Vertexing Studies

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SuperB WorkShop
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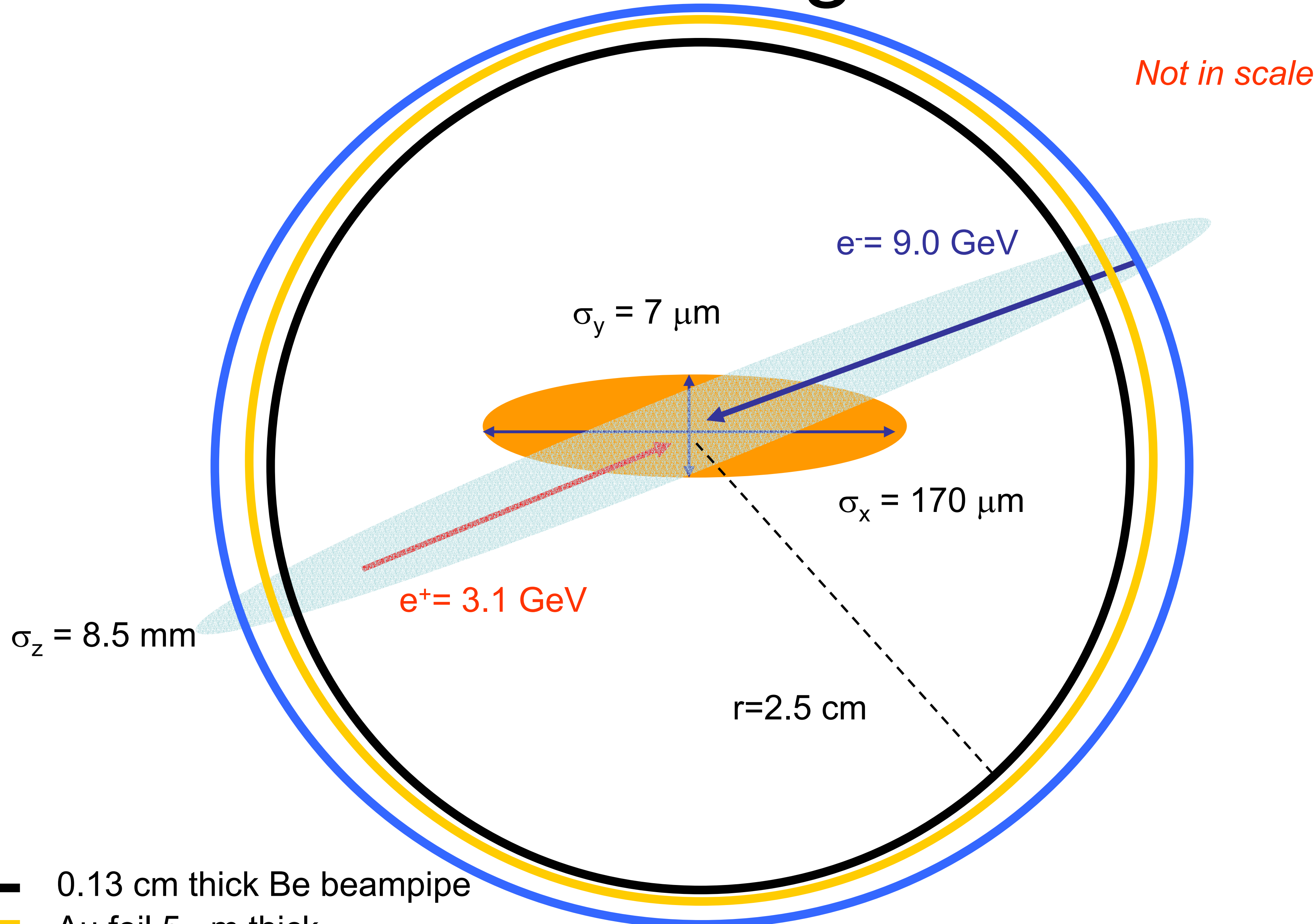
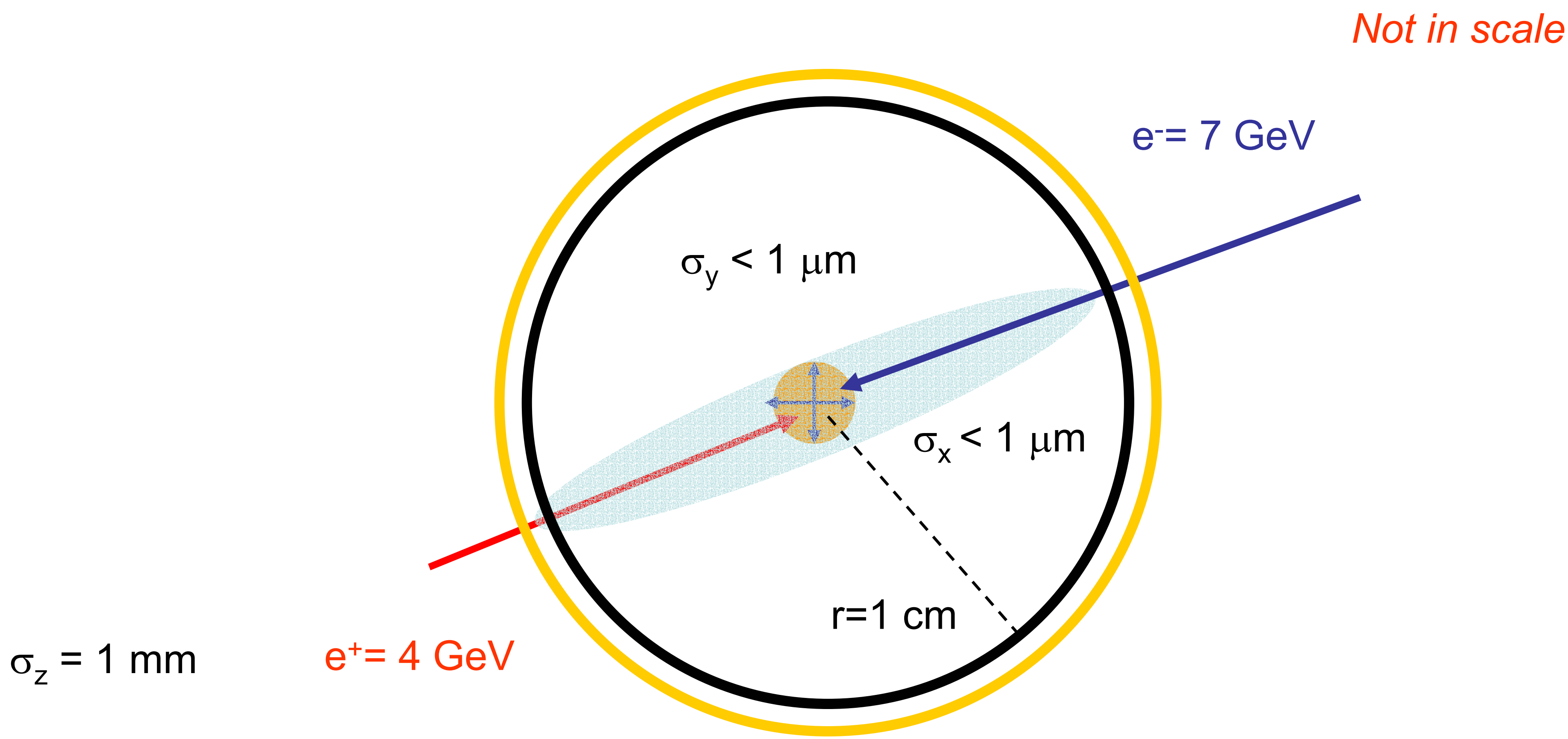
Interaction region PEP



- 0.13 cm thick Be beampipe
- Au foil 5 μm thick
- 0.147 cm thick cooling water
  14 μm Ni

Interaction region SuperB

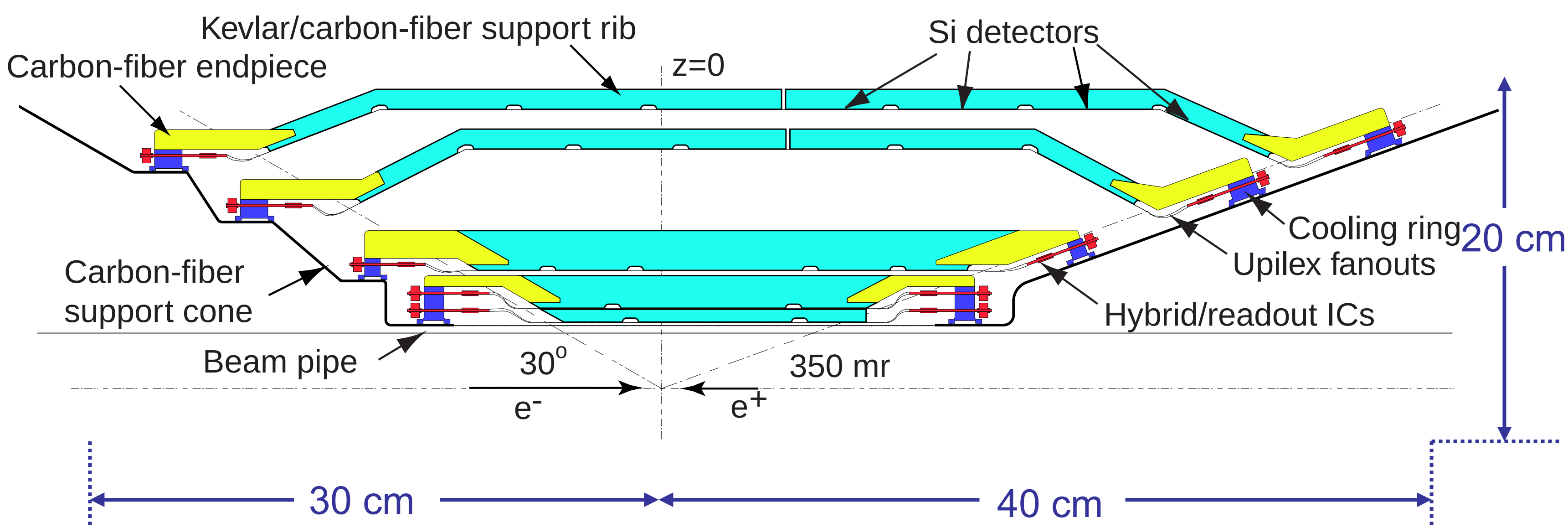


- 0.03 cm thick Be beampipe
- Au foil 5 μm thick

No cooling required in SuperB design “a la linear collider”

The BaBar Silicon Vertex Tracker

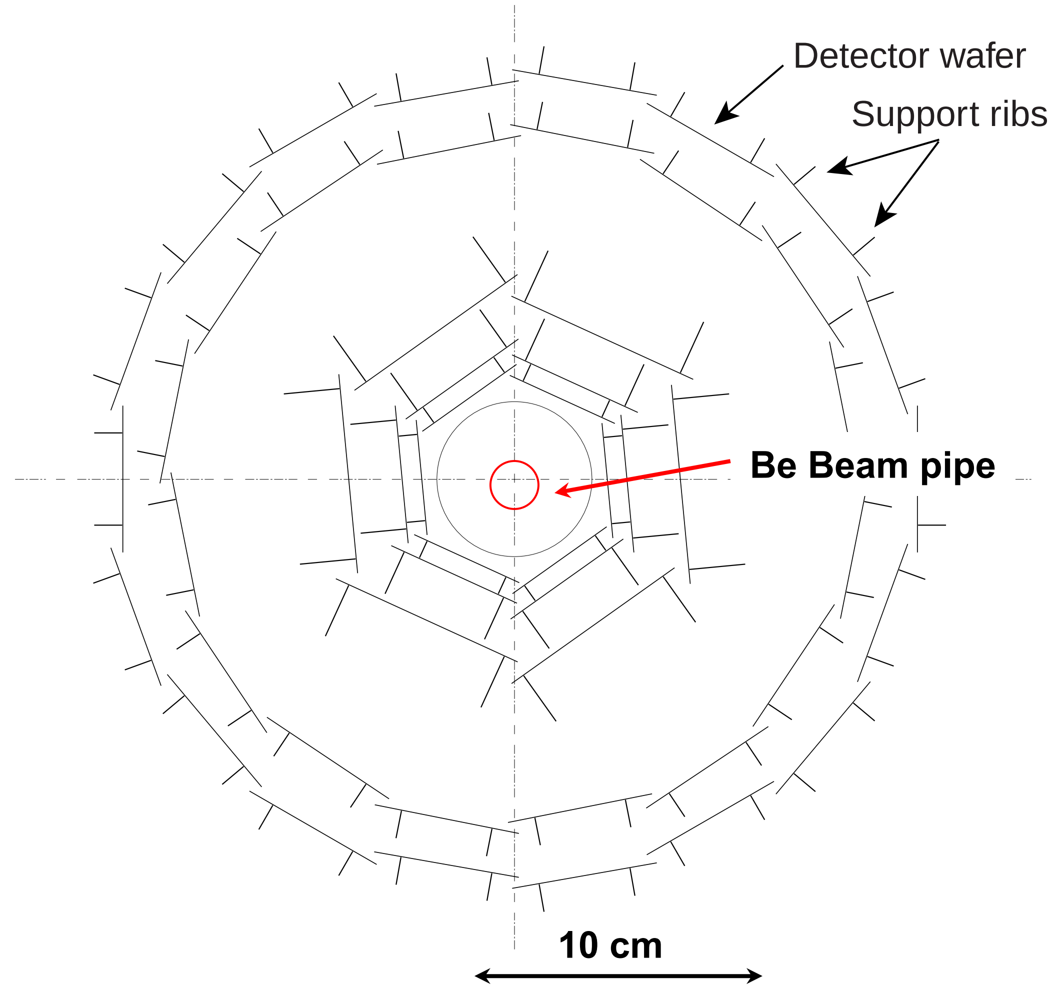
- 5 Layers of double-sided, AC-coupled Silicon.
- Custom rad-hard readout IC (the AToM chip).
- Low-mass design. (Pt < 2.7 GeV/c^2 for B daughters)
- Stand-alone tracking for slow particles.
  - Inner 3 layers for angle and impact parameter measurement.
  - Outer 2 layers for pattern recognition and low Pt tracking.



SuperB SVT Geometry

ADDED →

Layer	Radius
0	1.05 cm
1	3.3 cm
2	4.0 cm
3	5.9 cm
4	9.1 to 12.7 cm
5	11.4 to 14.6 cm



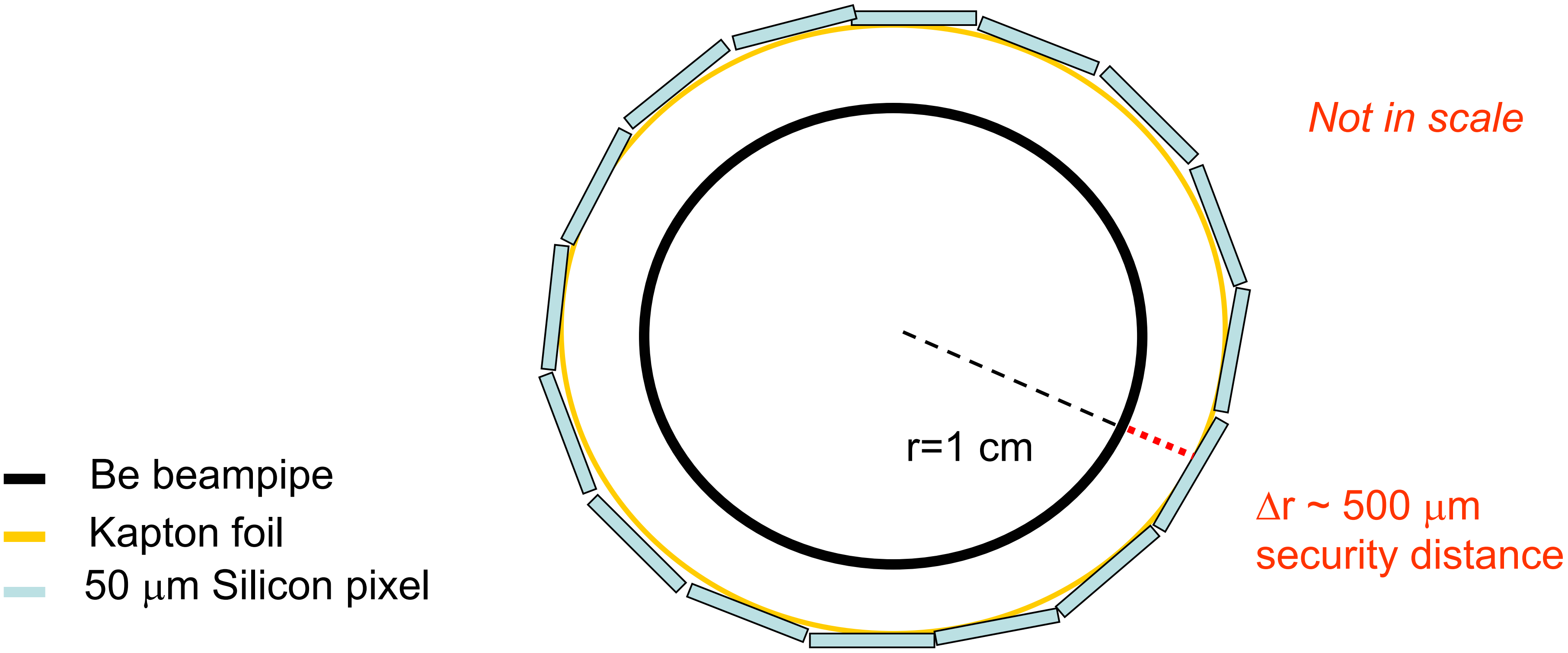
(Arched wedge wafers not shown)

- Added layer0
- Reduced beampipe radius 2.5→1cm
- Reduce Be thickness 1.3→0.3mm
- 5 μm Au foil before layer0

Layer0 design

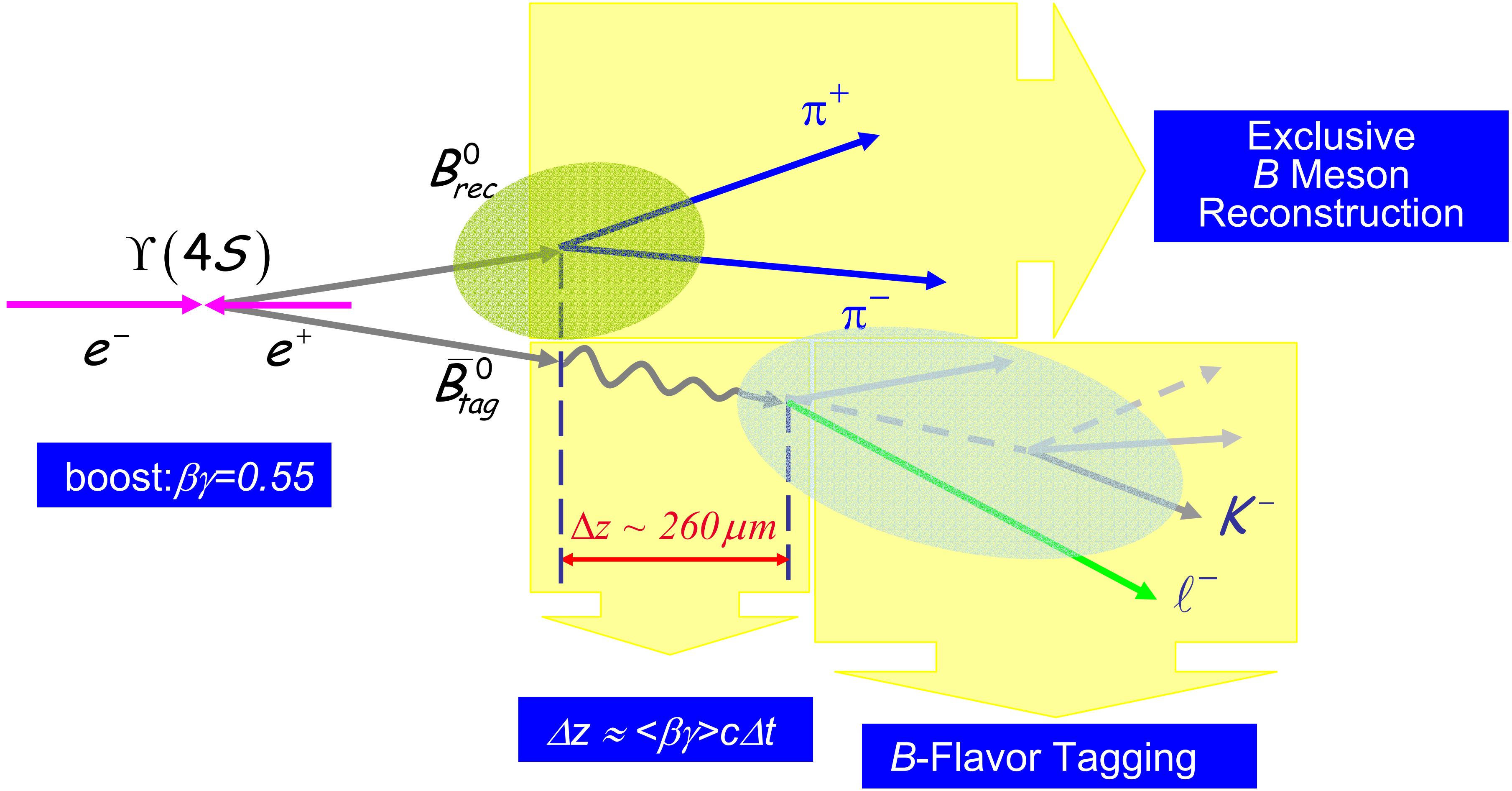
New conceptual design for layer0

- Use kapton foil ~50 μm as support structure for the Si pixel
- Beam pipe radius set the radial distance for the layer0
- Rule of thumb: vertex resolution improves almost linearly with layer0 radial distance

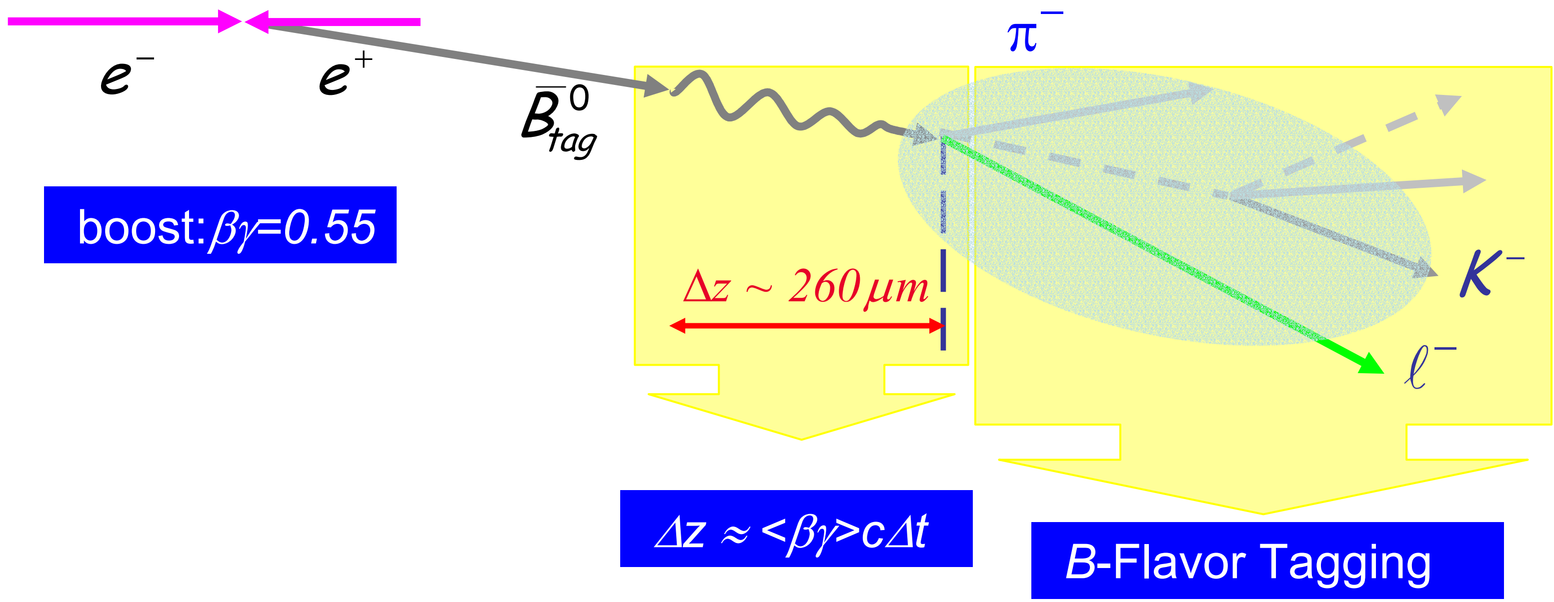


Time dependent measurement

Fundamental ingredients for TD measurements are the B reco vertex and B tag vertex.
In current B-factories tag vertex resolution is O(100 μm) and dominates the resolution on Δz.
B vertex resolution is O(50 μm) depending on the specific B decay mode.



B Tag Vertex



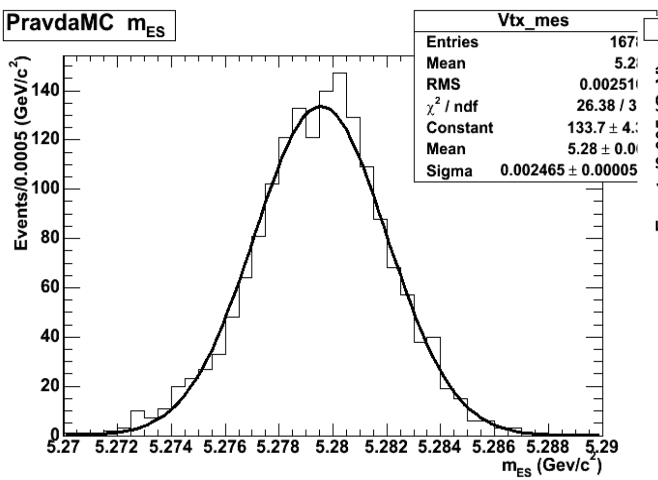
Tag vertex determination is worsened by several effects:

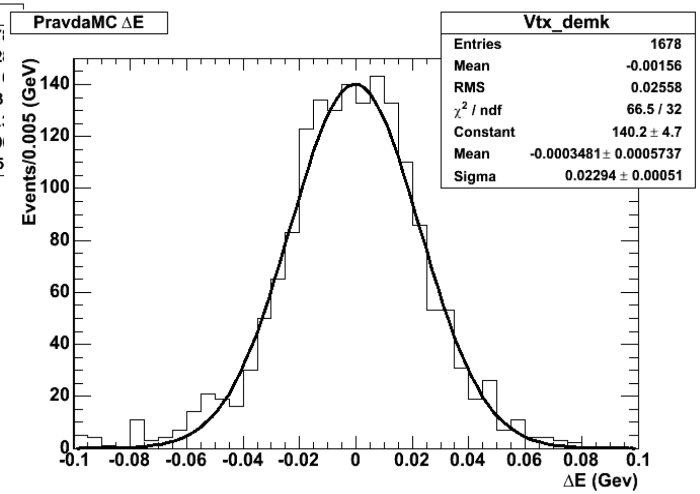
- multiple scattering: B decays with multiple daughters have low momentum tracks.
- long living particles: secondary vertex from charm decays.

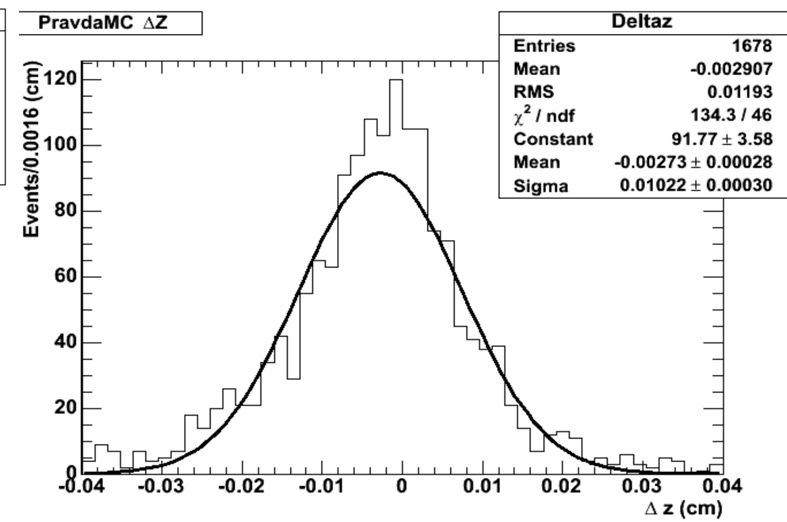
We considered the standard BaBar algorithm which consider all the tracks of the rest of the event (removed B reco, K_s and Λ_c tracks) and fit for the vertex.
A recursive algorithm rejects tracks not consistent with the vertex based on a χ^2>6 cut, reduce significantly the impact of secondary vertex tracks.

PravdaMC: simulation software

- PravdaMC is a fast simulation software which uses parameterization to simulate detector response.
- It has been validated and tested. It is able to reproduce current detector performances up to a good level of accuracy.



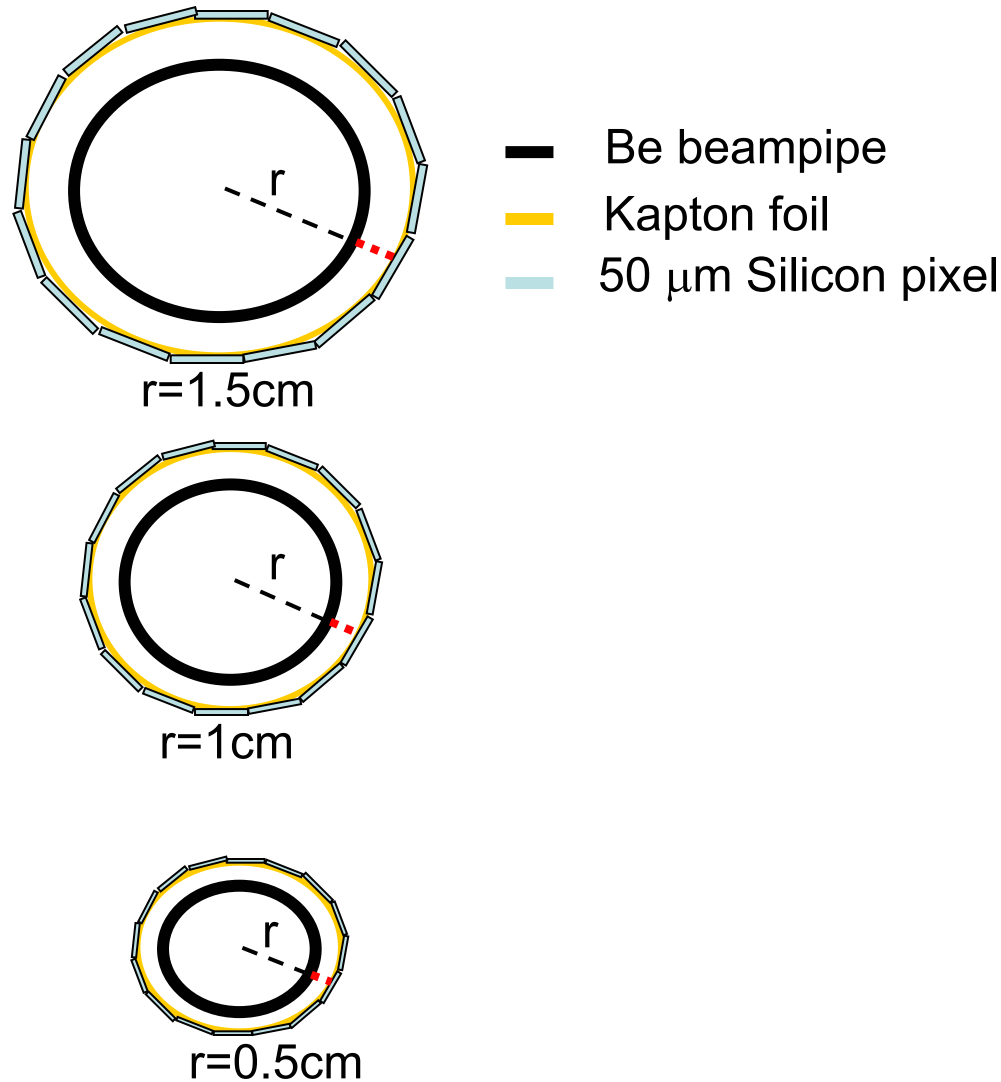




$\sigma(mES) \sim 2.5$ MeV $\sigma(\Delta E) \sim 23$ MeV $\sigma(\Delta z) \sim 102\ \mu m$

Beam-pipe scenarios

- **conservative scenario:**
  - beam pipe radius 1.5cm
  - hit resolution z,ϕ side = 10 μm
- **most likely scenario:**
  - beam pipe radius 1.0cm
  - hit resolution z,ϕ side = 10 μm
- **aggressive scenario:**
  - beam pipe radius 0.5cm
  - hit resolution z,ϕ side = 5 μm

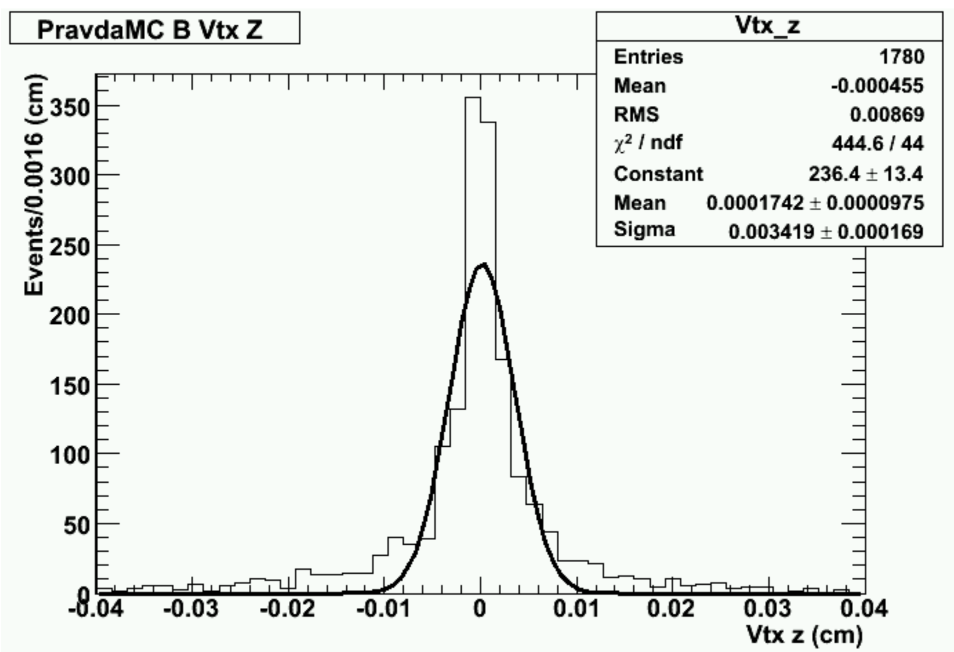


B Vertex beam-spot constraint

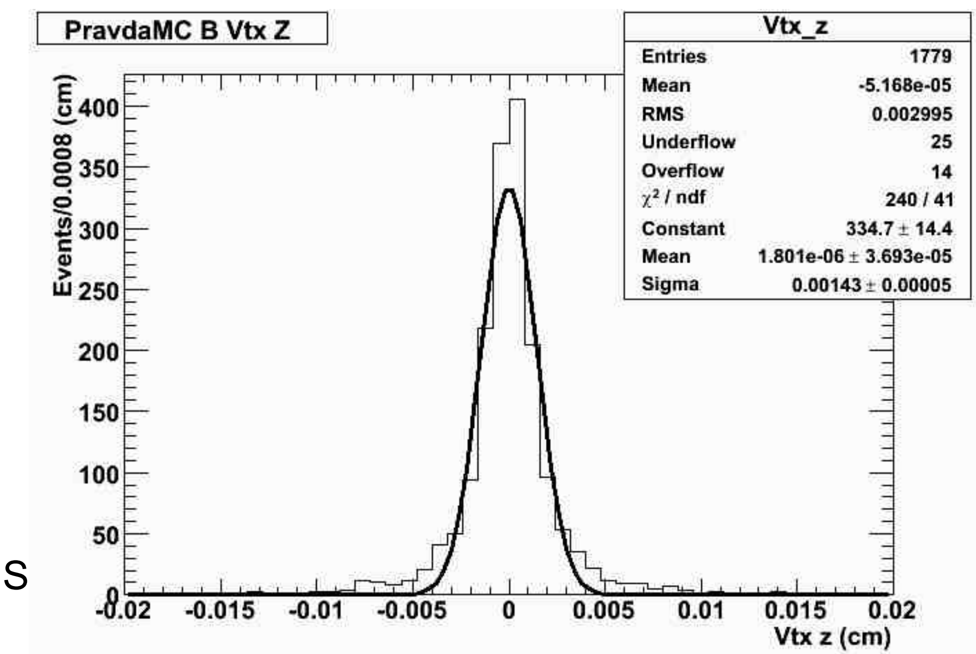
- The beamspot constraint forces the B production vertex to be inside the beam-spot.
- The $B^0 \rightarrow \pi\pi$ vertex benefits from the beam-spot constraint especially at lower $\beta\gamma$ where the 2 tracks are almost back-to-back in the lab frame.

$\beta\gamma$ = 0.10 beampipe=1cm
No beamspot constraint

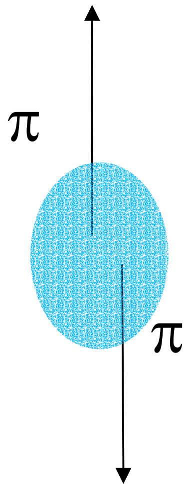
$\beta\gamma$ = 0.10 beampipe=1cm
with beamspot constraint



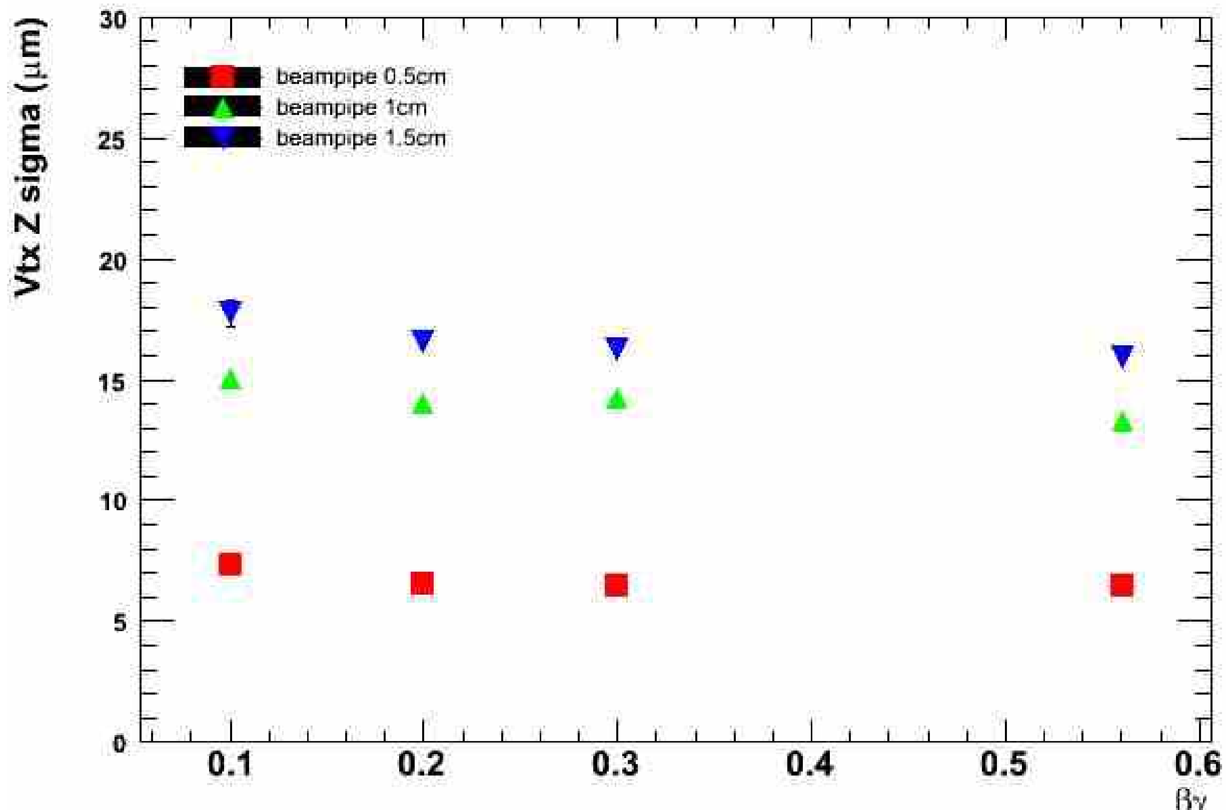
S

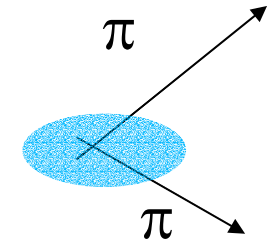


Reco Vertex Resolution



$\beta\gamma = 0.1$





$\beta\gamma = 0.56$

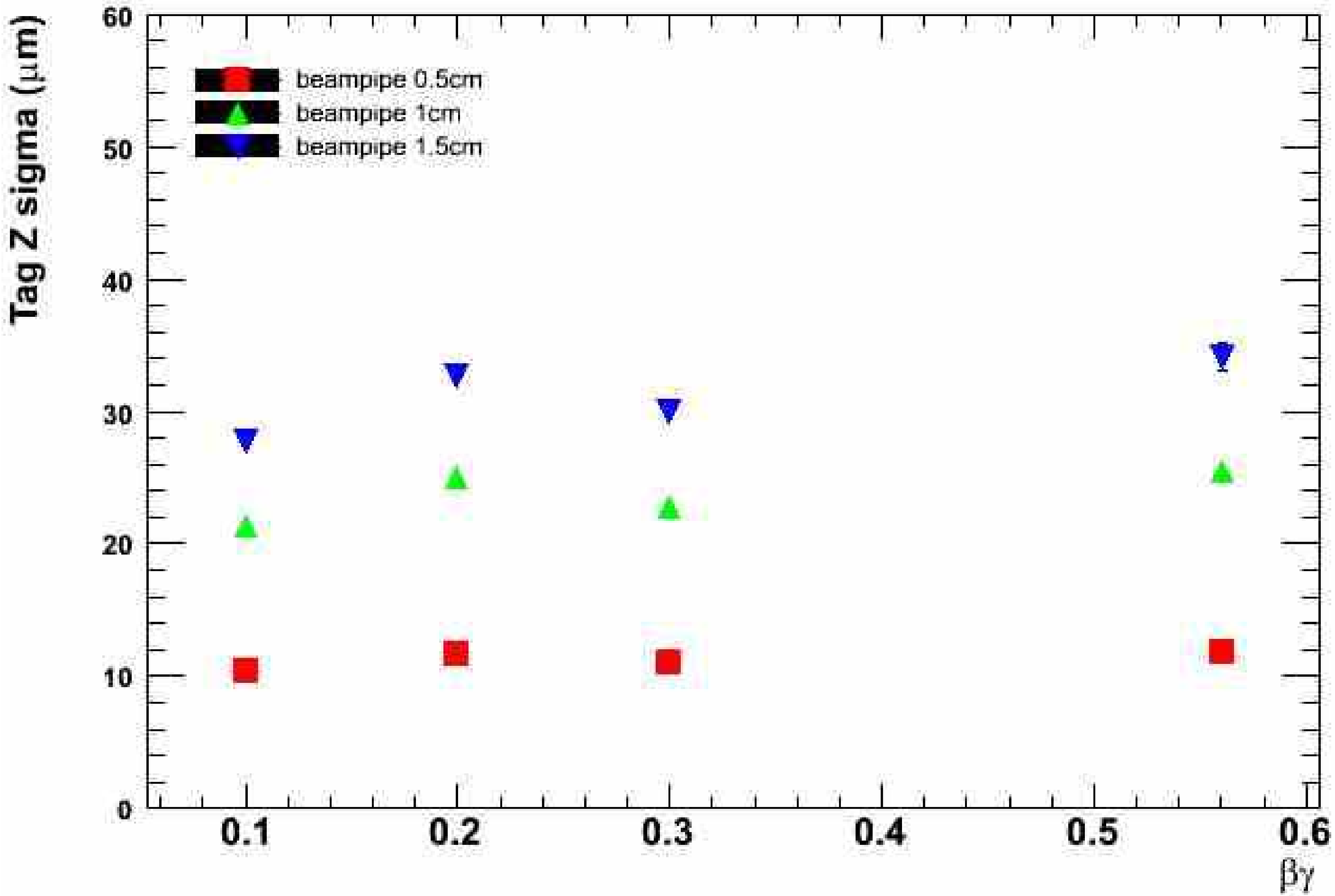
- Very mild dependence from the boost value. The boost enlarges the momentum but reduces the incidence angle wrt the Si layer.
- $\sigma_{ms} \approx \frac{14}{P(MeV)} R_1 \sqrt{x/X_0}$ $\qquad \sigma_{res} \approx \sigma_0 \sqrt{1 + 2\left(\frac{R_1}{R_2 - R_1}\right)^2}$

rule of thumb

I get $\sigma = \sigma_{ms} \oplus \sigma_{res} = 15.2 \mu m$

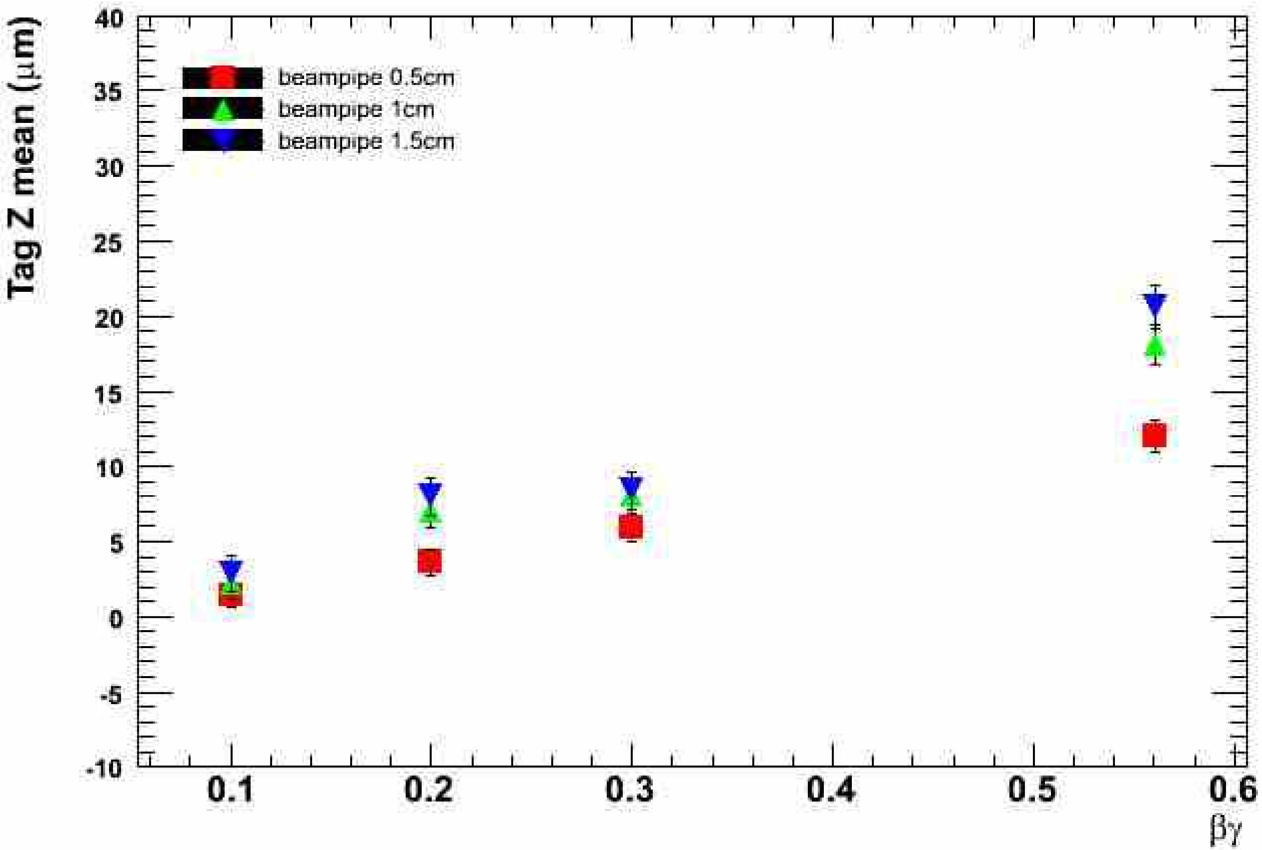
1 GeV tracks and 1cm configuration consistent with 15 μm from simulation.

Tag Vertex Resolution



Resolution constant as a function of the boost. Vertex efficiency is not affected. The resolution still dominates the Δz but great improvements!

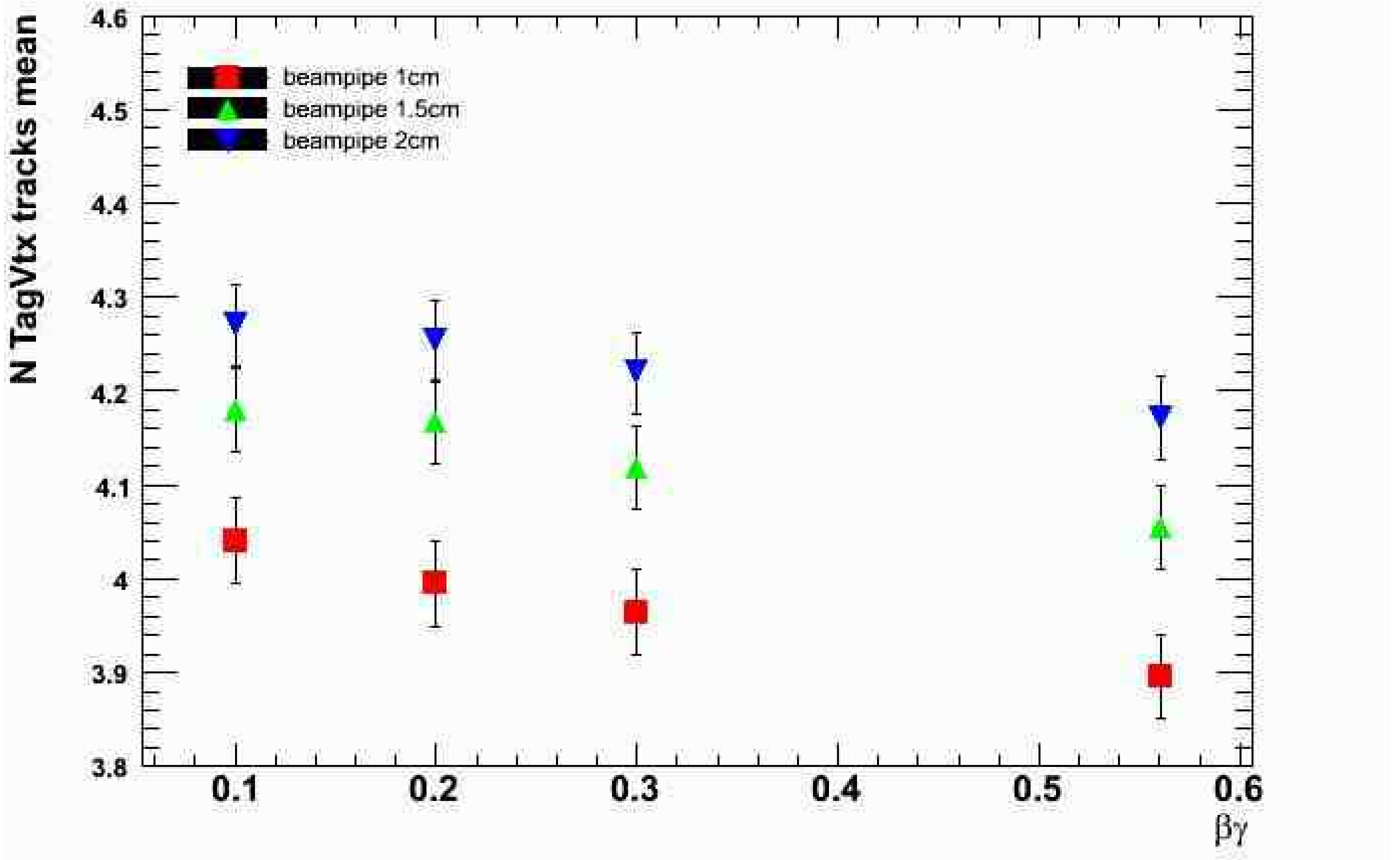
Tag Vertex Bias



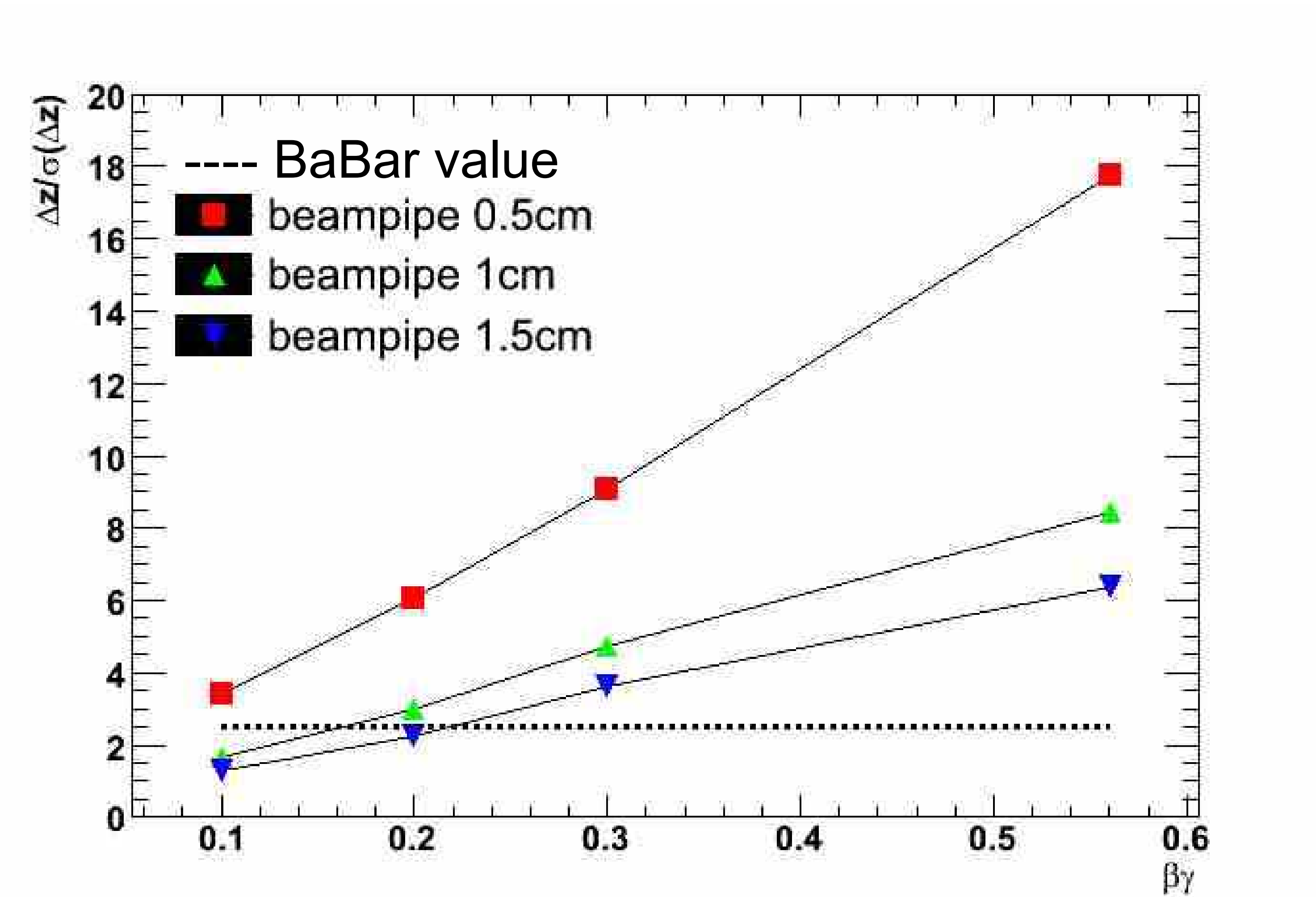
The tag vertex bias increases with the boost.
It depends also on the beam-pipe radius since the TagVertex algorithm better discriminates the secondary vertex tracks.

Tag vertex bias

- The charm bias reduces approx linearly with the boost.
- It reduces also with smaller beam pipe radius, i.e. with better determination of the tracks parameters.
- Number of tracks to determine the Tag Vertex decreases with a smaller beam-pipe radius. The track rejection algorithm (χ^2>6) can remove more bad tracks in superB configuration.



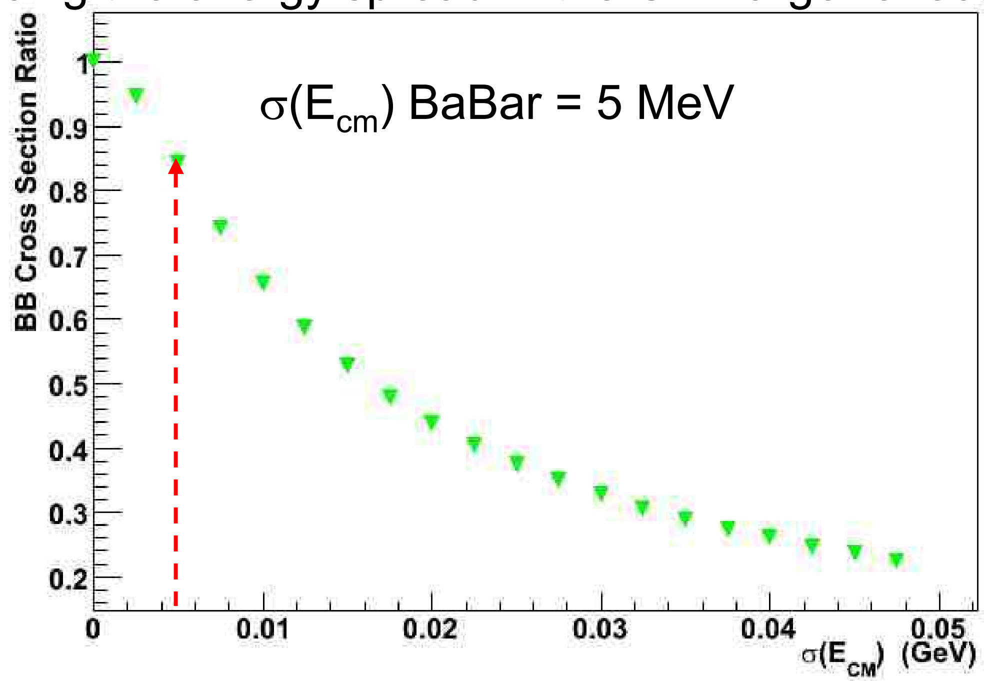
<ΔZ>/σ(ΔZ) vs βγ



Δz/σ(Δz)
---- BaBar value
beampipe 0.5cm
beampipe 1cm
beampipe 1.5cm
0
2
4
6
8
10
12
14
16
18
20
0.1
0.2
0.3
0.4
0.5
0.6
βγ

Benefits of reducing $\beta\gamma$

• Help reducing the energy spread in the CM: larger effective $b\bar{b}$ cross section



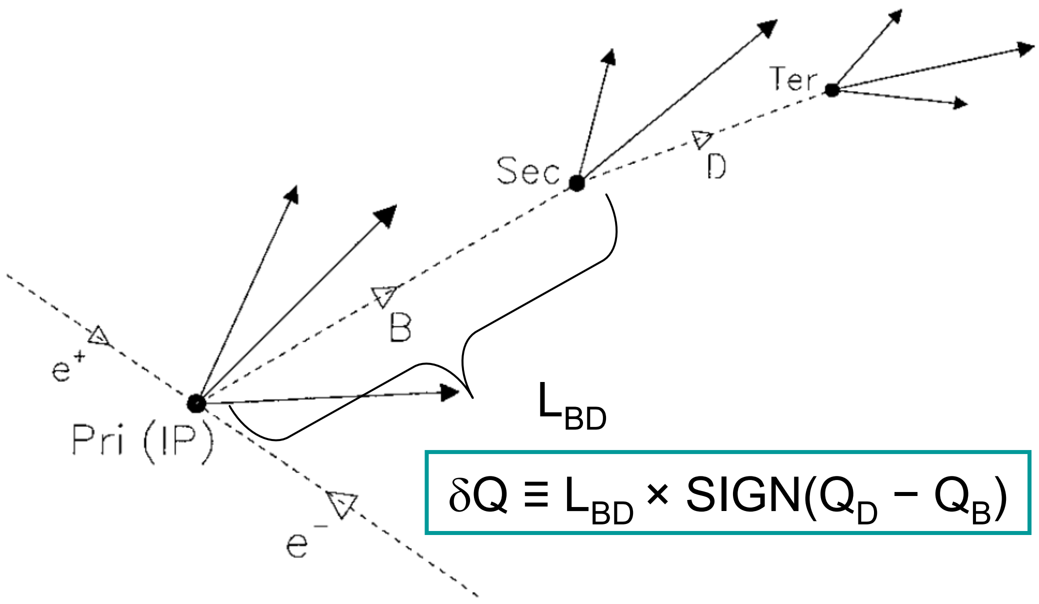
• Therefore better resolution on bkg discriminating variables (Energy substituted mass). $\sigma(m_{ES})\sim\sigma(E_{cm})$ /2

• better angular acceptance: e^-=7.0 GeV e^+=4.0 GeV $\beta\gamma$=0.28 and for θ=100 (300) mrad correspond to 99% (92%) coverage in the CM. BaBar has 88% coverage.

• an hermetic detector can detector improves significantly the sensitivity to decay modes with neutrinos (ex. $B\rightarrow\tau\nu$, $B\rightarrow D\tau\nu$ and τ decays).

Benefits of better vertexing

- Better vertex determination not only impacts the time dependent measurements but all the analysis in general.
- The Δz helps rejecting continuum uds events.
- One can think about *“ad-hoc”* topological algorithm to further discriminate against combinatorial bkg.
- If you are able to separate the D vertex from the B vertex. You can determine the flavor of the tag B decay from the charge difference between the B and the D.
- SLD tagging “dipole based” (δQ) technique could be helpful. $\delta Q>0$ ($\delta Q<0$) means B0bar (B0).



$$\delta Q \equiv L_{BD} \times \mathrm{SIGN}(Q_D - Q_B)$$

- ***REDUCE BKG***
- ***IMPROVE TAGGING PERFORMANCES***

Conclusions

- Precise decay vertex determination is fundamental for a SuperB-factory.
- Lower $\beta\gamma$ values improve the energy spread CM, therefore the resolution on bkg discriminating variables and the effective bb cross-section and increase the detector acceptance.
- A $\beta\gamma > 0.10$ should be considered for the beam-pipe and SVT layout studied so far.
- A $\beta\gamma = 0.20\text{-}0.30$ is advisable for the most likely IP configuration.
- Improved vertex performances not only impacts the Time Dependent measurements. They permit to improve bb effective cross-section, bkg rejection, tagging.