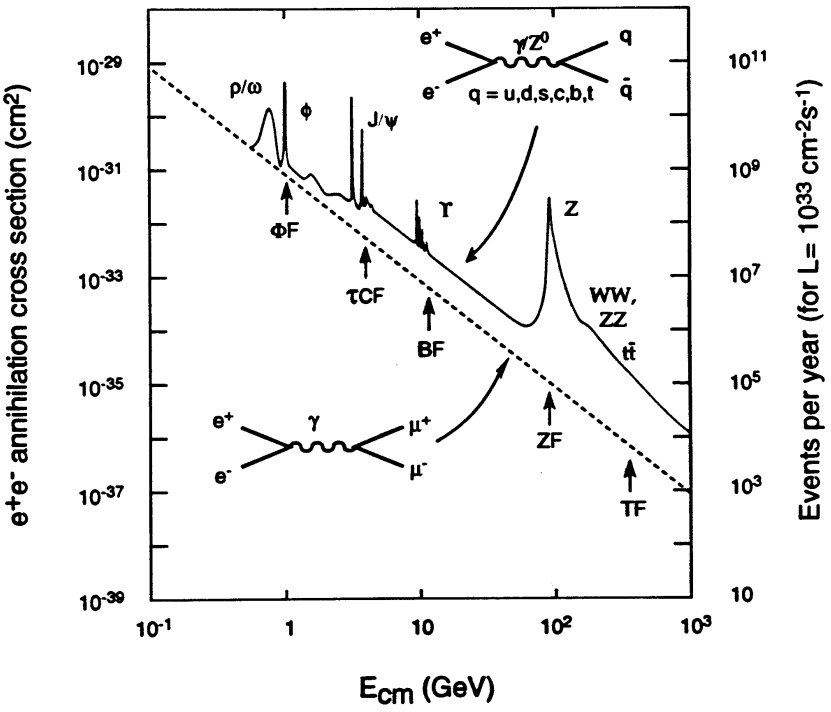
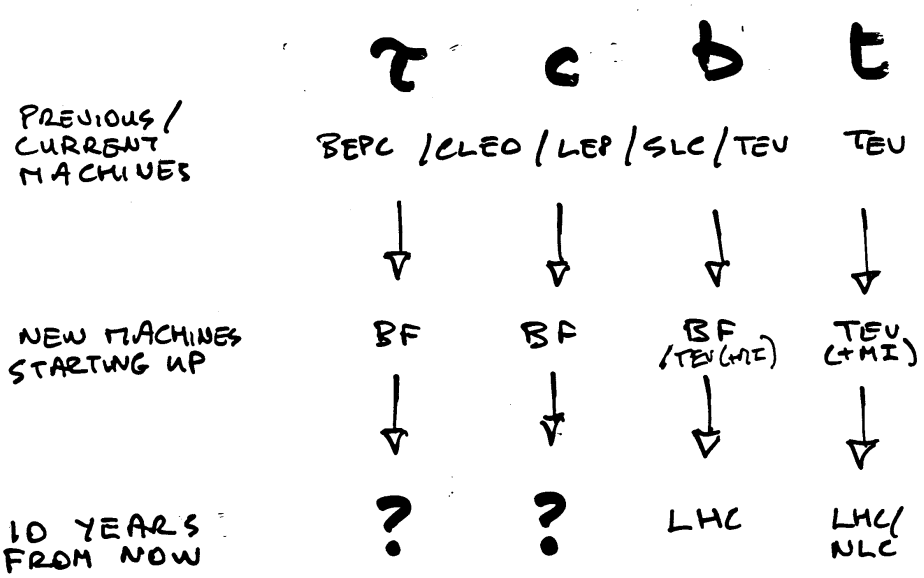
JASPER KIRKBY / CERN
SLAC τc WORKSHOP
9 MAR 99

VIEWS ON THE WORKSHOP AND FUTURE τc PHYSICS

Hadronic cross-section in e^+e^- annihilation



PRECISION HEAVY QUARK / LEPTON EXPERIMENTAL PROGRAMME



- ARE THE BF's THE END OF THE ROAD FOR τ AND c PHYSICS?
- WILL THEY HAVE ANSWERED ALL τ c PHYSICS 10 YR FROM NOW?

NEW CONCEPT [AT LEAST FOR ME]
FROM THIS WORKSHOP :

THE TCF IS THE
NEXT GENERATION MACHINE
FOR TC PHYSICS AFTER
THE BF'S

- EXPECTED τc PHYSICS REACH OF BF'S IS NOW ~'KNOWN' FROM CLEO II (10M $\tau^+\tau^-$)

- CLEAR SIGNS OF SOME LIMITATIONS
  - e.g. $M(\nu_\tau)$ LIMIT ~15 MeV SYST/BG-LIMITED MEAS.
  - TRIGGER LIMITATIONS NEW AT THIS W/S

- CAN THE TCF IMPROVE ON THE BF MEASUREMENTS?
  - DETAILED, CASE-BY-CASE REPLY REQUIRED
  - ONLY GENERAL COMMENTS HERE
  - REQUIRES NEW STUDY

1. ON BASIS OF STATISTICS THERE IS NO DIFFERENCE BETWEEN BF's AND TCF

2. WHAT THE TCF PROVIDES IS A

UNIQUE EXPTL. ENVIRONMENT

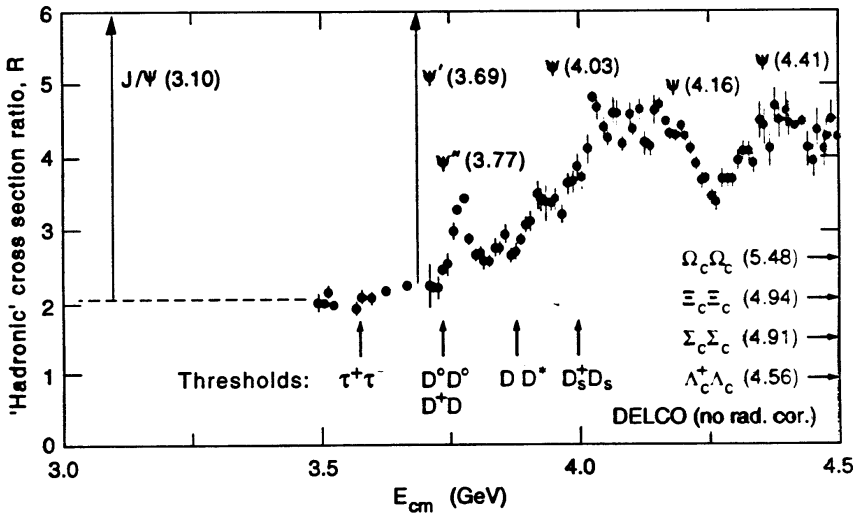
FOR τ PHYSICS

FOR c PHYSICS

AND FOR GLUEBALL SPECTROSCOPY

$\Rightarrow$ TCF SHOULD ACHIEVE SMALLER BACKGROUNDS AND SYSTEMATIC ERRORS THAN BF's / PREVIOUS MACHINES

Tau-charm threshold region



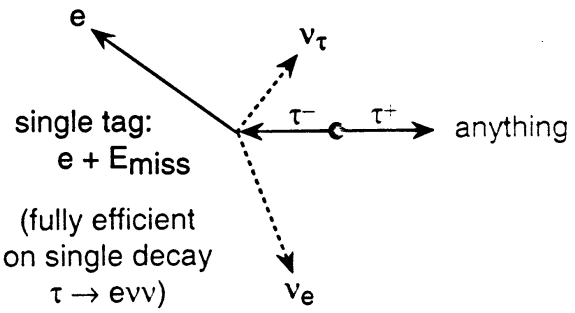
Unique experimental environment at TCF

- Extremely high statistics:
  - 30-50M τ/c /year
  - 10^{10}-10^{11} J/ψ /year
- Lower backgrounds than other machines:
  - τ production below c/b threshold:
    - ➤ Single-tagged τ samples
  - Tagged charm hadrons (absolute Br's):
    - ➤ D^0, $D^{\pm}$, $D_s^{\pm}$, $\Lambda_c^{\pm}$, Ξ_c, Σ_c, Ω_c
  - Absence of jet fragments / extra particles
- *Experimental* measurement of backgrounds (by operating machine below threshold)
- Favourable kinematics
  - Monochromatic 2-body decays
  - Constraint on single missing ν
  - Low particle overlap / high detection efficiency
  - Clean (low energy) particle i.d.
- High rate detector calibration sources: J/ψ, ψ'
- Special machine features:
  - Longitudinal polarization
  - (Monochromator optics)

• MORE OBSERVABLES
• EASILY REVERSED → POWERFUL EXPTL. X-CHECK
• POLN. OF DECAY μ ALSO IN DETECTOR

VERY SUBTLE EFFECTS

Single-tagged τ samples at TCF



- Non-τ backgrounds 10^{-4} - 10^{-3}
  (below charm threshold)

- Typical backgrounds at CESR/LEP ~1%

- At 3.67 GeV:

	ε (qq)	ε(ττ)	#qq/ττ
No cuts	1	1	6
Emiss>0.8 GeV	.005	.95	.03
+Ee>0.4 GeV	10^{-5}	.24	2×10^{-4}

Tagged charm samples

- Precision charm experiments require tagged particles.

- Techniques:
  - TCF: Opposite particle: $D^0\bar{D}^0$, D^+D^-, $D_s^+D_s^-$, $\Lambda_c^+\bar{\Lambda}_c^-$..
  - BF: **"D* trick"**: $D^{*+}\rightarrow D^0\pi^+$, $D_s^{*+}\rightarrow D_s^+\gamma$ (not low p_T).
    $D^{*+}\rightarrow D^+\pi^0$ (but, $D^{*0}\rightarrow D^0\pi^0$ also!)
  - Fixed target: Secondary vertex

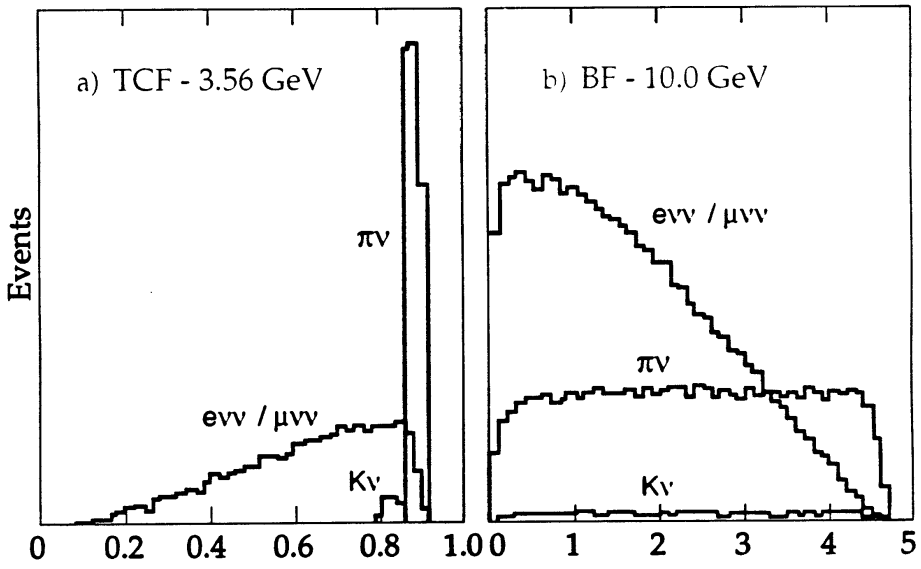
- All work well for easy channels like $D^0\rightarrow K^-\pi^+$

- But for more difficult decays, like semi-leptonics and pure leptonics, there are big differences in backgrounds:
  - eg. $D^0\rightarrow K^-l^+\nu$

Mark III (TCF)	1% bgd.
Fixed target	30%
CLEO (BF)	30%

- Also, TCF can tag *all* charm states: $D^0, D^\pm, D_s^\pm, D^{*0}, \Lambda_c^\pm$..

$\tau \rightarrow$ 1-prong spectra



Indirect ν_τ Mass Measurement

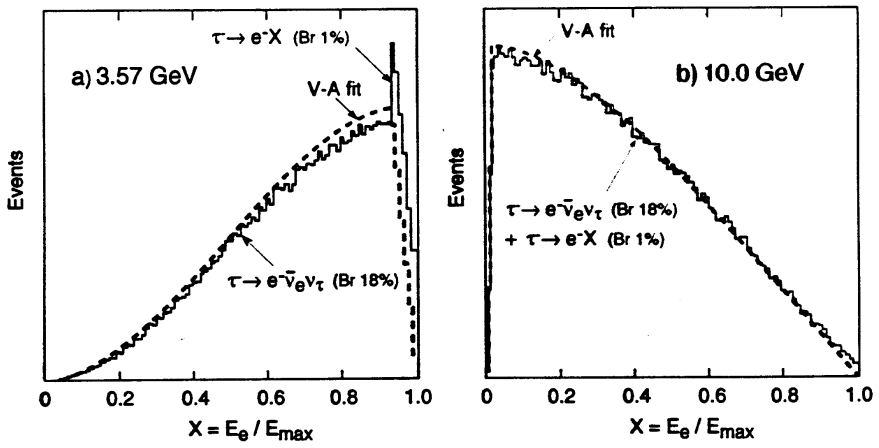
- A heavy ν_τ (≥100eV) must be unstable, eg:
  - $\nu_\tau \rightarrow \nu_e/\nu_\mu$ X, where X is a weak, massless, spin 0 Goldstone boson (majoron, flavon, etc.)

  => τ will decay via same process:
  $\tau \rightarrow e/\mu$ X (<3x10^{-3} at 95%CL - ARGUS)

  and estimated Br's may be ~10^{-5}-10^{-6} (Valle).

=> Indirect access to 100 eV < m(ν_τ) < 1 MeV

- TCF sensitivity is < 10^{-5} for $\tau \rightarrow$ e X

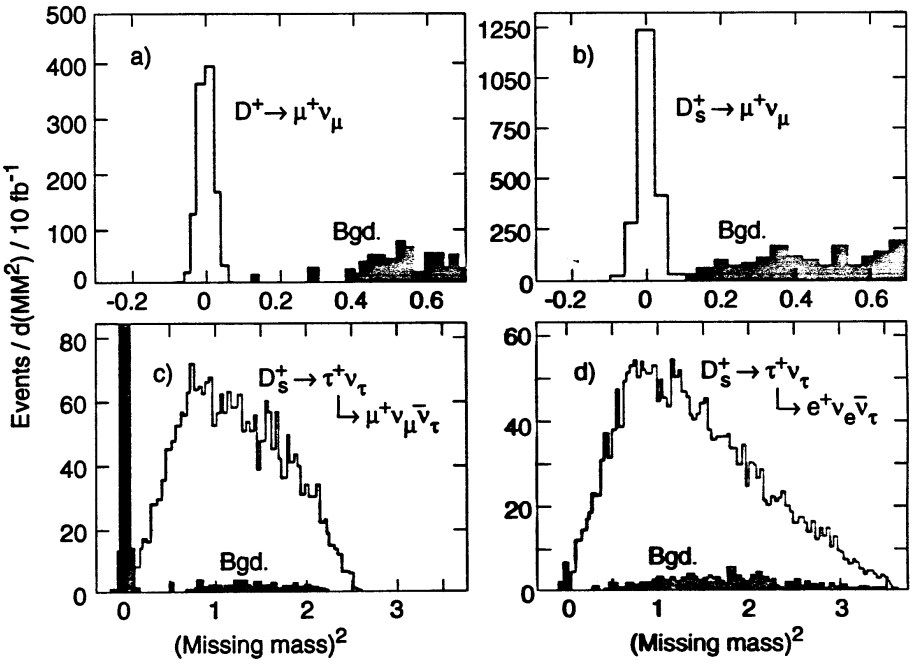


Pure leptonic D decays

- Present experimental errors are large, eg.

$$f_{D_s} = 344 \pm 37 \pm 52 \pm 42 \quad \text{CLEO II}$$

The TCF precision is 1% for f_D and f_{D_s} /1-year's data:



- The best way to determine f_B precisely is to measure f_D and use lattice QCD to extrapolate from the D to the B region. [Br($B^+ \to \tau^+\nu_\tau$) $\sim 7 \times 10^{-5}$, and $|V_{bu}|$ is poorly known.]

Detector calibration at TCF

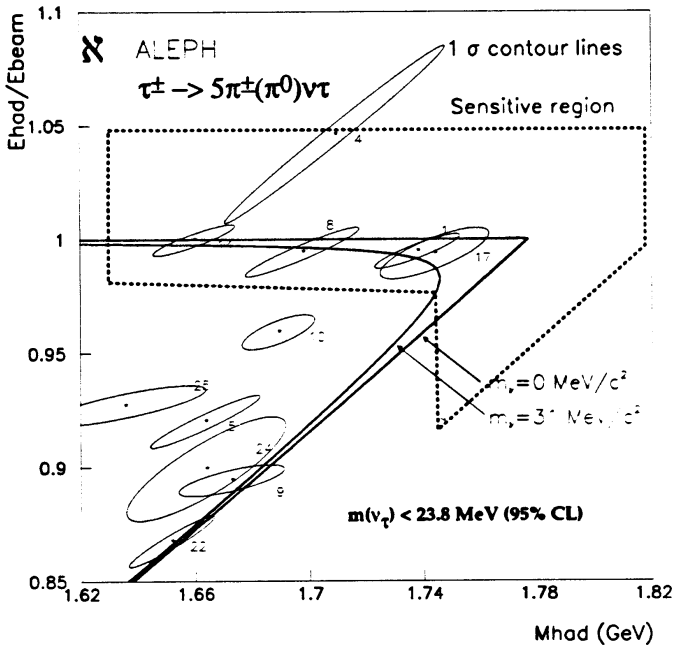
- Example of some calibration channels at the J/ψ (1.3kHz total rate):

Particle	Final states	Rate (/day)
$\pi^{\pm}, \pi^0$	$\rho\pi$	2M
$K^{\pm}$	K^*K	0.7M
p	$pp, pp\pi^0, pp\pi^{\pm}$	1.5M
γ	$\rho\pi, \gamma 4\pi^{\pm}, \gamma ee$	2M
K^0_L	$K^0_L K^0_S$	10k
n	$np\pi$	0.3M
e	$ee, \gamma ee$	8M
μ	$\mu\mu, \gamma\mu\mu$	8M

Direct ν_τ Mass Limit

$m(\nu_\tau) < 18.2$ MeV (95% CL)

ALEPH (3π/5π-2D, TAU96)



- Expected TCF improvement relative to ALEPH:
  - Per year, x100 statistics above
  - σ_m ~2 MeV $5\pi^\pm$ mass resolution (1/10 x ALEPH)
  - Background fraction $<10^{-4}$

- ν mass limit $\propto \sigma_m / \sqrt{N}$
  => TCF will reach $m(\nu_\tau) = 1$ MeV sensitivity

Interest in charm physics

1. Precision quantitative tests of QCD in a unique regime (perturbative/non-perturbative interface)
   - Charm tightly constrained in SM
   - D is accessible to precise predictions of lattice QCD
   - Fundamental charm parameters poorly measured:
     - V_{cd} = 0.224 ±0.016 **(unitarity: 0.2210±0.0030)**
       V_{cs} = 1.010 ±0.180 **(0.9743±0.0007)**

2. Input for precision physics at higher energies:
   - Poor charm data (Br, s.l. spectra,...) limits precision of *present* B, Z measurements
   - Test and calibrate theoretical tools, eg:
     - V_{td}/V_{ts} from $B\to\gamma\rho$, $\gamma\omega$, γK^{*0} needs $D^0\to\gamma K^{*0}$ etc.
     - f_B determination needs f_D, f_{Ds} in $D_{(s)}\to l\nu$

3. New physics discovery potential:
   - CP violation, D^0D^0 mixing, rare decays...
   - Rich variety of weak decays (CA,CS,DCS, leptonic, semi-leptonic, 2nd-order weak)
   - Sole window for +2/3 heavy flavour physics

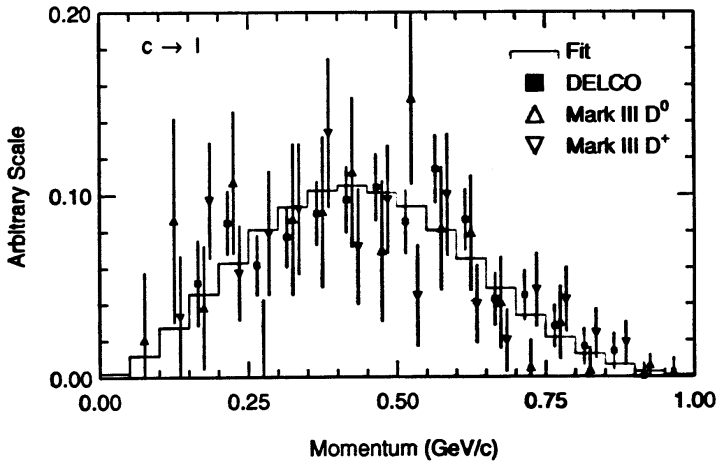
Experimental status of charm decays

- Experimental precision of charm Br's is poor:
  - D^0 / $D^{\pm}$ $\gtrsim$10%
  - $D_s^{\pm}$ $\gtrsim$20% (no absolute measurement yet)
  - $\Lambda_c^{\pm}$ $\gtrsim$20%
  - Ξ_c / Ω_c Br's are unknown

  ... and 20-50% of decays not yet seen. Stark contrast with τ decays!

- The TCF will measure absolute Br's with precisions:
  - D^0 / $D^{\pm}$ / $D_s^{\pm}$ 0.1-0.3% /1-year's data
  - $\Lambda_c^{\pm}$ 1% /y
  - Σ_c / Ξ_c / Ω_c 3-10% /y

- Present experimental status of c $\rightarrow$l spectrum:



τCF PHYSICS

1. SURE THING

- ALMOST ANY τC PHYSICS TOPIC YOU THINK OF INVOLVES AN ENORMOUS PROGRAMME OF IMPORTANT MEASUREMENTS
  (eg AW TALK ON QCD PHYSICS IN τ DECAYS)

⇒ "LEP-STYLE" PRECISION PHYSICS PROGRAM IS GUARANTEED

2. NO GUARANTEE

- REVOLUTIONARY DISCOVER!
- BUT POTENTIAL EXISTS $m(\nu_\tau)$, $\tau \to \mu\gamma$, $D^0\bar{D}^0$, $\pi_1 X$ ...
- IS τCF THE SPEAR AFTER ADONE?
  OR THE PEP/PETRA/TRISTAN/LEP AFTER SPEAR?

IMPORTANT TC PHYSICS EXPTS.

[PERSONAL CHOICE]

τ:
- $M(\nu_\tau)$
- MICHEL PARAMETERS
- RARE DECAYS:
  - ALLOWED $\tau \to \mu\gamma$, ...
  - FORBIDDEN $\tau \to \mu\gamma$, ...
- CP

C:
- D^0-$\bar{D}^0$ MIXING
- PURE LEPTONICS $D^\pm_{(s)} \to \mu\nu$, $\tau\nu$
- RARE DECAYS
- CP

EW:
- RHAD

QCD:
- GLUEBALL/HYBRID SPECTROSCOPY
  - ↳ "DREAM MACHINE"

TOPICS REQUIRING MORE STUDY IN TCF

- R_{HAD}
- $M(\nu_\tau)$ [ALL CHANNELS]
- τ MICHEL PARAMETERS (INC μ POL.)
- CP IN τ DECAY
- $D^0\bar{D}^0$ MIXING
- $\tau\bar{\tau}$ TAGGING AT 3.67 GeV
- L3TC DETECTOR
- SPLITOFFS IN ECAL
- MACHINE BGDS INC:
  - TOUSCHEK
  - ECAL NOISE HITS

⋮

MACHINE & DETECTOR

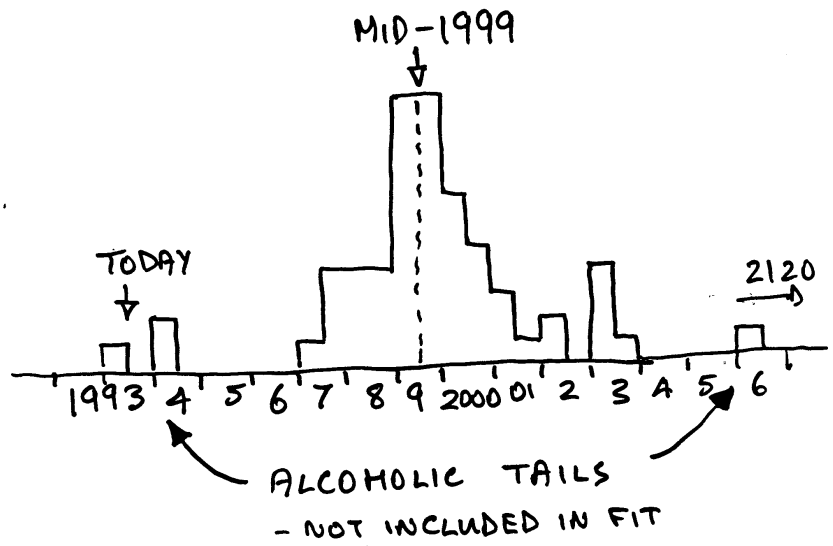
- THE LATENESS OF TCF SHOULD BE CHANGED INTO AN ADVANTAGE BY UTILIZING ALL THE
  - MACHINE RESULTS FROM DAΦNE / CESR / PEP II / KEKB
  - DETECTOR ADVANCES FROM BABAR / BELLE / LHC DETC. etc.

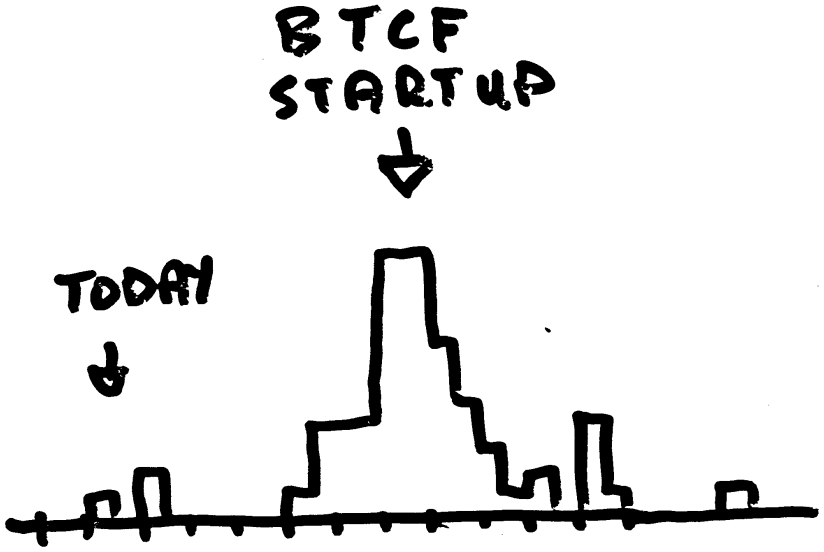
"GROUNDS-UP-REVIEW" OF MACH / DET. DESIGNS

MARBELLA TCF WORKSHOP BANQUET (3 JUNE 1993)

TCF BANQUET:

1ST TCF COLLISIONS EXPECTED IN ...




BTCF
STARTUP
TODAY