Tau/Charm Energy Operation

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Let's consider $\Psi(3770)$ at $D\bar{D}$ threshold

- Greater cross section:

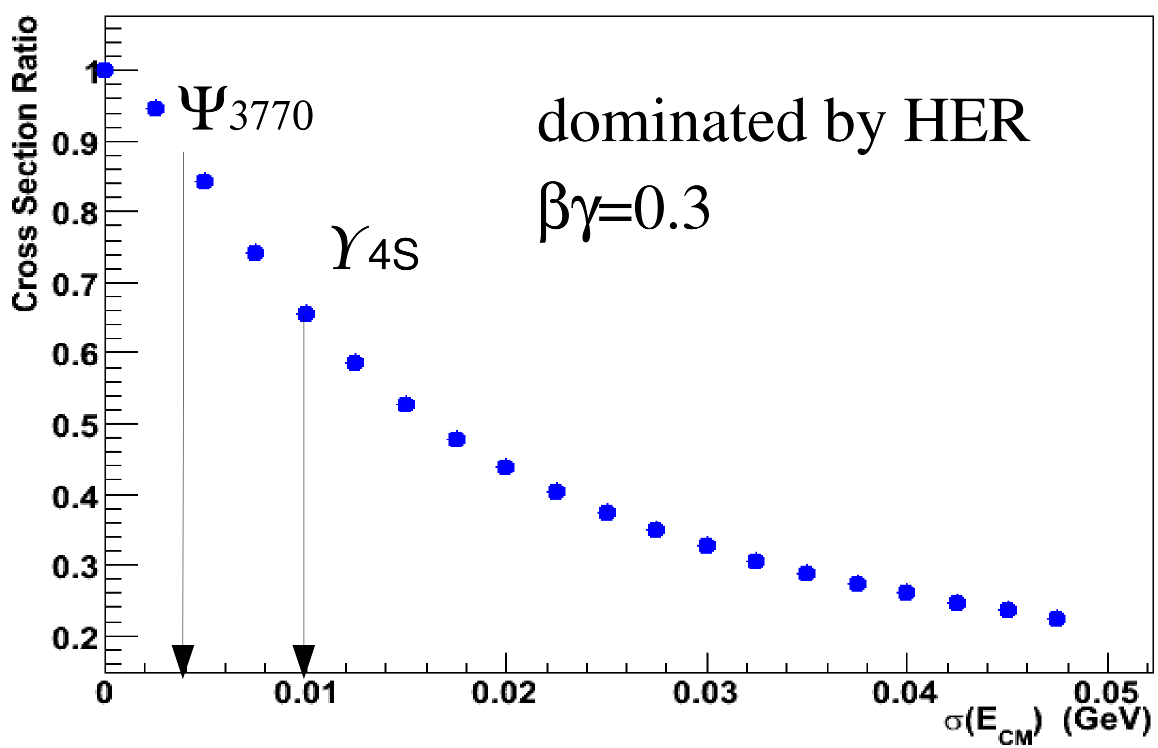
$\sigma(e^+e^- \rightarrow D\bar{D})$= 6.4 nb (CLEO-c) at 3.773 GeV

$\sigma(e^+e^- \rightarrow c\bar{c})$= 1.3 nb at 10.58 GeV

- Extremely clean environment: pure $D\bar{D}$ events.
- D recoil analysis: pure beams of D
- Quantum coherence: mixing and CP violation analysis.
- $\Psi(4140) \rightarrow D\bar{D}\gamma, D\bar{D}\pi^0, D_s\bar{D}_s^{(*)}$ similar considerations

Luminosity and Effective cross-section

- Lumi expected ~ factor 10 less wrt to 10.6 GeV
- $\Gamma(\Psi_{3770}) \sim \Gamma(\Upsilon_{4S}) \sim 20$ MeV: effective cross-section similar to Υ_{4S}.
- Energy spread reducing with E_{beam}: cross section ratio ~90%

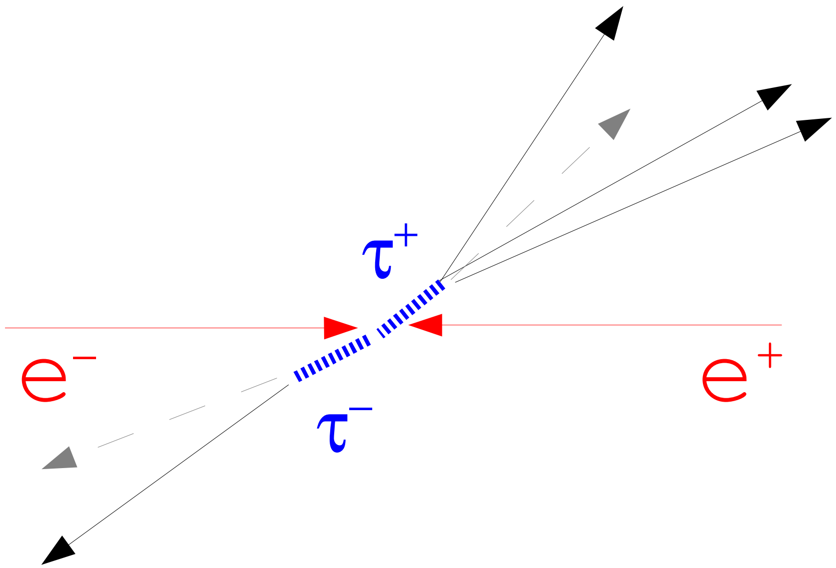


Charm physics

Focus on those areas that may potentially reveal NP

- D^0-$\bar{D}^0$ mixing
  - suppressed in SM (GIM mechanism + CKM factors), if observed may be hint of NP
- CP violation
  - example: direct CPV. SM~10^{-3}; NP up to 1% (but care is needed for possible hadronic enhancement in SM)
- Search for rare decays
  - Example: decays proceeding via FCNC strongly suppressed in SM but possibly enhanced with NP

τ physics



- τ selection is already pure at the Υ4S.

Use 1 vs 3 prong selection.

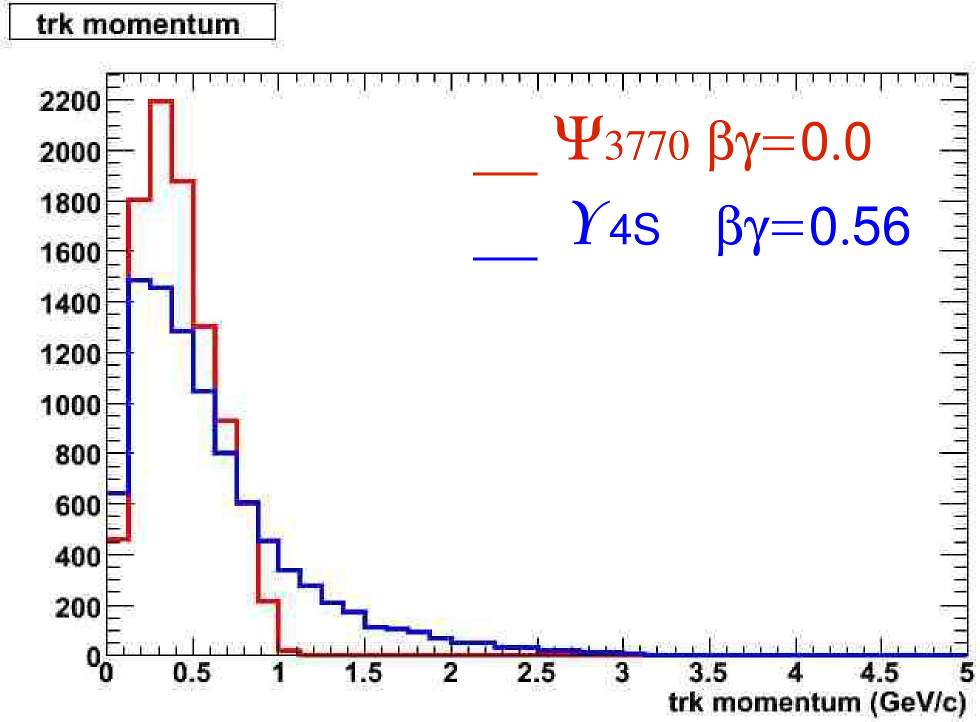
- $\tau \rightarrow \mu\gamma$ selection: better purity-efficiency for higher momentum μ and γ at Υ4S.
- Better vertex separation and lifetime measurement at Υ4S.
- Enhancement of cross-section at 4.0 GeV smaller than decrease of luminosity.
- No clear gain from selecting τ at 4.0 GeV.

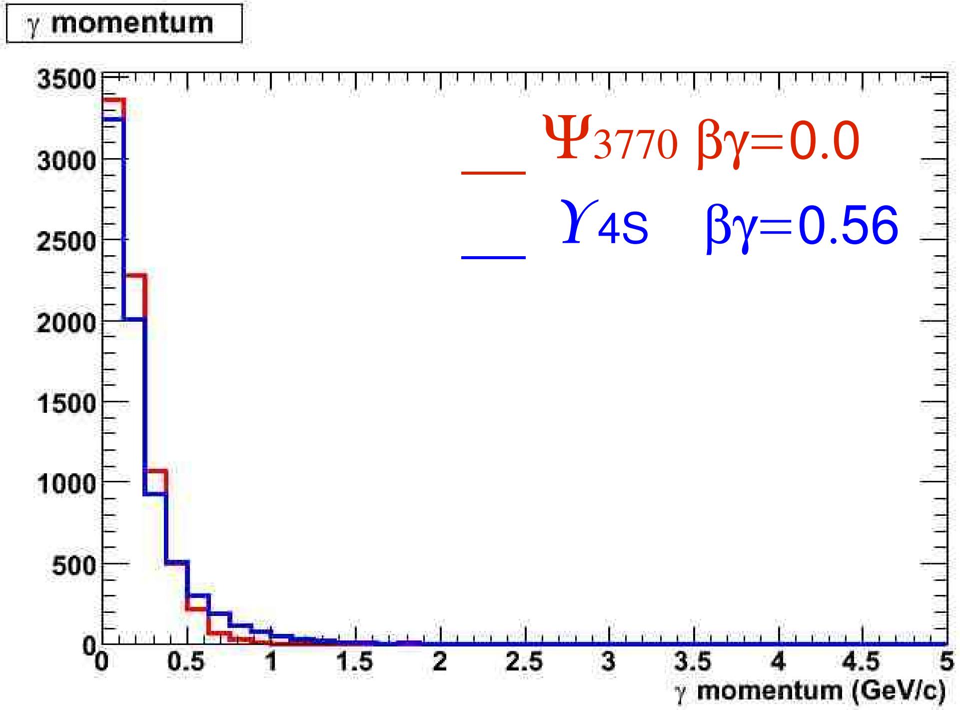
PravdaMC: Fast Simulation using parametric resolution

- Using BaBar detector layout with beamspot(10μm,1μm,1mm)
- Added layer0 near the beam-pipe and reduced the radial size and the radial amount of material of the beam pipe.
  - **beam pipe** radius **1.5cm** and Si+Cfbr 100 μm layer0 at 1.55 cm
    - Be 0.05 cm, Au 5 μm. 10 μm hit resolution
  - **beam pipe** radius **1.0cm** and Si+Cfbr 100 μm layer0 at 1.05 cm
    - Be 0.03 cm, Au 5 μm. 10 μm hit resolution
  - **beam pipe** radius **0.5cm** and Si+Cfbr 100 μm layer0 at 0.55 cm
    - Be 0.02 cm, Au 5 μm. 5 μm hit resolution

Ψ_{3770} $\beta\gamma$=0.0 vs Υ_{4S} $\beta\gamma$=0.56

momentum spectra

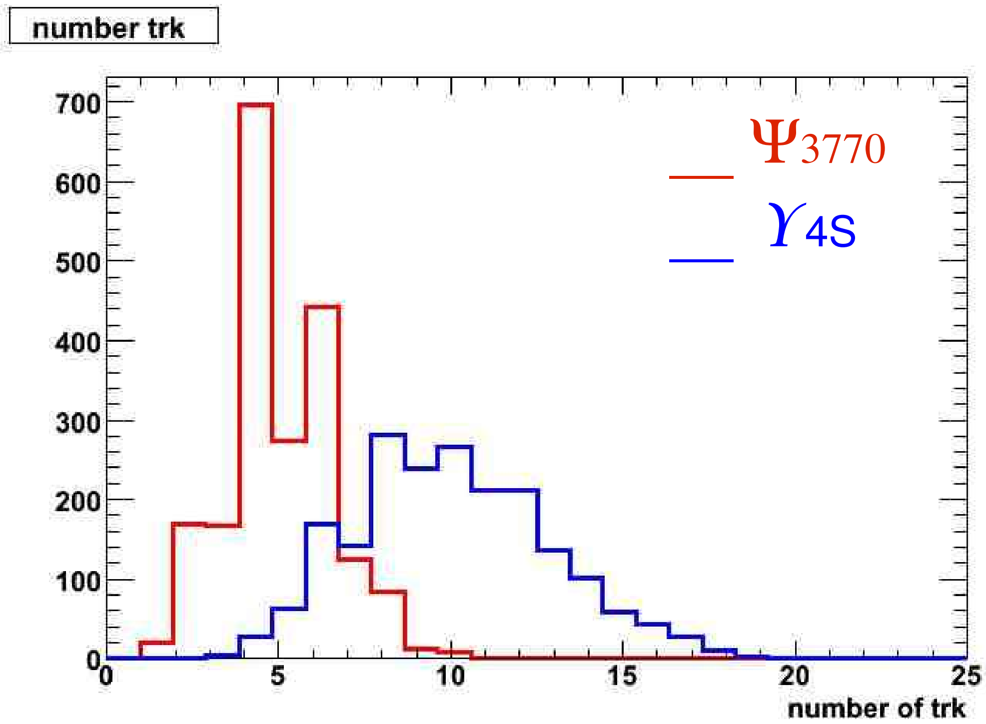


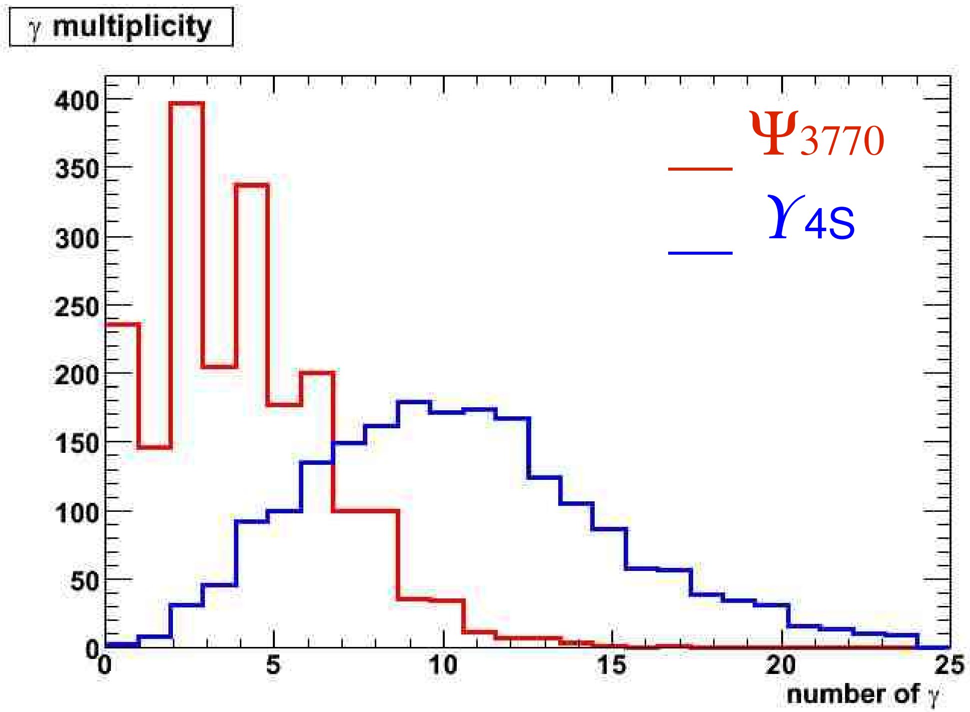


Higher fragmentation in B decays wrt to D decays makes the spectra to overlap.
Very high momentum events (i.e. $B \rightarrow \pi\pi$) are no more present at Ψ_{3770}

Ψ_{3770} vs Υ_{4S}

track multiplicity





Lower number of tracks improves reco efficiency, signal purity.

Most analysis techniques gain: recoil analysis, flavor tagging, vertexing, etc.

Considerations for a B Factory Detector

- CP sensitivity from:
  - Observe many exclusive final states with high efficiency and low backgrounds
    - need large solid angle coverage
  - Tag flavor with high efficiency
    - good lepton ID, particle ID over large momentum range (complicated by boost of asymmetric energies of beams): good π/K separation to over 4 GeV (dE/dx; Cherenkov counter)
  - Measure the relative decay times of the B mesons
    - z position of the vertex depends on the amount of material (beam pipe) between the IP and first layer of silicon sensors, radius of beam pipe
    - resolution of z separation between B vertices is key

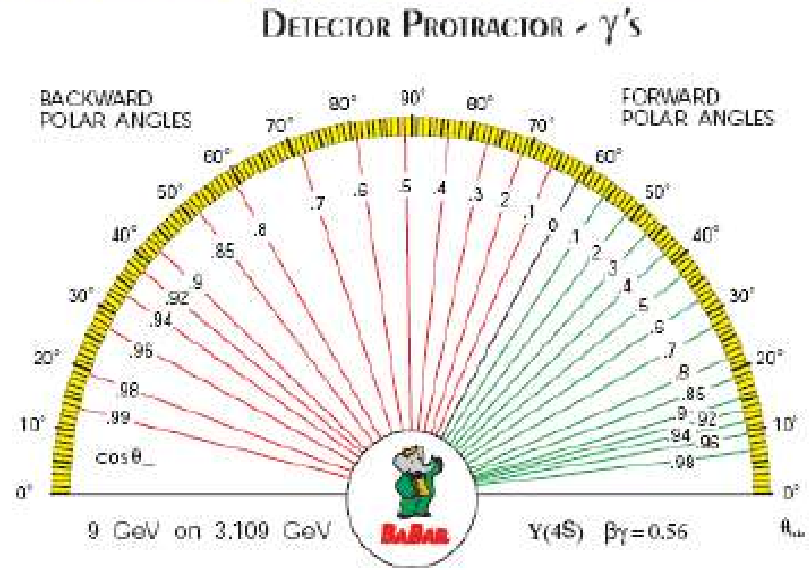


Figure 2-1. Protractor showing the relationship between center-of-mass and laboratory polar angles for photons at $\beta\gamma = 0.56$.

.45 Belle

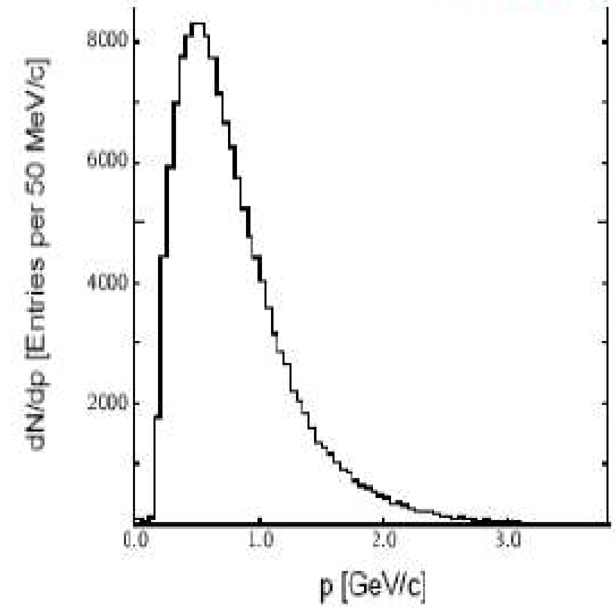


Figure 2-4. Momentum spectrum for kaons from B decays, which are used for tagging the flavor of the B.

Considerations for a B Factory Detector (2)

- B decays: many modes with low BRs
  - Decays with many particles, many low momentum (soft π's from D^* decays): require good low momentum resolution (little material, 'high' B)
  - Decays with soft γ's from soft π^0's, as well as high energy electrons and photons: require good low energy photon energy measurement with low noise and minimum material in front of the calorimeter, as well as calorimeter depth to contain higher E photons and electrons

DAQ: buffer data extensively; minimize trigger deadtime

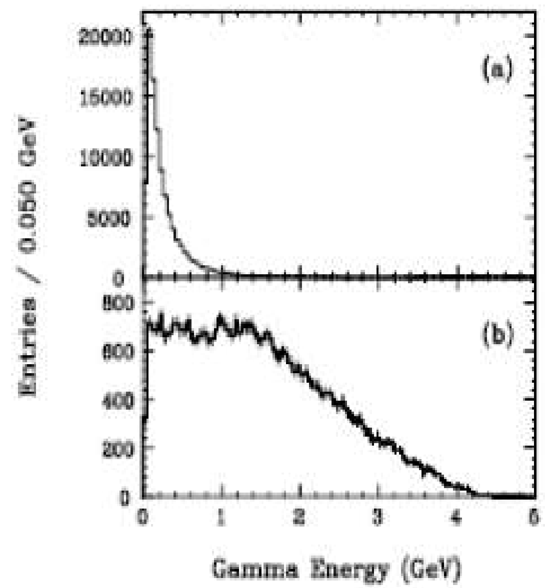


Figure 7-1. *Photon energy spectrum in (a) generic B decays and (b) $B^0 \to \pi^0\pi^0$ events.*

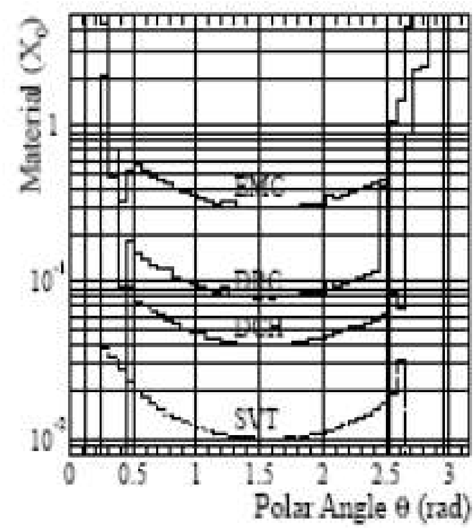


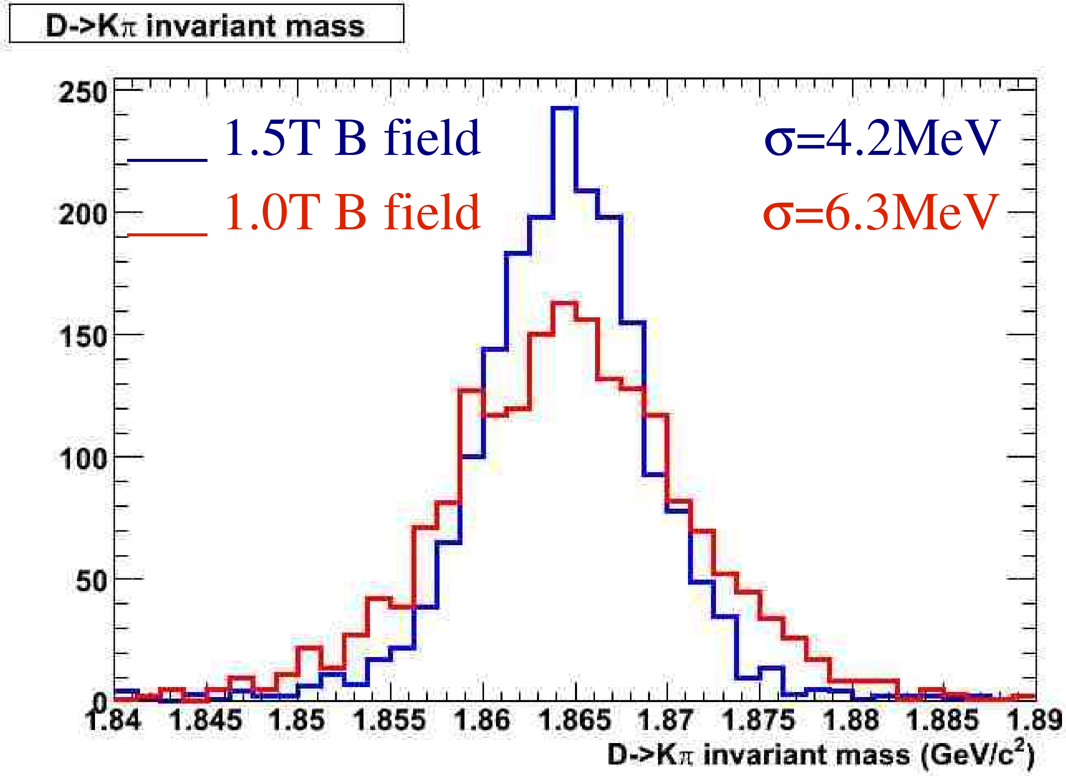
Figure 3. Amount of material (in units of radiation lengths) which a high energy particle, originating from the center of the coordinate system at a polar angle θ, traverses before it reaches the first active element of a specific detector system.

A 4.0 GeV detector: important peculiarities

- BaBar-Belle detector are similar to CLEO-c detector.
- CLEO-c use CLEOIII detector operated at Υ4S with some differences due to reduced particle momentum range:
  - **Multiple scattering** reduces vertexing capability.
  - **Low pT tracks** have **lower reco efficiency** since they reach only the inner layers of the DCH .
  - Low pT tracks **loops in the DCH** complicating pattern recognition.

CLEO-c $\beta\gamma$=0 replaced Vertex detector with Micro Vertex Chamber.
Reduced B magnetic field 1.5T$\rightarrow$1.0T
Ameliorate the tracking efficiency with loss of vertex capability and reduction of invariant mass resolution.

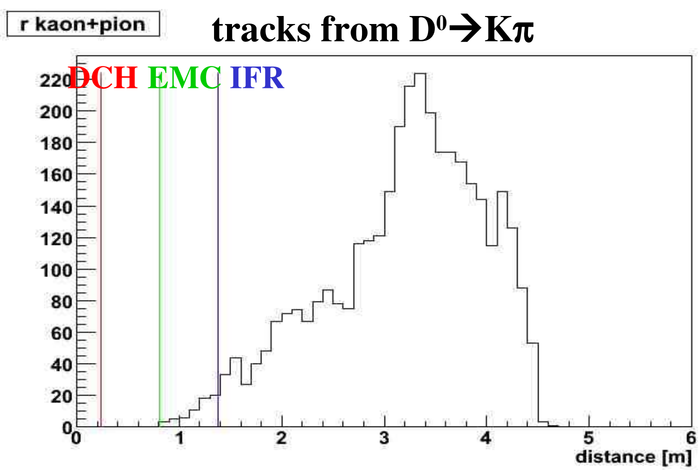
Reducing B Magnetic field



- What happens to the mass/momentum resolutions and reconstruction efficiency if B is reduced to 1.0 T?
  - the D^0 mass resolution deteriorates by ~50% (figure above)
  - the reco. efficiency of high multiplicity D decays improves. No significant gain for low-multiplicity D decays (next slide)

Reducing the B magnetic field @ Ψ_{3770}

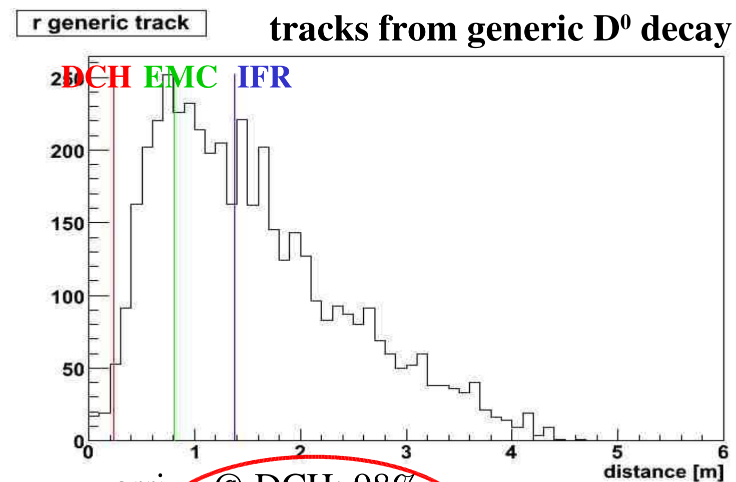
B=1.5 T



arrive @ DCH: 100%

arrive @ EMC: 100%

arrive @ IFR: 98%

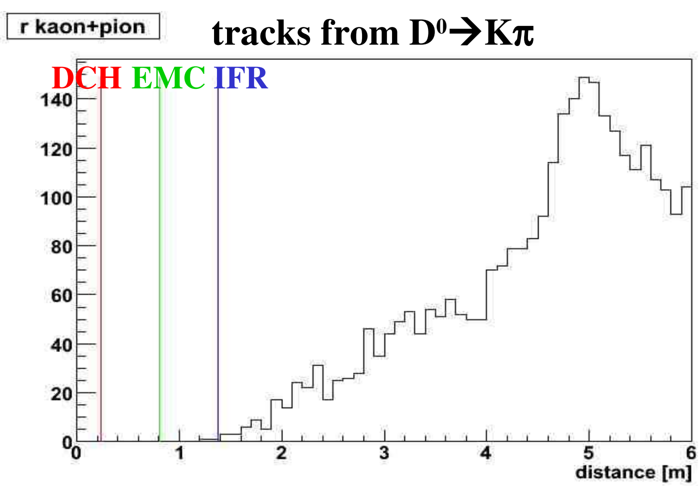


arrive @ DCH: 98%

arrive @ EMC: 76%

arrive @ IFR: 50%

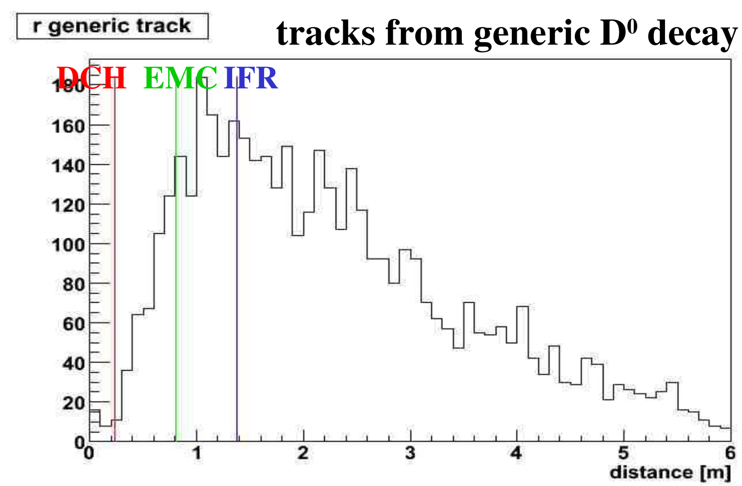
B=1.0 T



arrive @ DCH: 100%

arrive @ EMC: 100%

arrive @ IFR: 99%



arrive @ DCH: 99%

arrive @ EMC: 90%

arrive @ IFR: 70%

Operation without CM boost

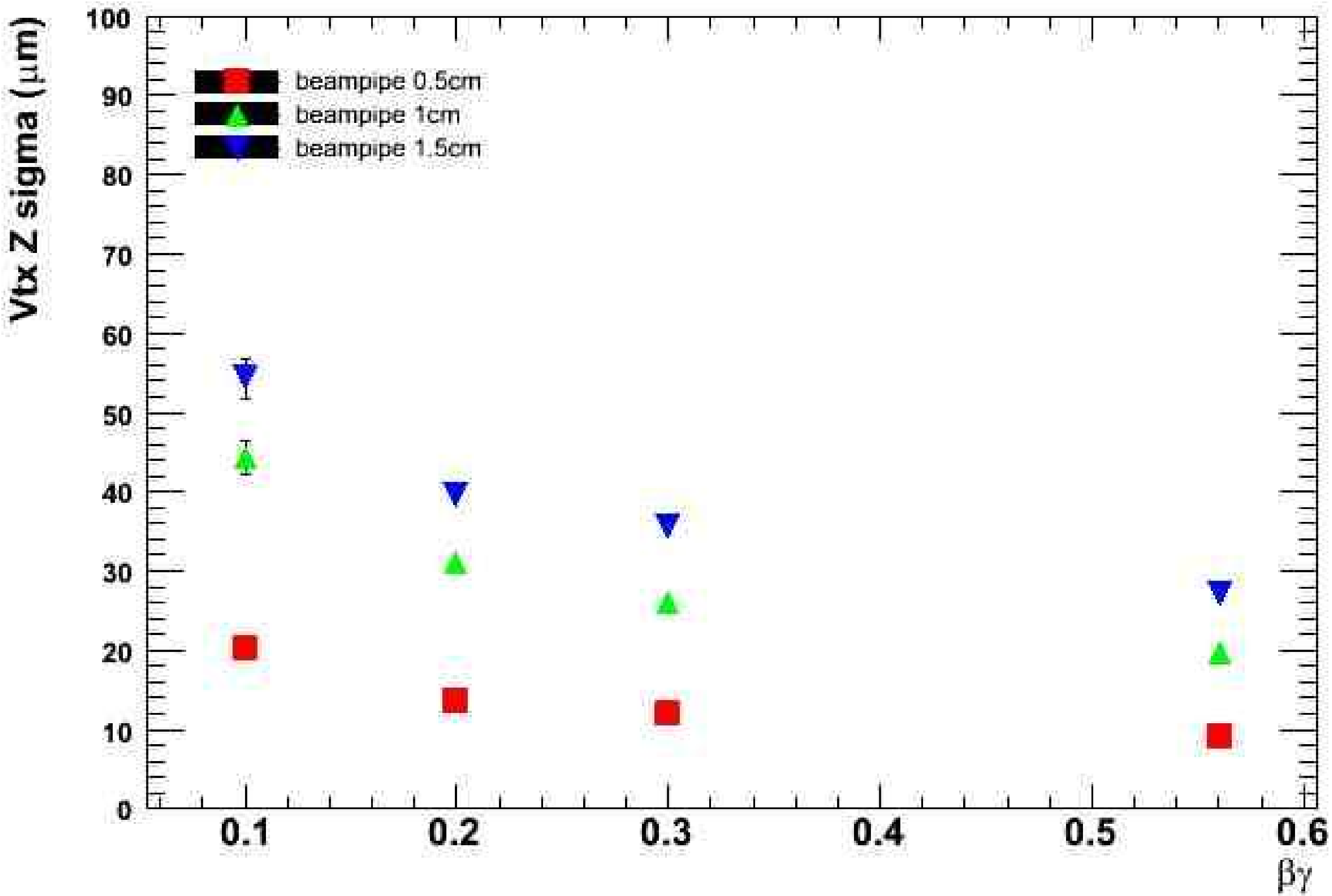
- Enlarge detector acceptance:
  - $\beta\gamma=0$ 300 (150) mrad $\rightarrow$ 95.5% (98.9%) coverage
  - $\beta\gamma=0.3$ 300 (150) mrad $\rightarrow$ 92.0% (98.0%) coverage
  - $\beta\gamma=0.56$ 300 (150) mrad $\rightarrow$ 87.6% (96.8%) coverage
- Lower multiplicity D decays are less affected by inefficiency due to limited detector coverage.
- No boost cancel the possibility of time dependent measurement and limit vertexing capabilities (multiple scattering)

Does the boost help in charm physics?

- Separation of the D vertices
  - possibility of time-dependent measurements
  - additional handle to fight the background

- Increase of the average particle momenta
  - reduction of the multiple scattering
  - impact on PID?

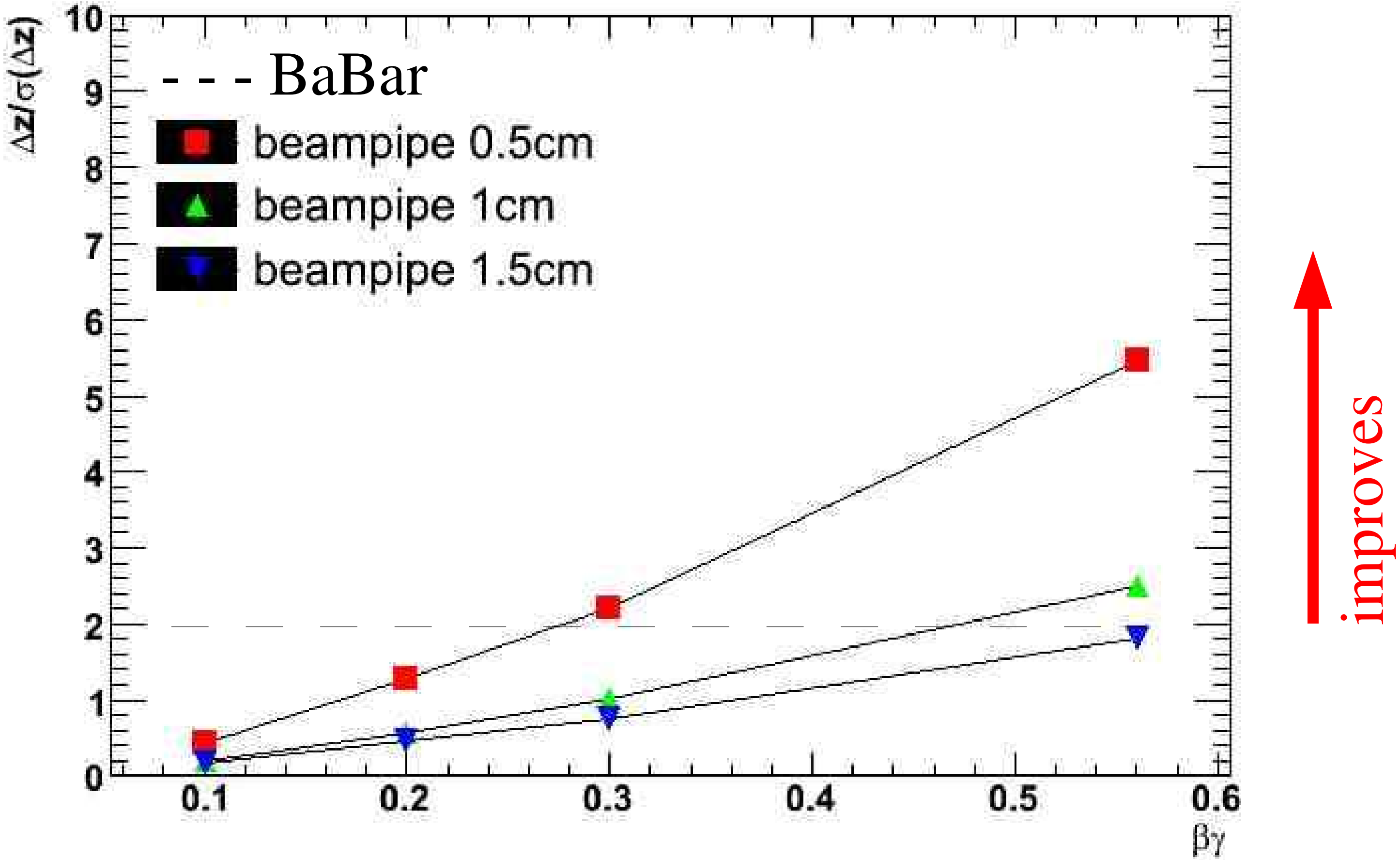
Vertex resolution *vs* βγ



Vertexing benefits from CM boost: reduction of multiple-scattering and increase of D vertex separation.

Time dependent measurements

Assume σ(Tag)=σ(Vtx): low track multiplicity, no charm bias in Tag vtx



D lifetime 0.4 ps, for B it is 1.5 ps ⇒ Smaller Δz significance.

Layer0 at 0.5cm and reduction of the radial material is important.

PID: only some considerations

- Average track momentum @Ψ_{3770} lower than @Y(4S) but not *dramatically* lower
  - at Ψ_{3770} smaller phase space partially compensated by lower particle multiplicity
- ~100% of tracks from two-body D^0 decays reach the Cher. detector (all over the Cher. threshold)
- ~75% of tracks from generic D^0 decays reach the Cher. detector (B=1.5T). The fractions raises to 90% with B=1.0T. All kaons are over threshold. A small fraction of muons and pions are under threshold.
- So far no striking problems using SuperB PID system when running @ Ψ_{3770} . **Detailed study needed**

Summary
(no conclusions at this stage)

- There is no evident incompatibility for the SuperB detector to operate at the Charm threshold energy.
- CM Boost improves vertexing performance allowing Time Dependent analysis with modest reduction of the geometrical acceptance.
- More detailed studies are needed to valuate tracking efficiency and optimal value of the magnetic field.
- PID and neutral reconstruction require further studies.

BACK-UP SLIDES

4.0 GeV vs 10 GeV: tracks multiplicity