 fb^{-1} ($L = 10^{33}$ cm^{-2}sec^{-1}) and $f_D \simeq 200$ MeV. The background events are shaded.

CP violation in D decays for 1 year's data in a τcF.
(J.R. Fry and T. Ruf)

DIRECT CP VIOLATION		
$A = \frac{N(\overline{D} \to \overline{f}) - N(D \to f)}{N(\overline{D} \to \overline{f}) + N(D \to f)}$		
channel	Theory* $A[10^{-3}]$	Experiment $\sigma_A[10^{-3}]$
$D^+ \to \bar{K}^{*o}K^+$	2.8 ± 0.8	2.3
$D^+ \to \pi^+\eta$	-1.5 ± 0.4	2.3
$D^0 \to K^+K^-$	$\sim 10^{-3}$	2.5
$D^+ \to \pi^+\pi^0$	0	2.8
$D^+ \to \phi\pi^+$	0	2.4

*** Rome-Naples (A. Pugliese et al.)**

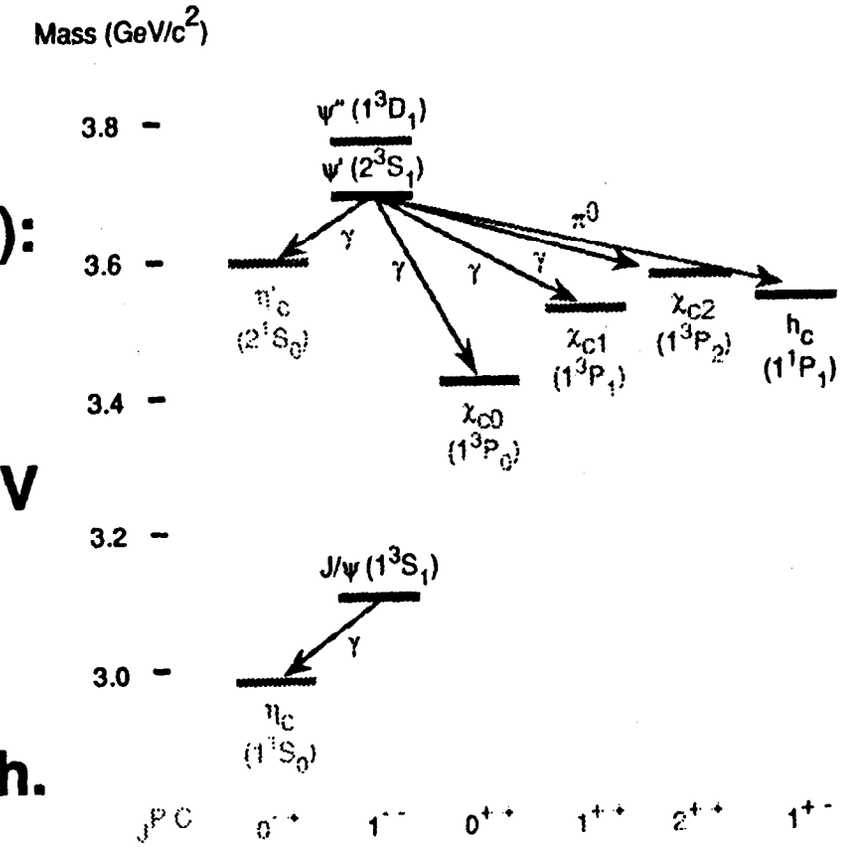
INDIRECT CP VIOLATION		
channel	Theory $A[10^{-3}]$	Experiment $\sigma_A[10^{-3}]$
sum of several final states	0.1–0.01	2

Interest in Charmonium

- Complete the narrow $c\bar{c}$ states below DD threshold:
  - Precision masses and widths.
  - EM couplings: γ, $\gamma\gamma$, e+e-
  - Hadronic decays.
- Clarify $c\bar{c}$ states above DD threshold:
  - e.g. $^1D_2$: $\psi^* \rightarrow \gamma\,(2^{-+})$ @ E_{cm}= 4.03 GeV (10^3 evs/day)
  - Measure DD, DD*, D*D*, DD** etc. production vs. E_{cm} - test HQET and find optimum operating points.
- Complete the low-mass hadron spectroscopy:
  - u,d,s hadrons.
  - Glueballs and hybrids.
- Study hybrid charmonium, H_c ($c\bar{c}g$); expect m=4.4±0.4 GeV.
  - Important test of lattice QCD, MIT bag, flux-tube models.
- J/ψ is secondary factory of cleanly-tagged light hadrons:
  - CP violation in Λ, Ξ decays.
  - C violation in η, η' decays.
- Rare decays, e.g. $J/\psi \rightarrow D_s e\nu$, Br ~$10^{-8}$

Experimental Environment for Charmonium

- All narrow charmonium states cleanly accessible, directly or via γ/π^0 transitions from J/ψ, ψ'.
- Narrow resolutions (with mono.):
  - $\sigma(m)$: 100 keV
  - $\sigma(\Gamma)$: J/ψ, ψ' - 100 keV,
  - $\sigma(\Gamma)$: χ_c, η_c, h_c - 300-700 keV (pair spectrometer).
- Huge statistics (1000 x today):
  - J/ψ 13B /y
    100B /y with monoch.
  - ψ' 4B /y
  - χ_c 1B /y
  - η_c 100M /y

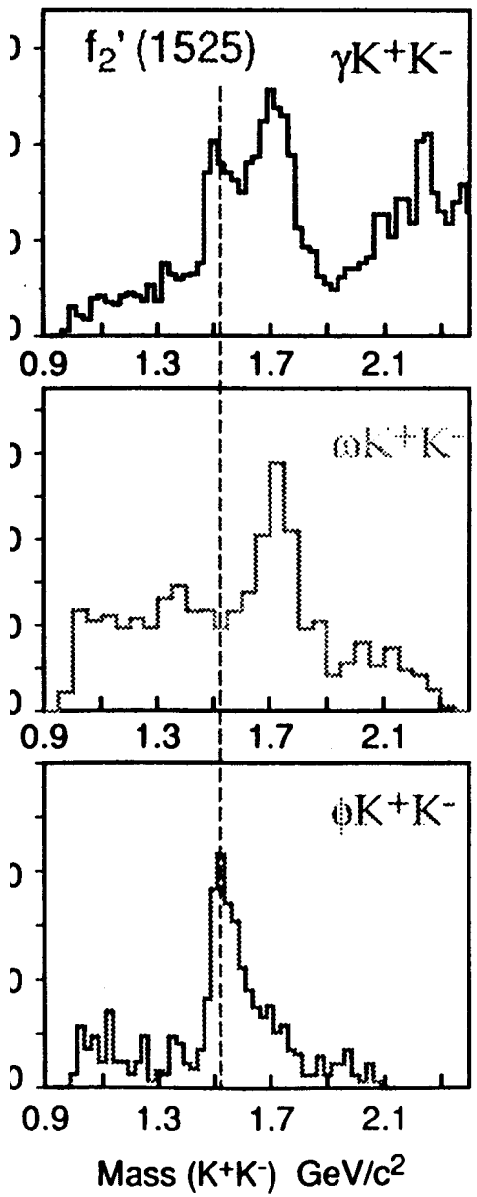


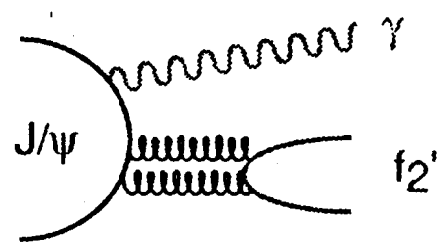
- High-res. detector for ch & neut particles / clean particle id.

Glueball and Hybrid Studies

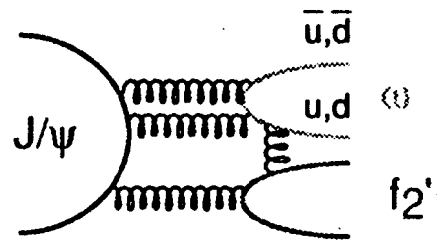
- J/ψ is the pre-eminent tool for glueball/hybrid searches:
  - Radiative decays are the ideal source for glueballs.
  - Unique filter of (g,u,d,s) structure of light hadrons.
  - Known J^{PC} for partial wave analysis.
  - Covers mass range of interest (<3 GeV).
- χ_c states allow J^{PC} to be tuned:
  - e.g. $\chi_1 \rightarrow \pi + 1^{-+}$ (exotic $\neq qq$) $\rightarrow \pi + \pi f_1$
- $\gamma\gamma \rightarrow C+$ (qq only) complements C+ studies in J/ψ decay.
- Hybrid charmonium, H_c ($c\bar{c}g$) may be an excellent way to study gluonic matter ($c\bar{c}$ spectrum is well understood):
  - Mass>4.3 GeV: $H_c \rightarrow DD^{**}$ dominates; $\Gamma \sim 100$ MeV. For non-1^{--}, run @ Ecm ~ 5 GeV, e.g. $e^+e^- \rightarrow \eta H_c \rightarrow \eta\eta J/\psi$.
  - Mass<4.3 GeV: narrow $\Gamma \sim 10$ MeV? e.g. $H_c \rightarrow \chi_c h$.

ing quark/gluon content by comparing $J/\psi \rightarrow \gamma X$ / ωX / ϕX.

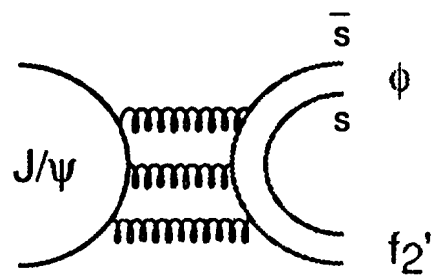




Single OZI



Double OZI



Single OZI

Accelerator Requirements

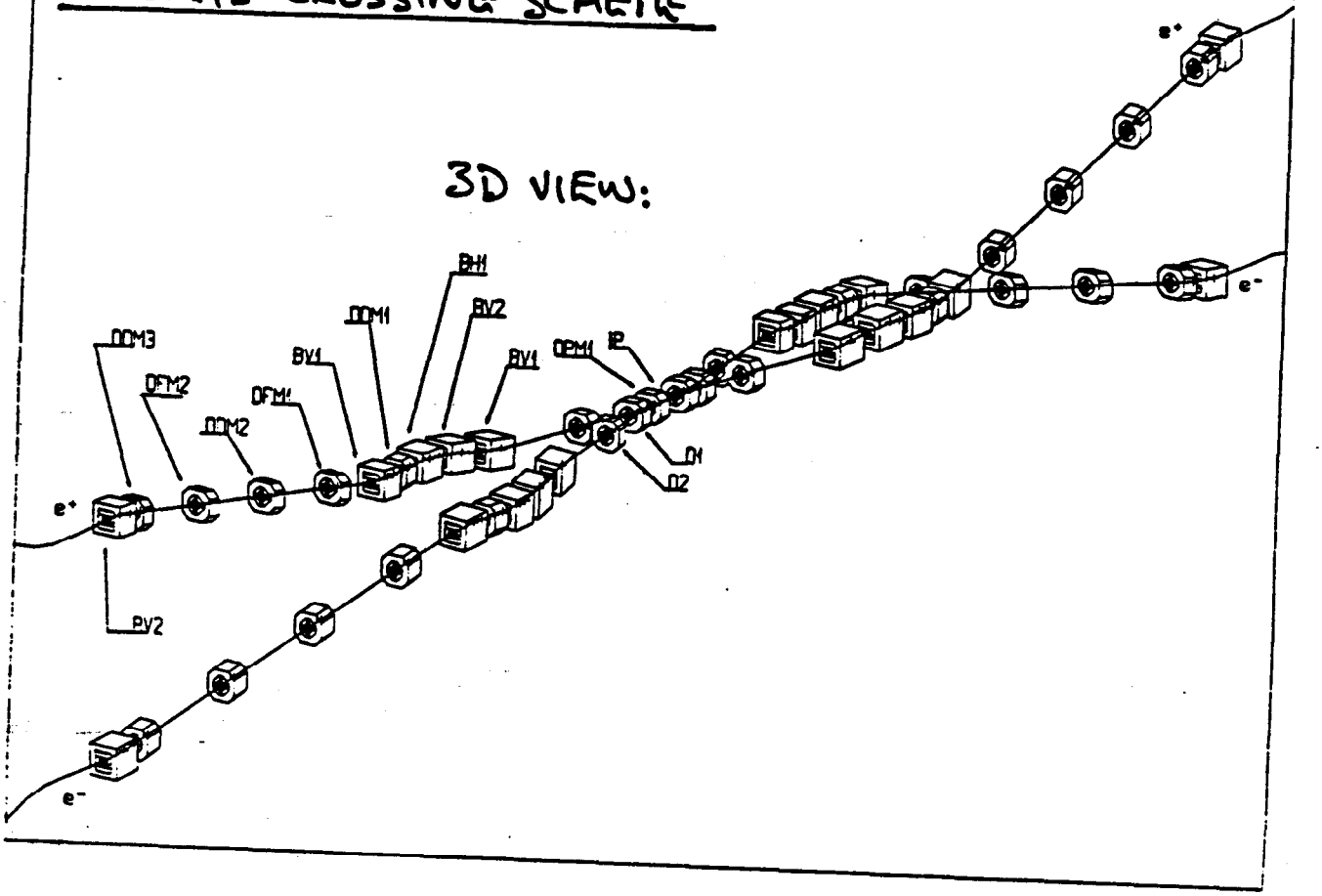
- Energy range: J/ψ -> 5.6 GeV ($>\Omega_c \overline{\Omega}_c$ threshold).
- Peak luminosity at 4 GeV.
- Flexible lattice required, with 4 operational phases:
  - Stage 1: Conservative design for 10^{33}
    - 10^{32}, physics starts
  - Stage 2: Monochromator optics (σ_E=140 keV @E=2GeV)
    - J/ψ, ψ'
    - $\tau^+\tau^-$ threshold: precise $\sigma(\tau^+\tau^-)$, m_τ, monoch. 2-body
    - Beam-energy-constrained masses (charm)
  - Stage 3: Increased L - 4 x 10^{33} - with crab-crossing.
  - Stage 4: Longitudinally-polarized beams
    - CP violation in hyperon decays
    - τ decays

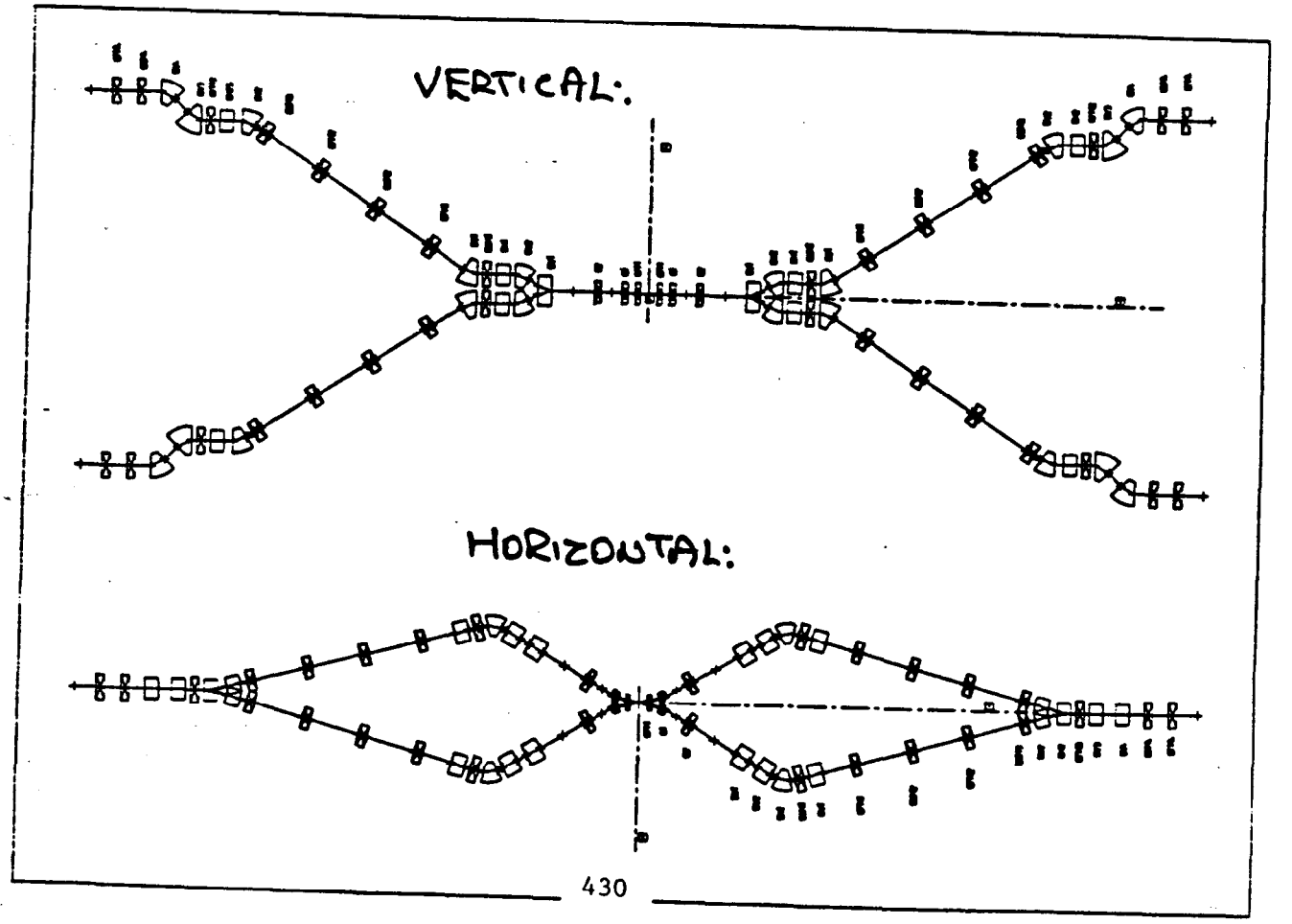
P. BELOSHITSKY, J. LE DUFF, B. MOUTON, E. PERELSTEIN (ORSAY-DUBNA)

		Standard scheme	Monochrom. scheme	Cros. angle scheme
Beam energy, GeV	E	2.0	2.0	2.0
Luminosity, $cm^{-2}s^{-1}$	L	$1.0 \cdot 10^{33}$	$1.0 \cdot 10^{33}$	$3.6 \cdot 10^{33}$
C.M. energy resolution, MeV	σ_w	1.8	0.14	1.6
Circumference, m	C	359	359	359
Natural emittance, nm	ε_0	378	17.0	225
Vertical emittance, nm	ε_y	19 *	2 †	5 ‡
Damping partition numbers	$J_x/J_y/J_\varepsilon$	0.58/1/2.42	2/1/1	0.66/1/2.34
Bending radius in arc, m	ρ	10.5	10.5	10.5
Damping times, msec	$\tau_x/\tau_y/\tau_s$	39/23/9	17/34/32	37/24/10
Momentum compaction	α	$1.67 \cdot 10^{-2}$	$8.43 \cdot 10^{-3}$	$1.67 \cdot 10^{-2}$
Energy spread	σ_E	$6.23 \cdot 10^{-4}$	$7.31 \cdot 10^{-4}$	$5.59 \cdot 10^{-4}$
Total current, A	I	0.564	0.537	2.0
Number of particles per bunch	N_b	$1.32 \cdot 10^{11}$	$1.26 \cdot 10^{11}$	$0.78 \cdot 10^{11}$
Number of bunches	k_b	32	32	192
RF voltage, MV	V	8	5	7
RF frequency, MHz	f_{RF}	481	481	481
Harmonic number	q	576	576	576
Energy loss per turn, kV	U_0	211	142	196
Bunch length, mm	σ_s	7.43	8.01	7.13
Bunch spacing, m	S_b	11.2	11.2	1.9
Required long. impedance, Ohm	$\lvert Z_n/n \rvert$	0.24	0.19	0.31
Beta functions at I.P., m	β_x^*/β_y^*	0.20/0.01	0.01/0.15	0.50/0.01
Vertical dispersion at I.P., m	D_y^*	0.	0.36	0.
Beam-beam parameters	ξ_x/ξ_y	0.04/0.04	0.04/0.03	0.04/0.04

INTERACTION REGION IN CRAB-CROSSING SCHEME

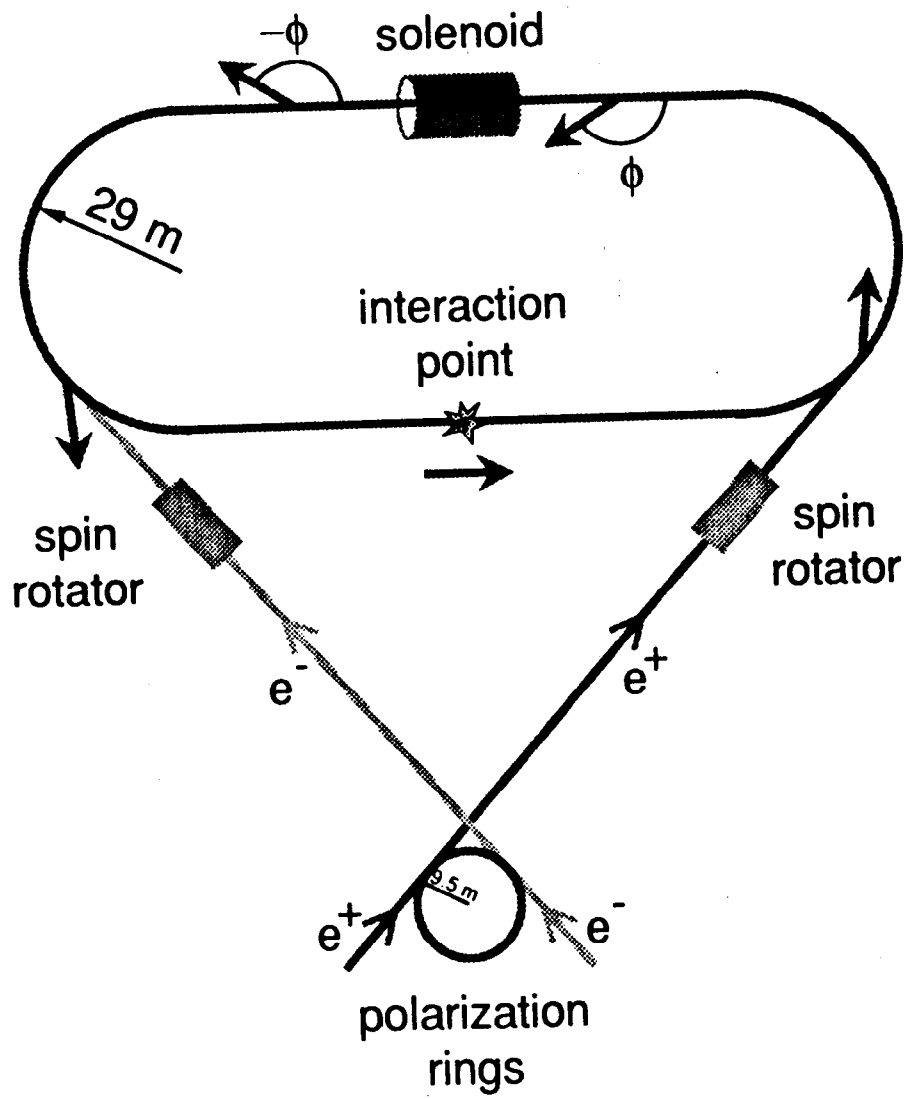
ORSAY - DUBNA

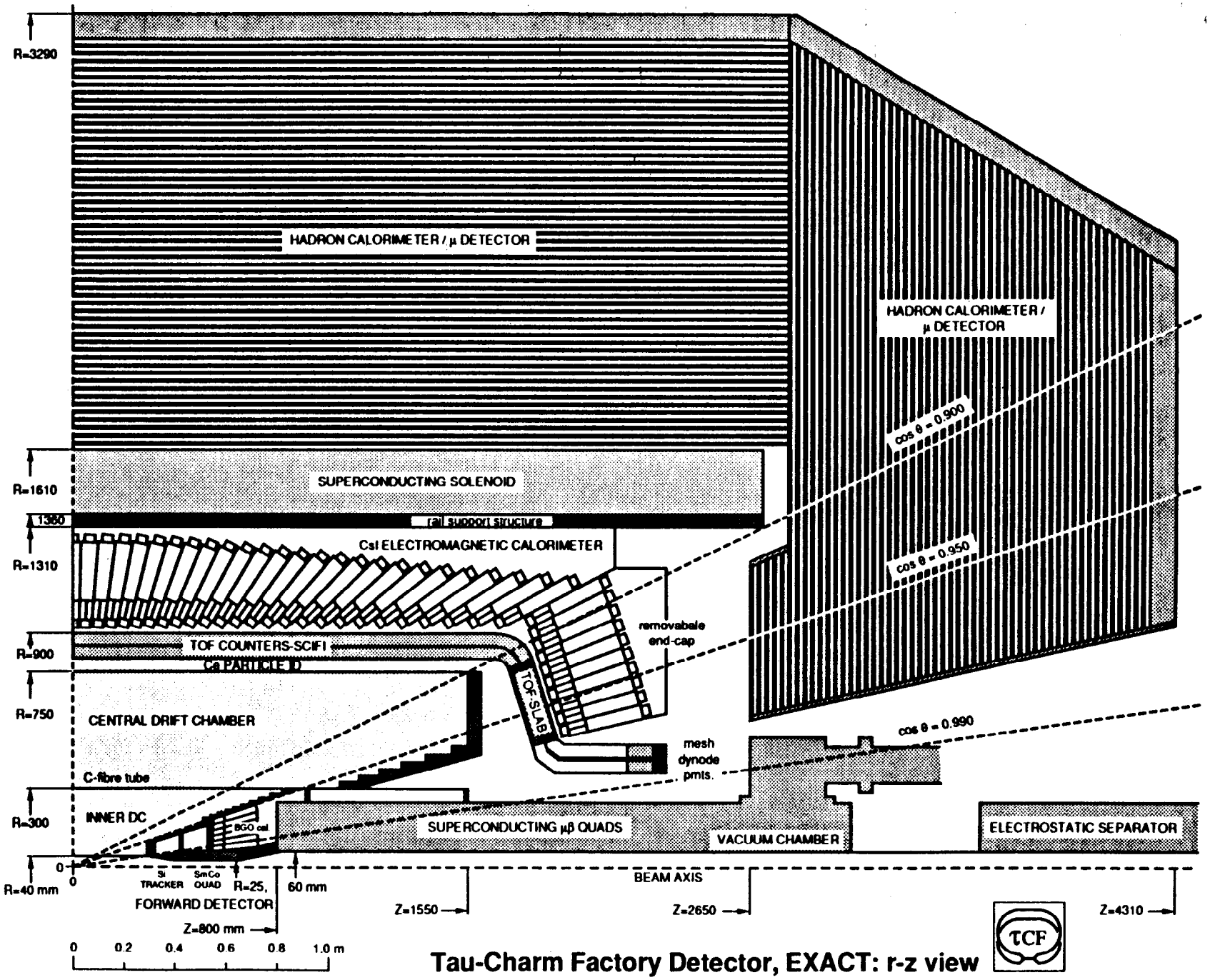




Scheme for longitudinal beam polarization

(A. ZHOLENTS)

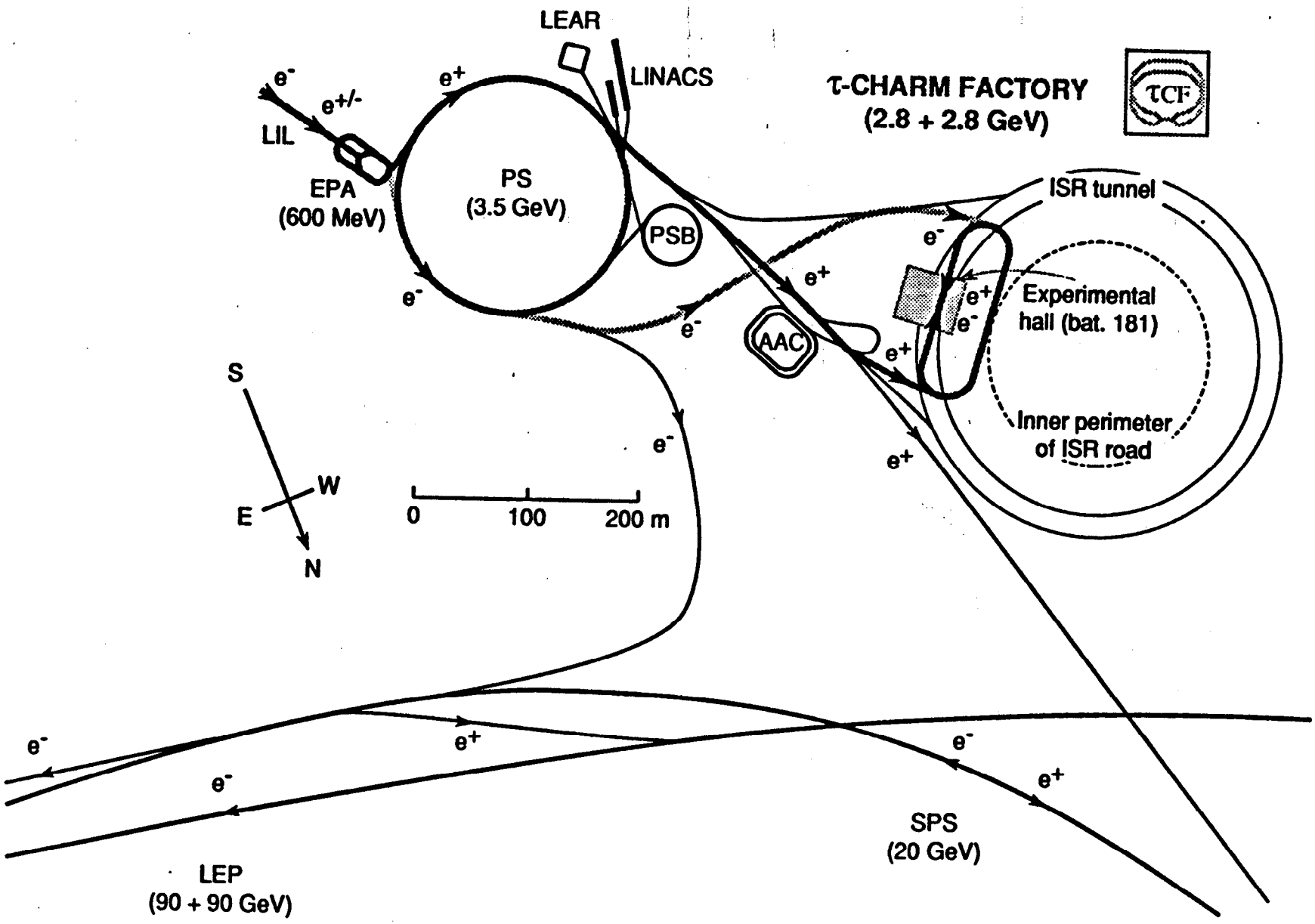




Tau-Charm Factory Detector, EXACT: r-z view

Comparison of detector performances.

	Mark III (SPEAR) / BES (BEPC)	EXACT (τcF)
Charged particles:		
Momentum res.: σ_p/p(GeV/c)	$1.5\%p \oplus 1.5\%/\beta$ [MkIII] $0.7\%p \oplus 1.3\%/\beta$ [BES]	$0.4\%p \oplus 0.4\%/\beta$
Angular resolution: σ_ϕ (mr)	$2 \oplus 2/\mathrm{p}\beta$	$0.5 \oplus 1.1/\mathrm{p}\beta$
p^{π}_{min}(MeV/c) for efficient tracking	80	50
Ω(barrel) ($\times 4\pi$ sr)	70%	90%
Photons:		
Energy resolution: σ_E/E(GeV)	$17\%/\sqrt{E}$	$2\%/E^{\frac{1}{4}} \oplus 1\%$
Angular resolution: $\sigma_{\theta,\phi}$ (mr)	10 [MkIII]; 5 [BES]	$1.7 + 2/\sqrt{E}$ (at $\theta = 90°$)
2γ angular separation: $\Delta\theta_{2\gamma}$ (mr)	20	50
E^{γ}_{min}(MeV) for efficient detection	100	10
Particle identification:		
$\pi \rightarrow$ K separation	3σ at 0.7 GeV/c	3σ at 1.0 GeV/c (10^{-4} inc. Cě.)
π/K $\rightarrow$ e separation	4% at 0.5 GeV/c	0.1% (10^{-5} inc. Cě.)
π/K $\rightarrow \mu$ separation	5% at 1.0 GeV/c	1.5%/p(GeV/c) + (1–4)%
K^0_L detection efficiency	60%	95%
n mean detection efficiency	-	50%
ν 'detection': $p^{\perp}_{min}$(MeV/c)	-	100


τ-CHARM FACTORY
(2.8 + 2.8 GeV)
τCF
LEAR
LINACS
LIL
EPA
(600 MeV)
PS
(3.5 GeV)
PSB
AAC
ISR tunnel
Experimental
hall (bat. 181)
Inner perimeter
of ISR road
S
W
E
N
0
100
200 m
LEP
(90 + 90 GeV)
SPS
(20 GeV)

Accelerator construction cost.
($1 ≈ 1.5 CHF)

Item	Green-Field Site [MCHF]	CERN ISR Site [MCHF]
Site & infrastructure:		
Buildings & civil engineering	76	9
Expl. zone infrastructure	12	8
Site equipment	37	0
Lab. computing & networks	15	0
Subtotal:	140	17
Accelerators:		
Collider	87	79
Booster	23	0
Linac	17	0
Transfer lines	8	6
Technical equipment	7	0
Recurrent cost	7	0
Subtotal:	149	85
Total (material):	**289**	**102**
Personnel:		
Total (personnel):	**660 man-y**	**315 man-y**

Detector construction cost.
($1 ≈ 1.5 CHF)

Item	Cost [CHF]
Inner & central drift chamber	3.8
Superconducting solenoid	7.0
Cerenkov (DIRC)	2.3
Time-of-flight	1.2
Electromagnetic calorimeter [CsI(Tl)]	30.7
Forward BGO calorimeter	1.2
Forward Si tracker	1.6
Hadron calorimeter/μ detector	7.3
Trigger & data acquisition	7.9
Subtotal:	63.0
Contingency (10%):	6.3
Total:	**69.3**

Conclusions

- The TCF is a unique tool for probing the high-precision frontier of EW interactions and (non-) perturbative QCD in τ, charm and charmonium decays.
- The TCF has a rich physics programme, addressing fundamental aspects of the SM.
- TCF physics is complementary to other approved accelerators.
- Full exploitation of the physics potential of the BF's requires new precision charm measurements from a TCF.
- The TCF satisfies most of the requirements for approval:
  - 1. Compelling physics interest
  - 2. Technical feasibility (machine & detector)
  - 3. Reasonable cost
  - 4. User community
    - ➢ The remaining requirement is a site!