L_0 solutions and impact on time-dependent measurements

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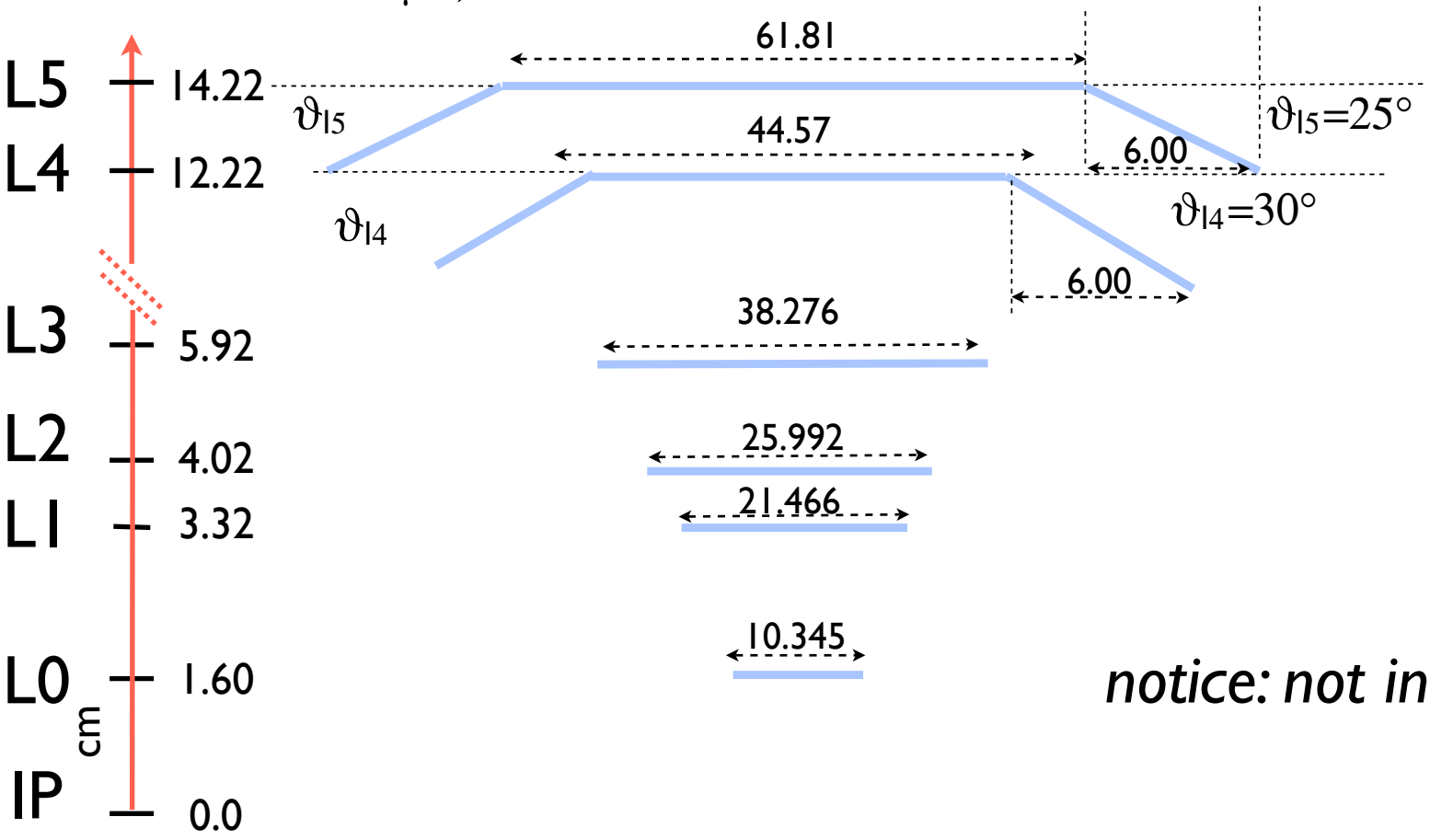
1. SuperB baseline:

- SVT baseline: L0 + L1-L5 strip detectors, ±300 rad angular coverage;
- DCH baseline: 10 SuperLayers (4 cell layers per SL); inner radius 23.6 cm, spatial resolution 125 μm;



notice: not in scale

Coverage down to 300 mrad FW and BW

L_0 solutions: striplets vs Hybrid pixels

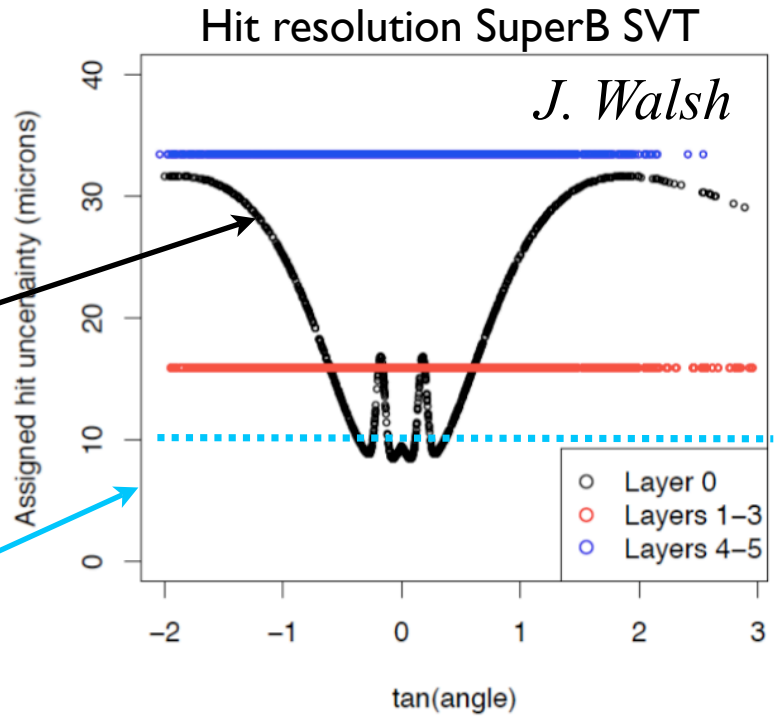
Decision will be based on bkg rates on L_0, dominated by pair production process $e^+e^- \rightarrow e^+e^-e^+e^-$. According to recent bkg simulations, (see Riccardo Cenci's talk) hit rate on L_0 is reduced compared to previous estimates and a striplet L_0 solution looks viable in terms of occupancy.

Hybrid Pixel

- material= 1.08% X_0
- digital readout
- average radius = 1.60 cm
- hit res ~ <14 μm> (ad hoc model)

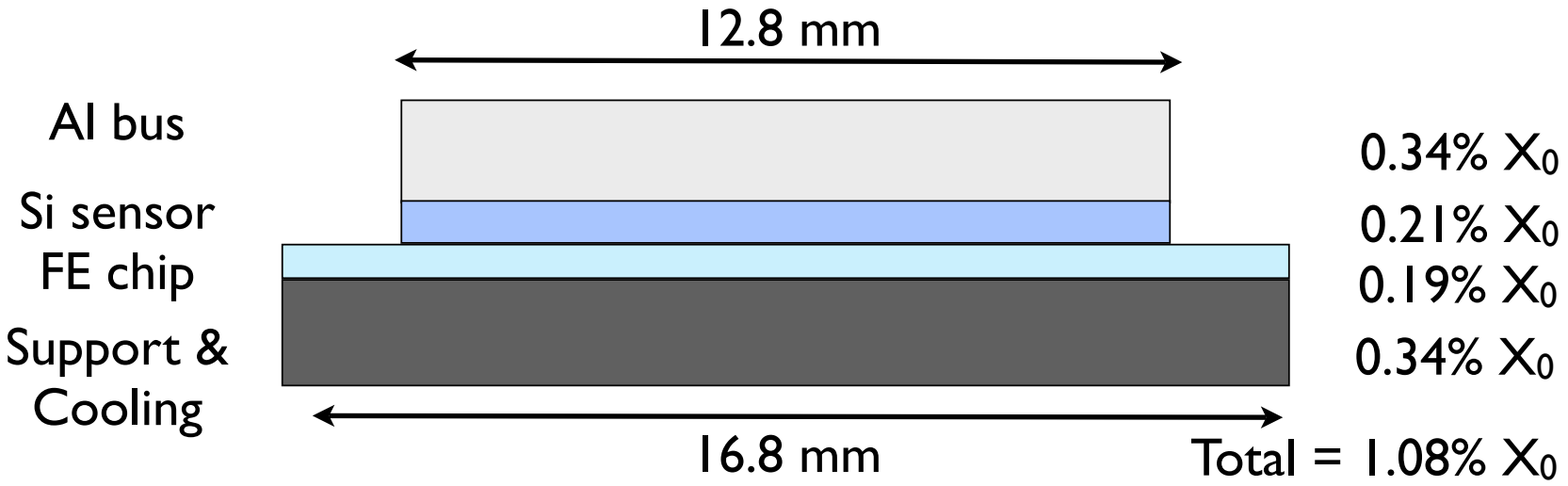
Striplets

- material= 0.4% X_0
- analog readout
- average radius = 1.60 cm
- hit res ~ 8 μm (core gaussian)



Hybrid pixel solution

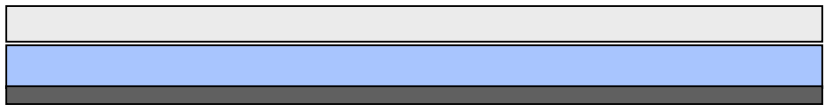
- Module cross section



Striplet solution

- Module cross section

Fan out
Si sensor
Support

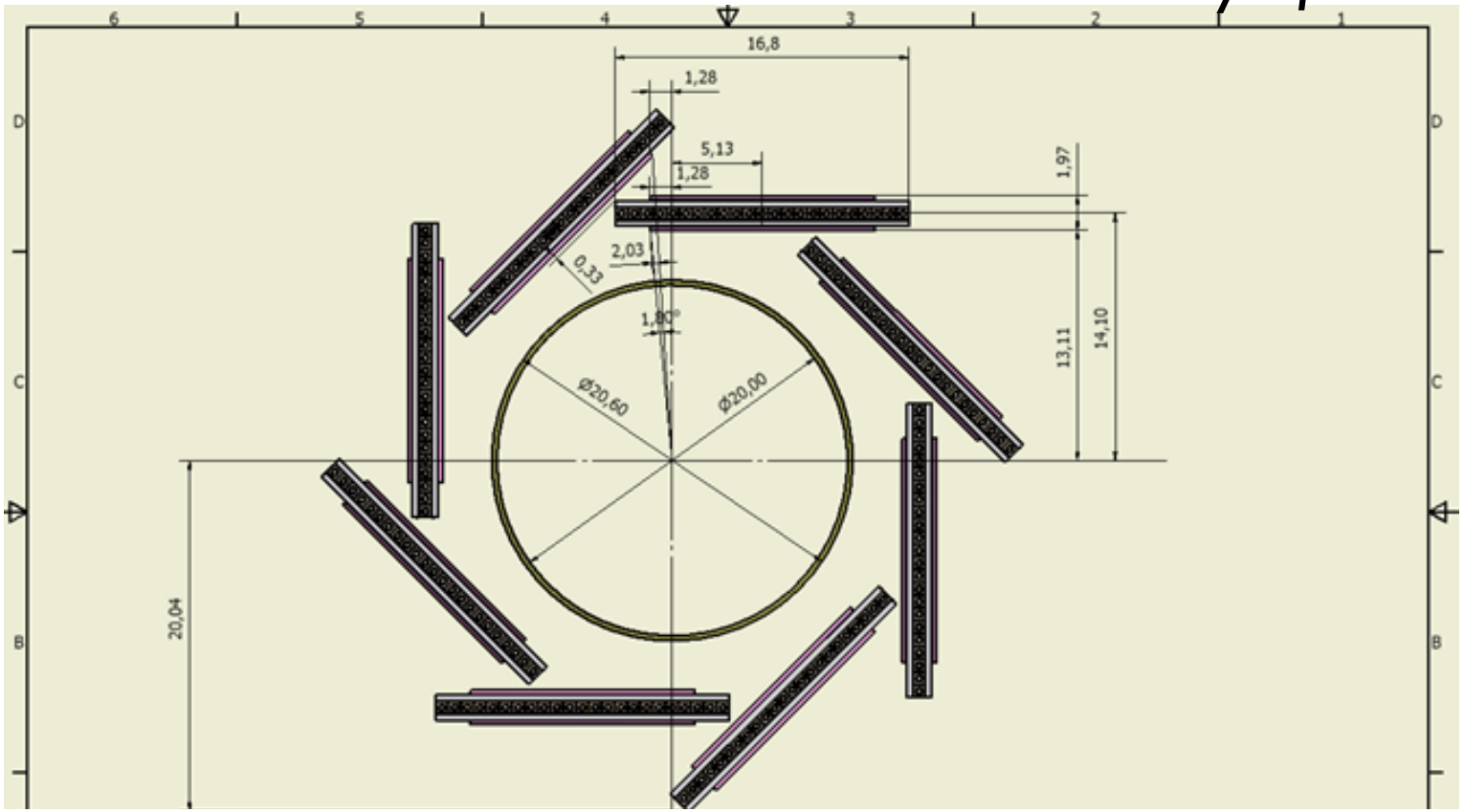


Si sensor overlap 3.4%

0.14% X_0
0.21% X_0
0.05% X_0
Total = 0.40% X_0

Pinwheel layout for L_0

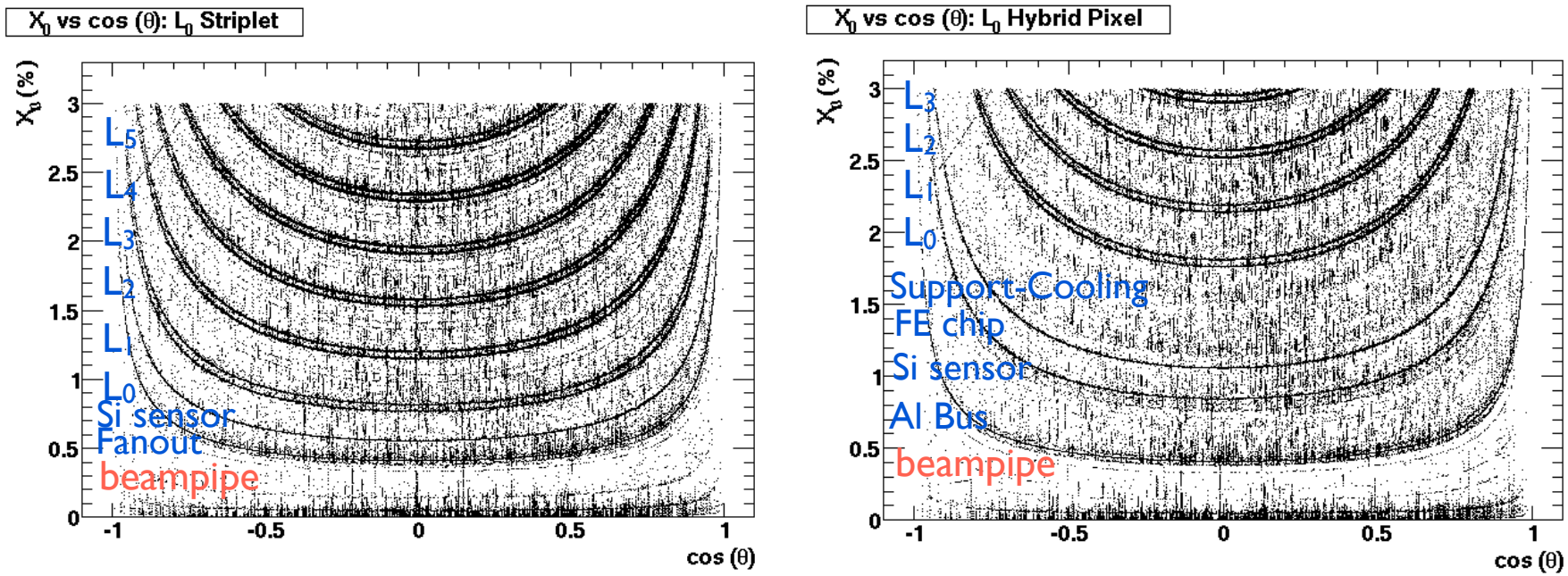
courtesy of F. Bosi



Design for MAPS solution

Mechanical design can be considered valid also for Hybrid Pixel solution though small changes could be applied when finalized design will be ready.

L_0 solutions and SVT material



Total SVT material is about 3.3% (2.4%) X_0 for L_0 Hybrid pixel (Striplets) solution.

L_0 impact on Δt resolution for $B^0 \to \phi K_S$

- Reconstruct $B^0 \to \varphi K_S$, $\varphi \to K^+K^-$, $K_S \to \pi^+\pi^-$
  - Δt resolution using `TreeFitter` vertex algorithm for B_{rec} with `beam` constraint and `VtxTagBtaSelFit` algorithm for B_{tag}.
  - Apply loose selection cuts: m_{ES}>5.27 GeV, Δt error <10.0 ps, $P(\chi^2_{Vtx})$>0.05, nB=1.

Vertex and Δt resolution

- Improvements with respect to BaBar:
  - additional L_0 at smaller radius
  - reduced beamspot size
  - lower material budget beamp pipe

FastSim parameters

SuperB 1.60 cm

BaBar 3.32 cm

SuperB (5.6 μm, 35 nm, 330 μm)

BaBar (203 μm, 4 μm, 8.5 mm)

SuperB 0.42% X_0

BaBar 1.06% X_0

- Worse wrt BaBar
  - reduction of CM boost

$$\Delta z \simeq \beta\gamma\Delta t \qquad \sigma(\Delta t) \simeq \frac{\sigma(\Delta z)}{\beta\gamma}$$

SuperB $\beta\gamma = 0.28$

BaBar $\beta\gamma = 0.56$

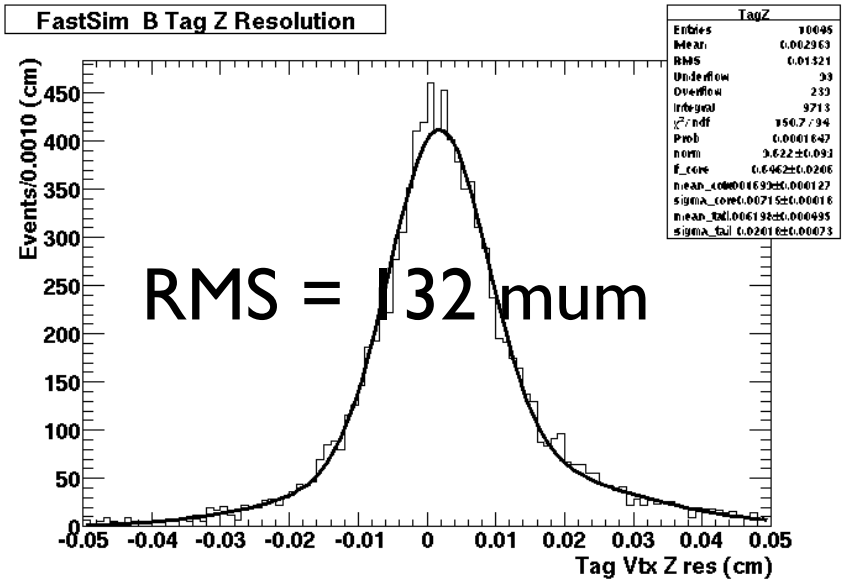
Effect of beamspot constraint

BaBar SVT detector:

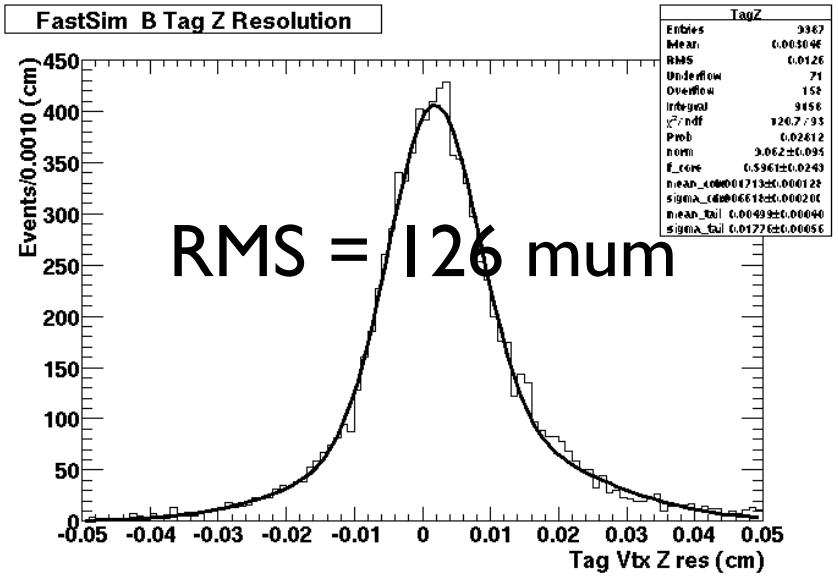
- BaBar beams and beamspot
- BaBar beams and SuperB beamspot
- SuperB beams and beamspot

Tag vertex test

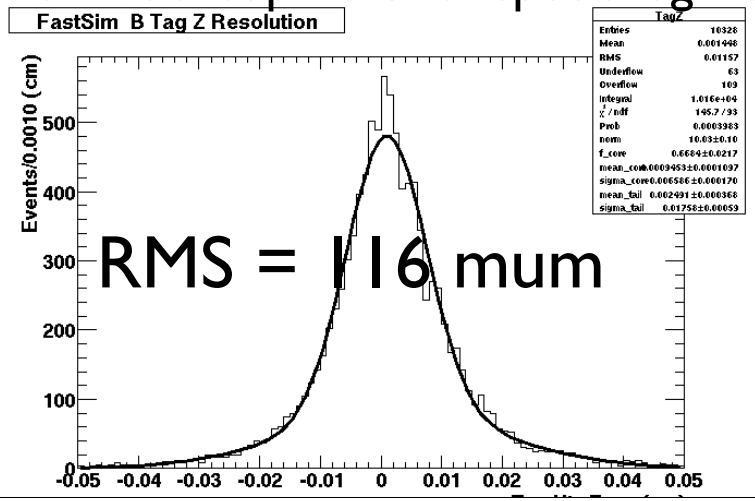
BaBar detector



BaBar det & SuperB beamspot



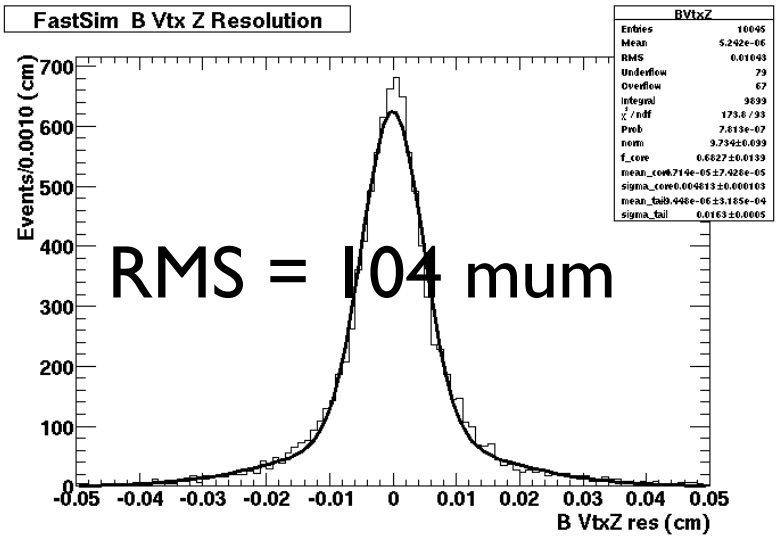
BaBar det & SuperB beamspot & bg=0.28



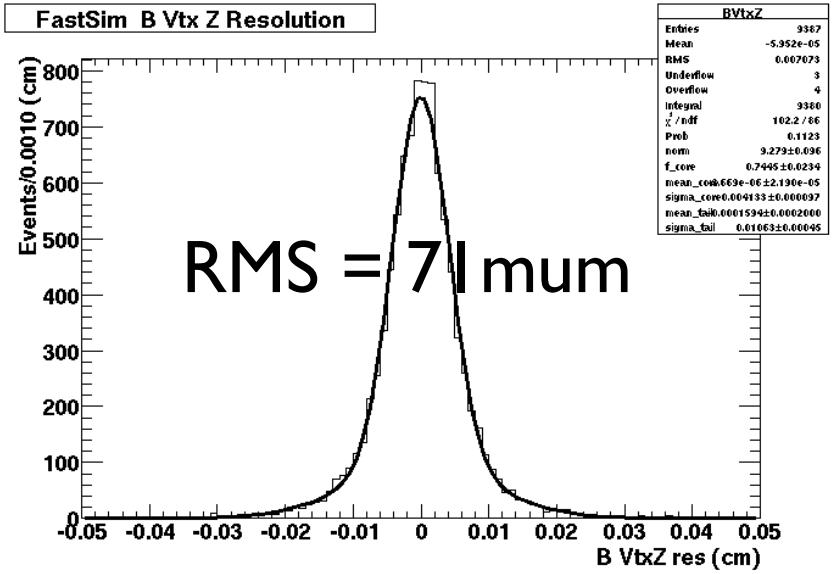
B_{tag} vertex improves because of better beamspot and smaller boost (smaller charm vertex bias)

B_{rec} vertex test

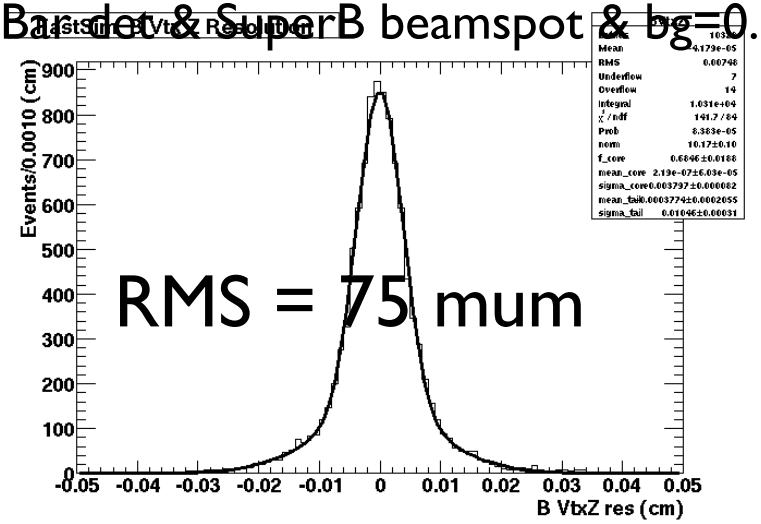
BaBar detector



BaBar det & SuperB beamspot



BaBar det & SuperB beamspot & bg=0.28



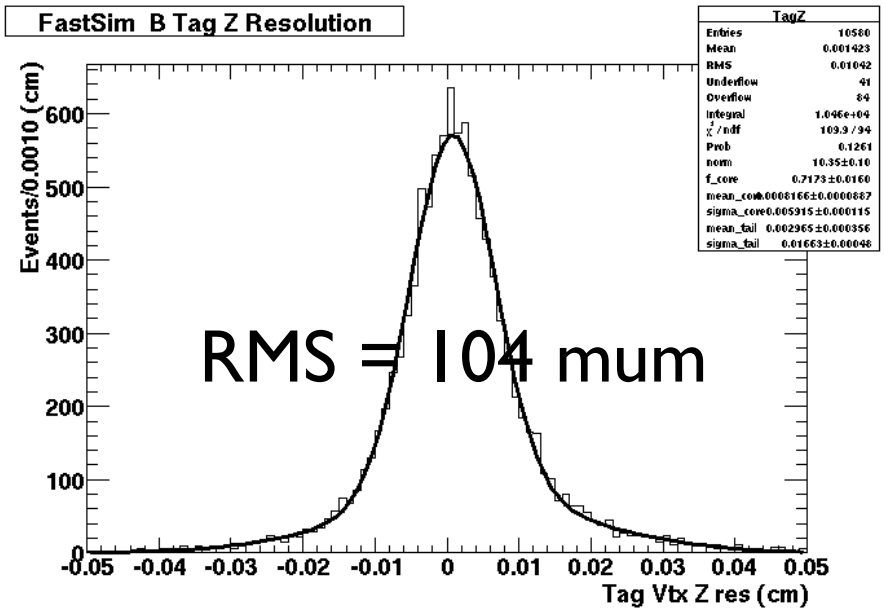
B_{rec} vertex improves because of better beamspot but does not improve reducing the boost

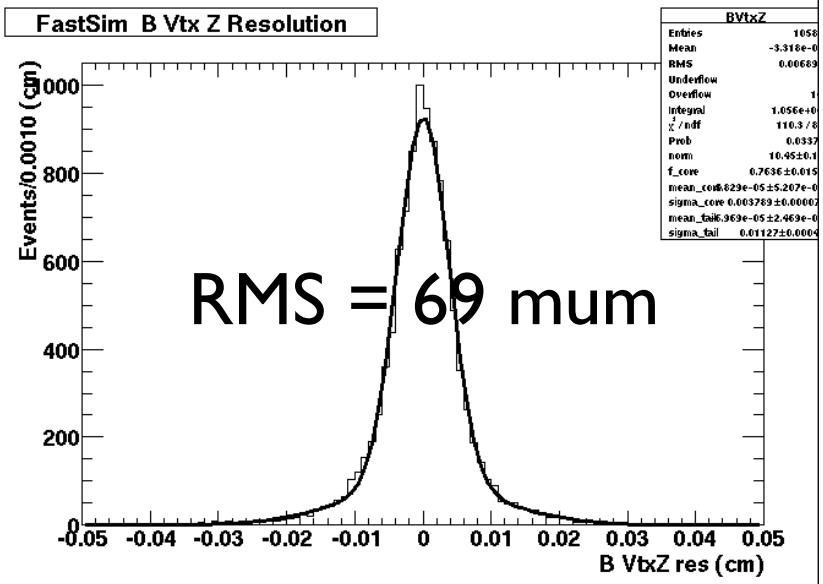
Effect of reduced material beampipe

BaBar SVT detector:

- SuperB beams, beamspot and beampipe

B_{tag} and B_{rec} vertex





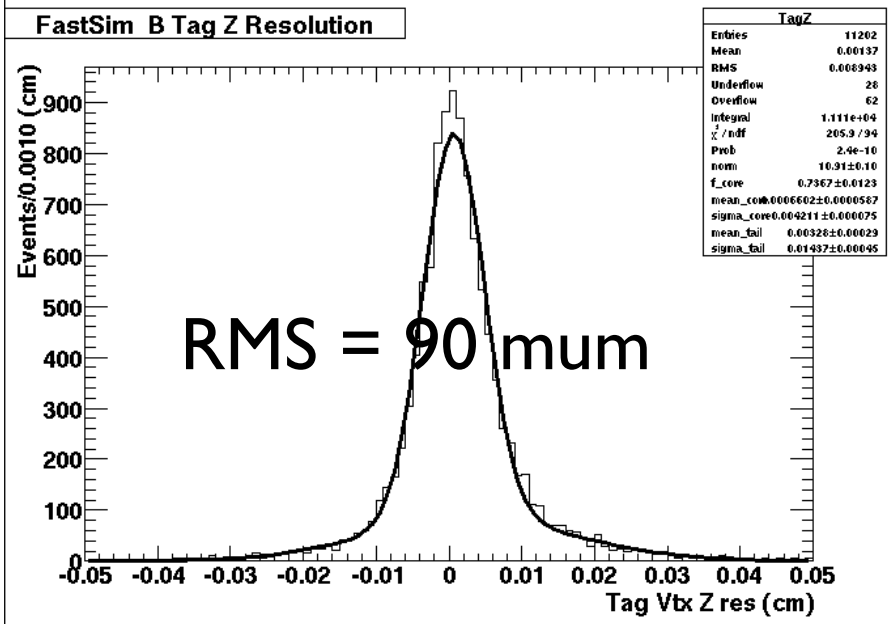
BaBar SVT detector and SuperB beams and beampipe

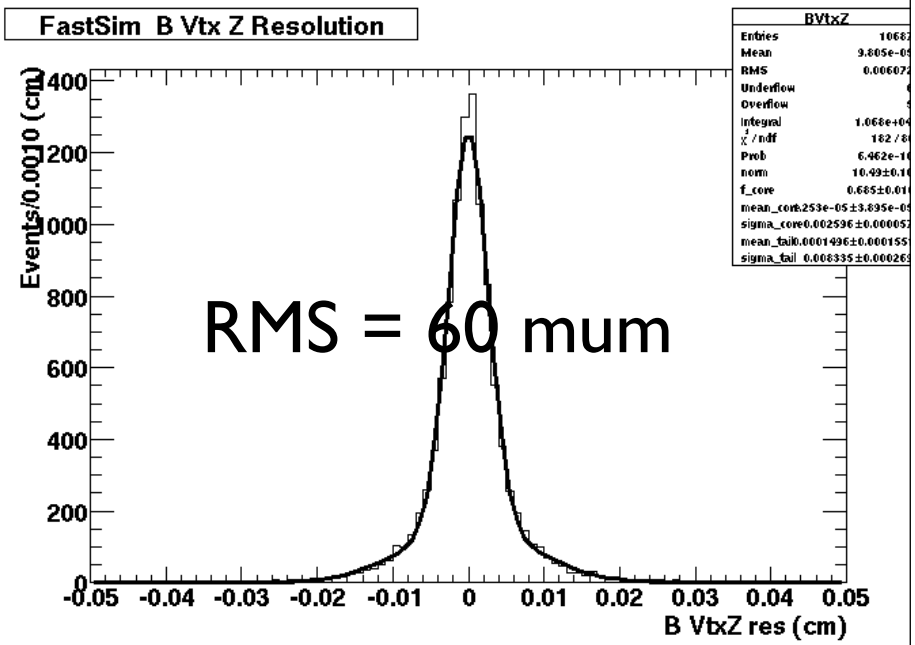
Effect of additional L_0 hit measurement

SuperB SVT detector (Hybrid Pixel L_0):

- SuperB beams, beamspot and beampipe

B_{tag} and B_{rec} vertex





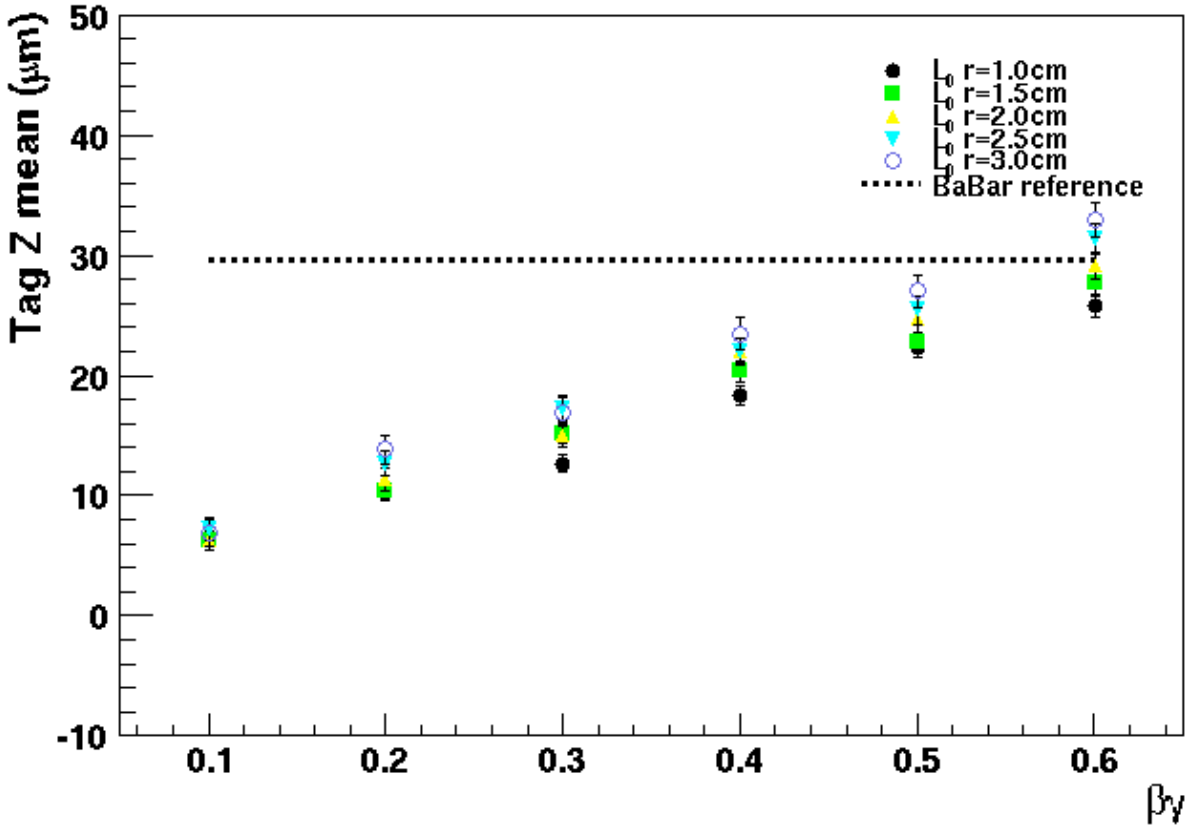
SuperB detector configuration with Hybrid Pixel L_0.
L_0 striplets solution even better especially for B_{tag} vertex with RMS = 73 mum.

Summary of vertex resolution improvements

L_0	boost	beamspot	beampipe	Tag res(μm)	Reco res(μm)	Δt(ps)
no	0.56	BaBar	BaBar	132±1	104±1	1.25±0.01
no	0.56	SuperB	BaBar	126±1	71±1	1.07±0.01
no	0.28	SuperB	BaBar	116±1	75±1	1.71±0.01
no	0.28	SuperB	SuperB	104±1	69±1	1.53±0.01
HP	0.28	SuperB	SuperB	90±1	60±1	1.35±0.01
Str	0.28	SuperB	SuperB	73±1	47±1	1.08±0.01

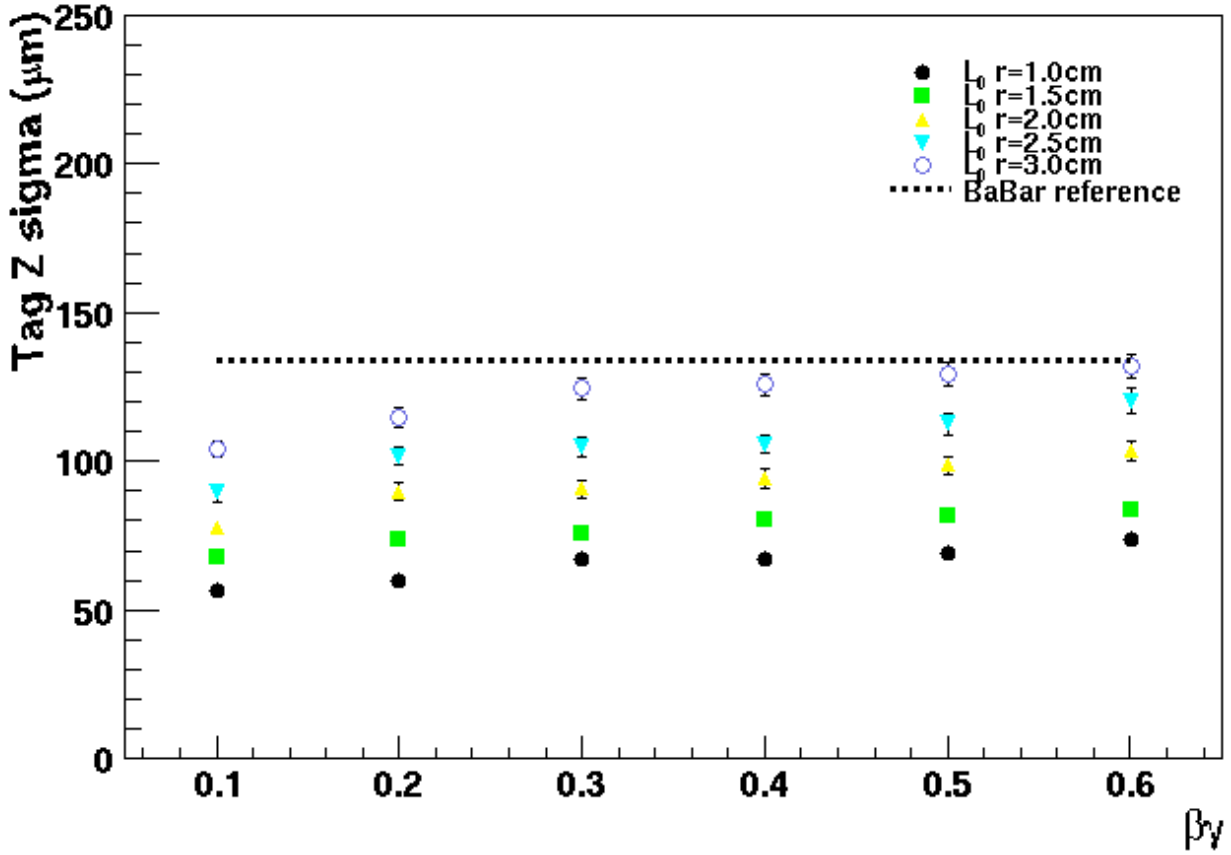
Effect of boost and L_0 radius (L_0 Hybrid Pixel solution)

Tag vertex bias vs boost



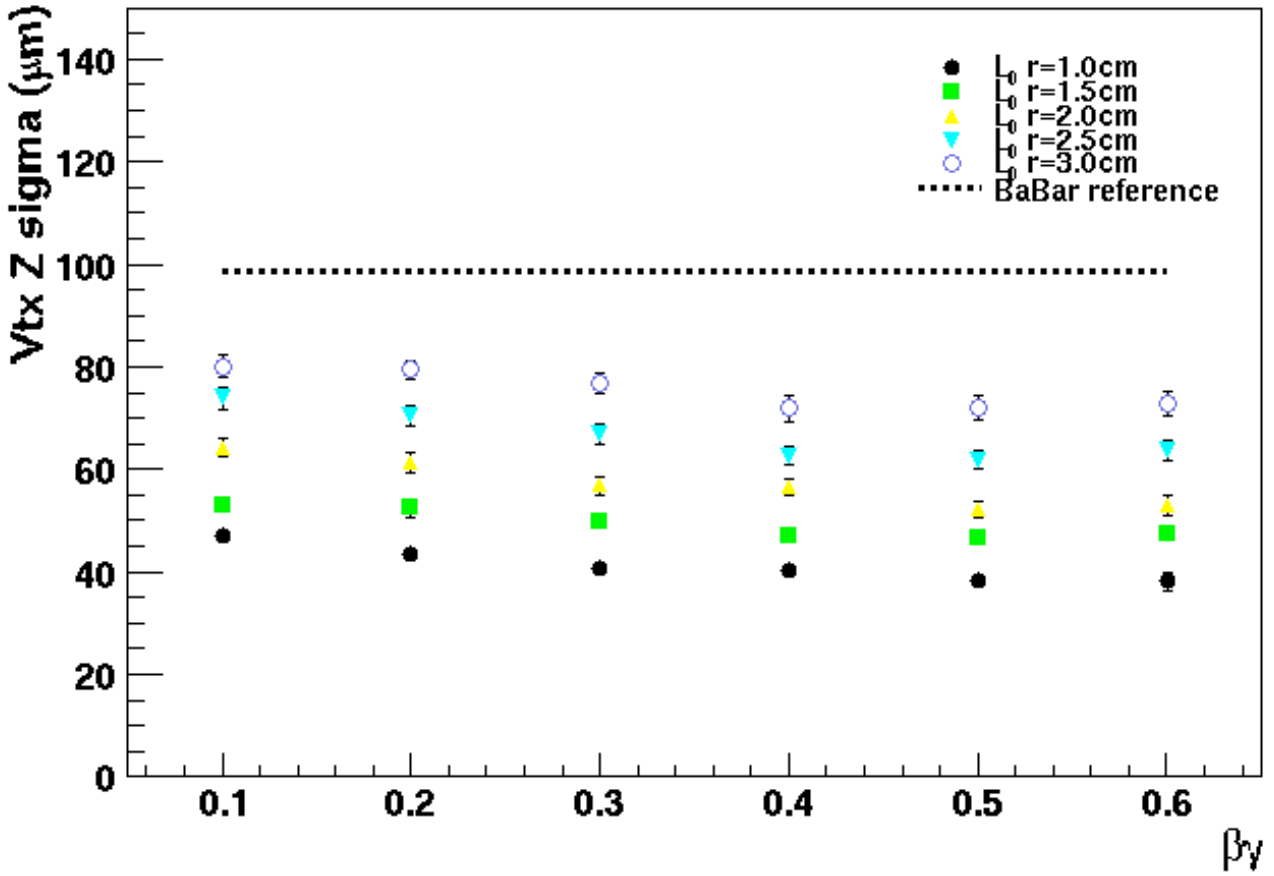
Tag vertex bias increases with boost (and L_0 radius).
Positive effect of boost reduction on vtx resolution.
Reduction charm vertex bias.

Tag vertex resolution



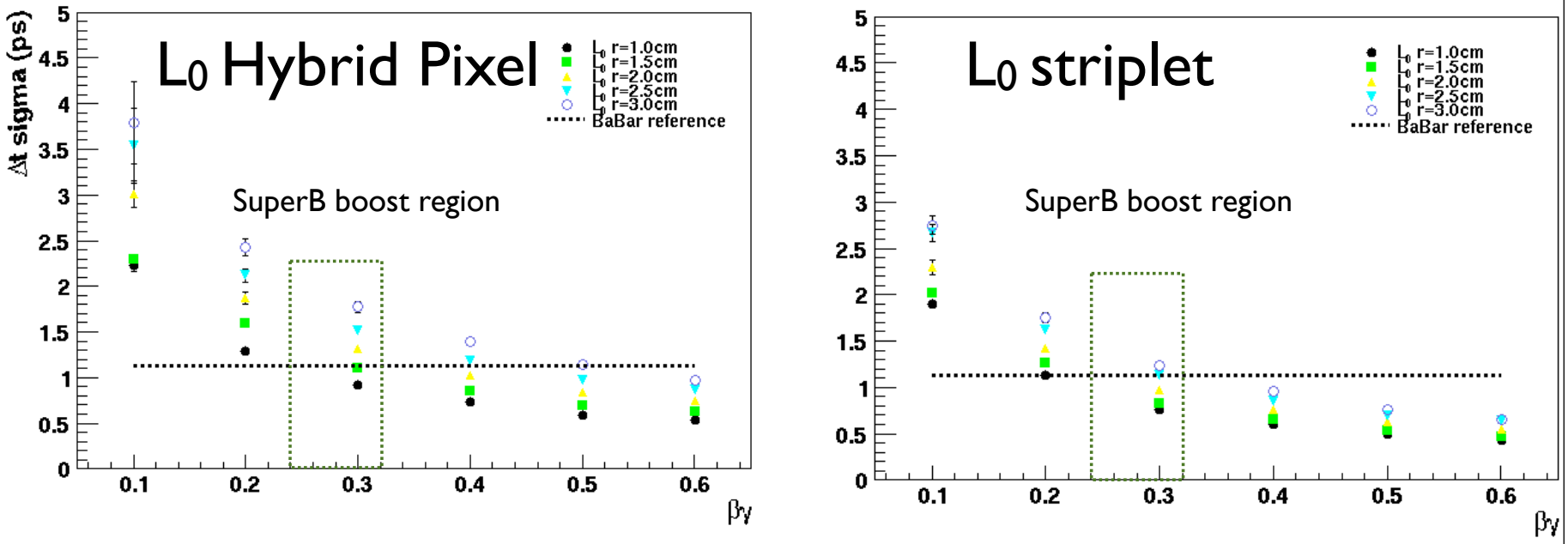
Tag vertex sigma increases with boost oppositely to B_{rec} vertex resolution.
Tag vertex resolution correlated with Charm vertex bias.
Positive effect of boost reduction.

B_{rec} vertex resolution



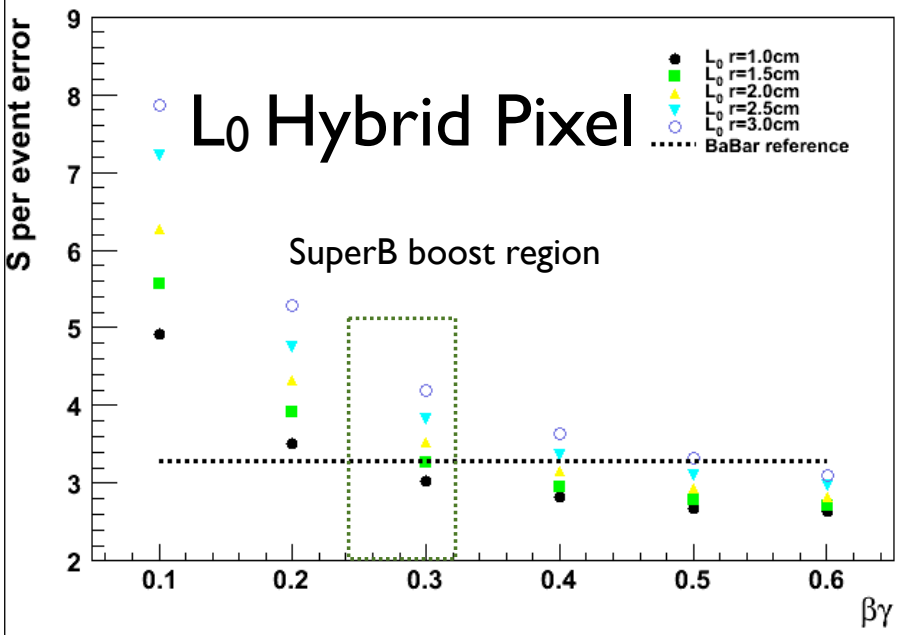
B_{rec} vertex resolution slightly decreases with boost: reduction of multiple scattering by increasing the average track momentum

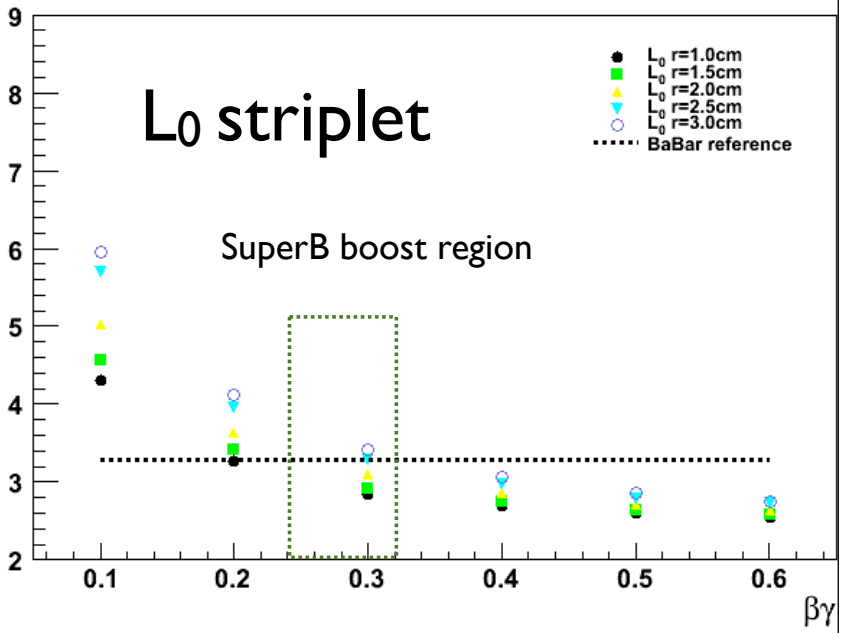
Striplet vs Hybrid Pixel: Δt resolution



Hybrid Pixel solution is reaching BaBar reference of Δt resolution with L_0 radius ~1.5 cm. Striplet solution can afford a larger L_0 radius ~2.0 cm where bkg is much lower.

Striplet vs Hybrid Pixel: S per event error

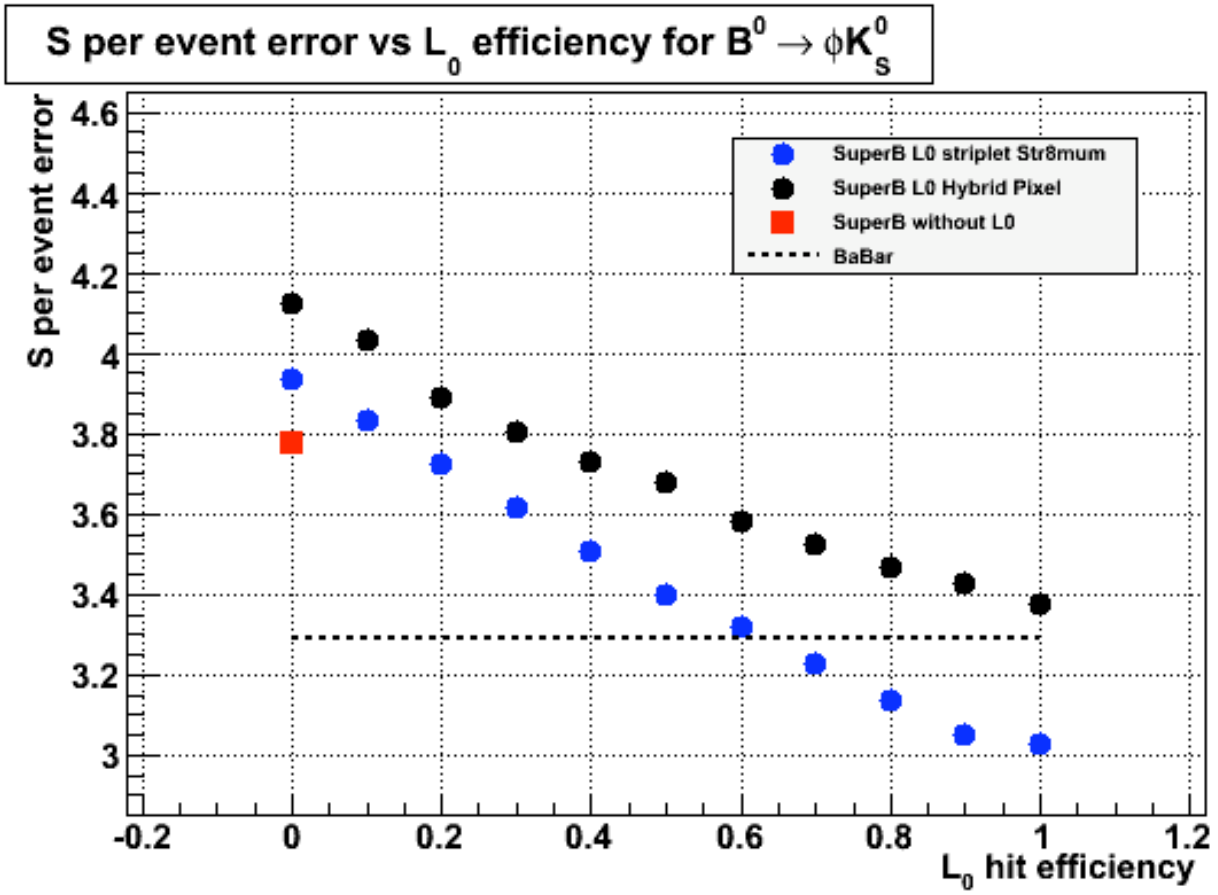




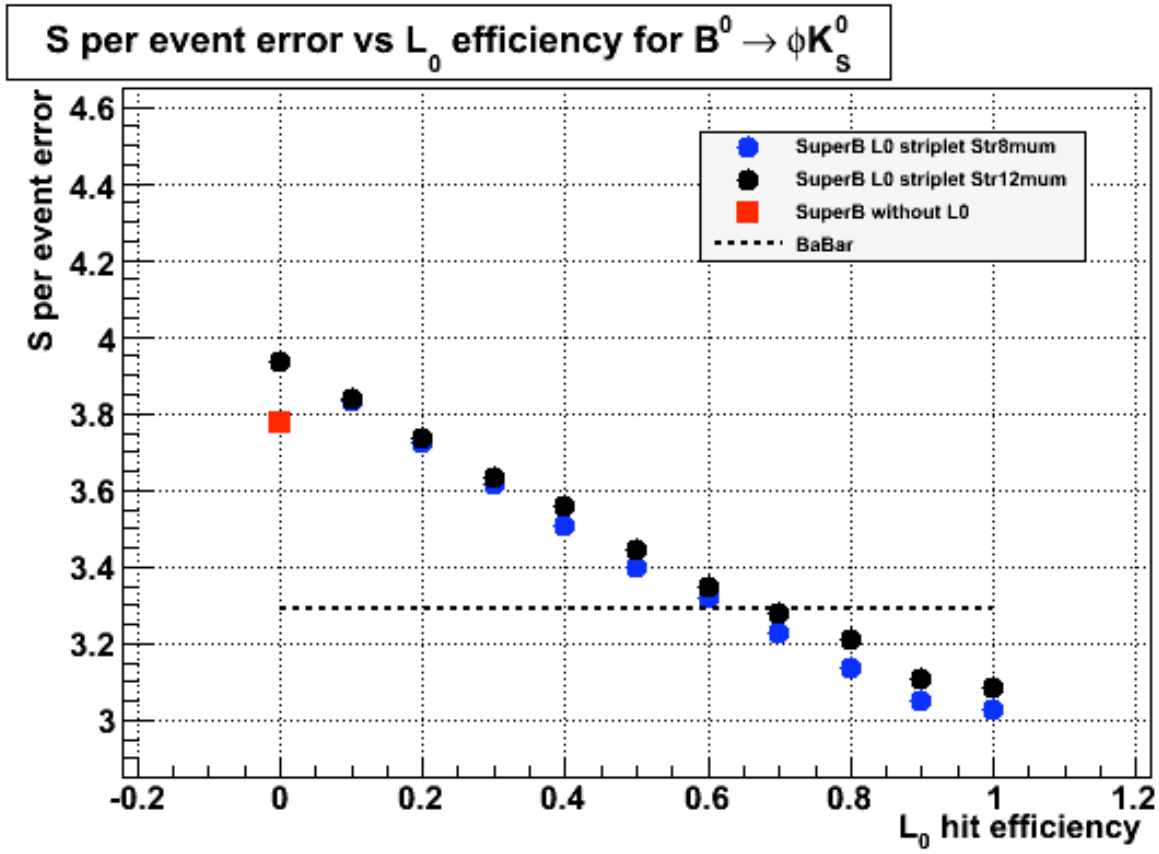
Same story in terms of per event error on S (sin2β).

Effect of L_0 efficiency and hit resolution

Striplet vs Hybrid Pixels



Striplet performance vs degraded hit resolution



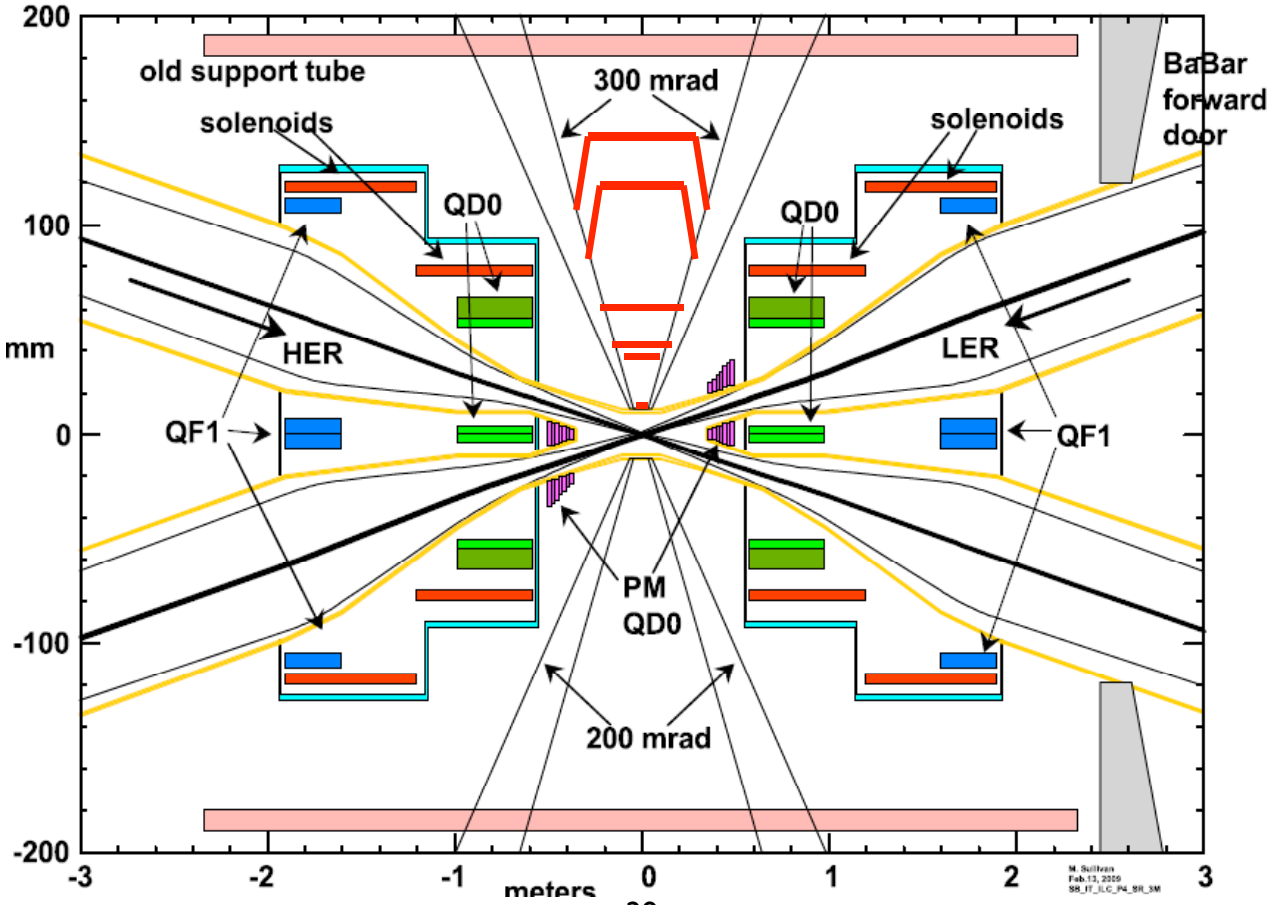
Nominal resolution 8 μm.
Considering 50% worsening (12 μm) from high occupancy in L_0.
Rough estimate to be studied in detail.

Conclusions

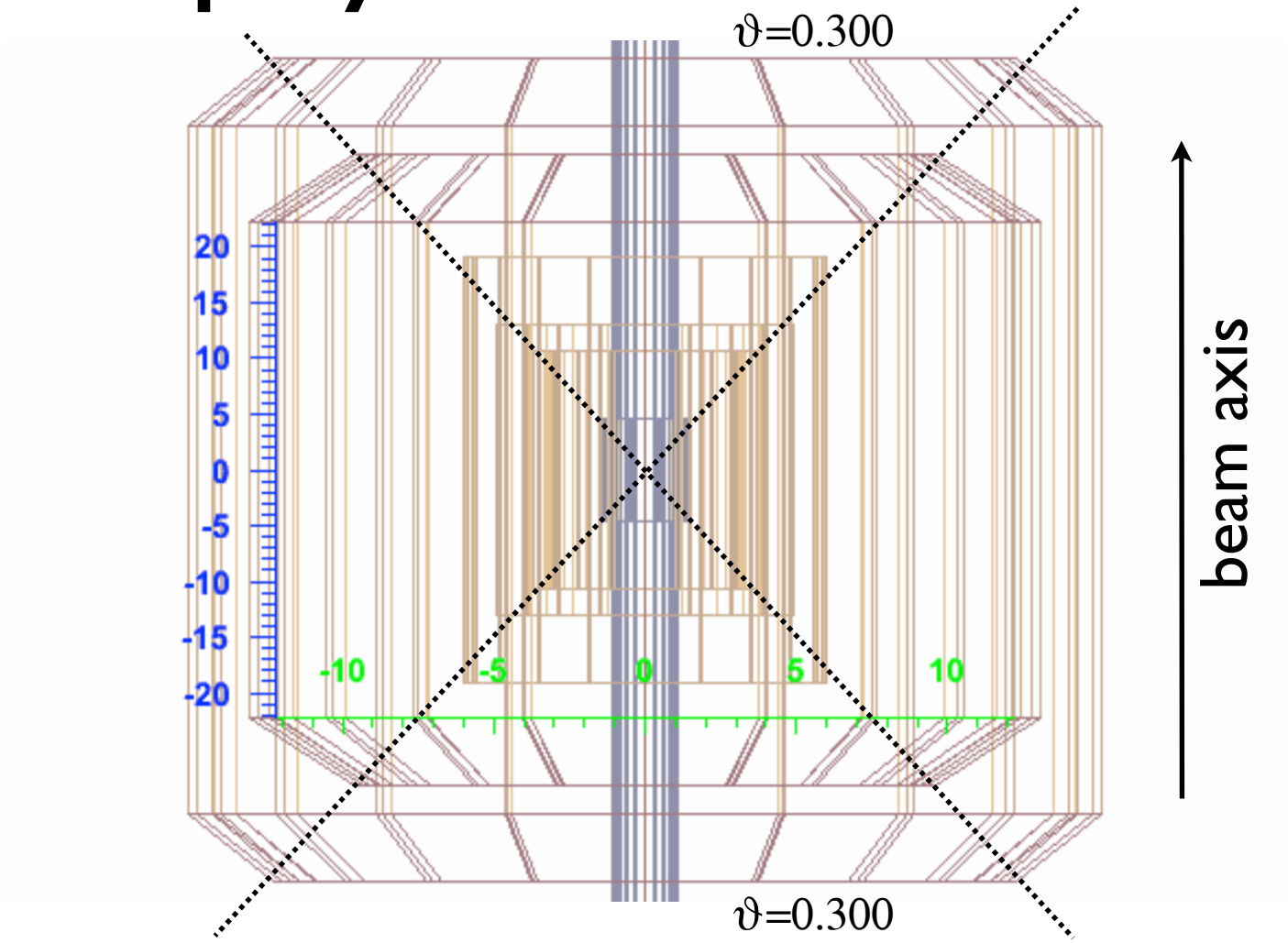
- Striplet detector seems to represent a viable solution for L_0 in terms of vertex and proper time resolution for time-dependent measurements in alternative to Hybrid Pixel or Maps detectors (assuming current bkg estimates on L_0 are robust).
- Some increase of the L_0 radius with respect to the nominal 1.60 cm value is possible if required for bkg reduction, up to ~2 cm, maintaining comparable Δt resolution with BaBar.
- Studied effect of efficiency on Δt resolution. Striplet detector maintains better or comparable Δt resolution with BaBar down to 60-70% efficiency.
- Degradation of striplet hit resolution ($8\mu m \rightarrow 12\mu m$) seems to have fairly small effect on vertex and proper time resolution.

Backup

Angular coverage down to 300 mrad FW and BW



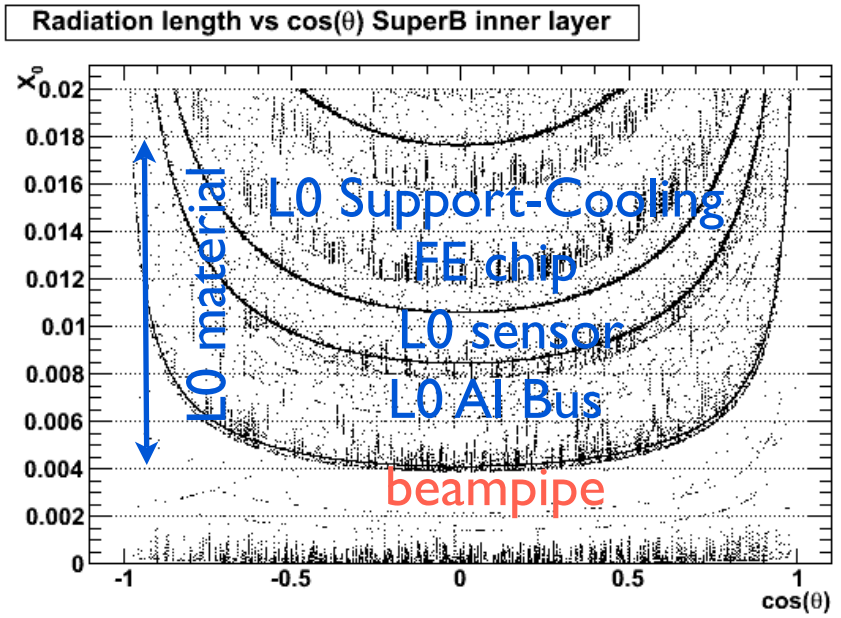
Display of SVT modules



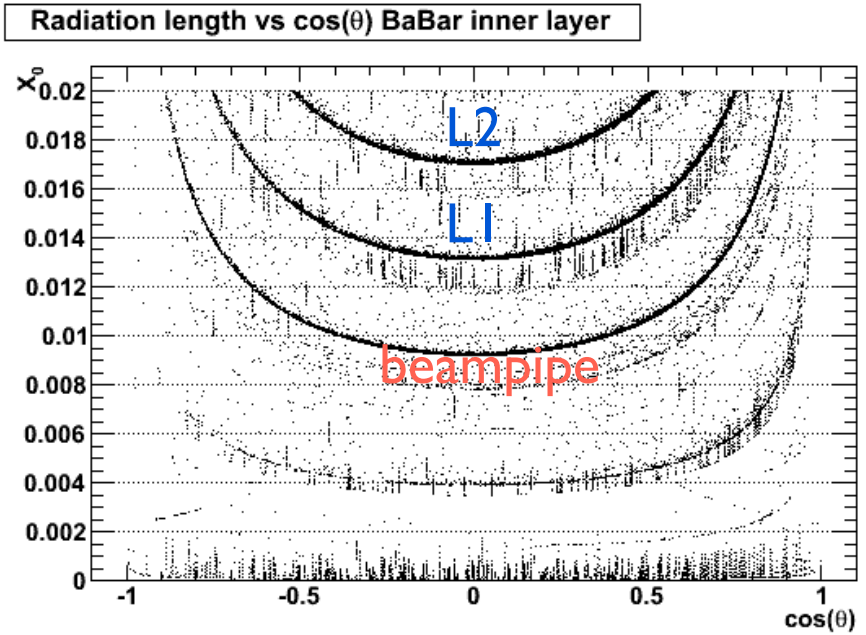
angular coverage in CM_{30}~ 95% (BaBar SVT ~89%)

Radiation length vs cos(theta) in FastSim

SuperB

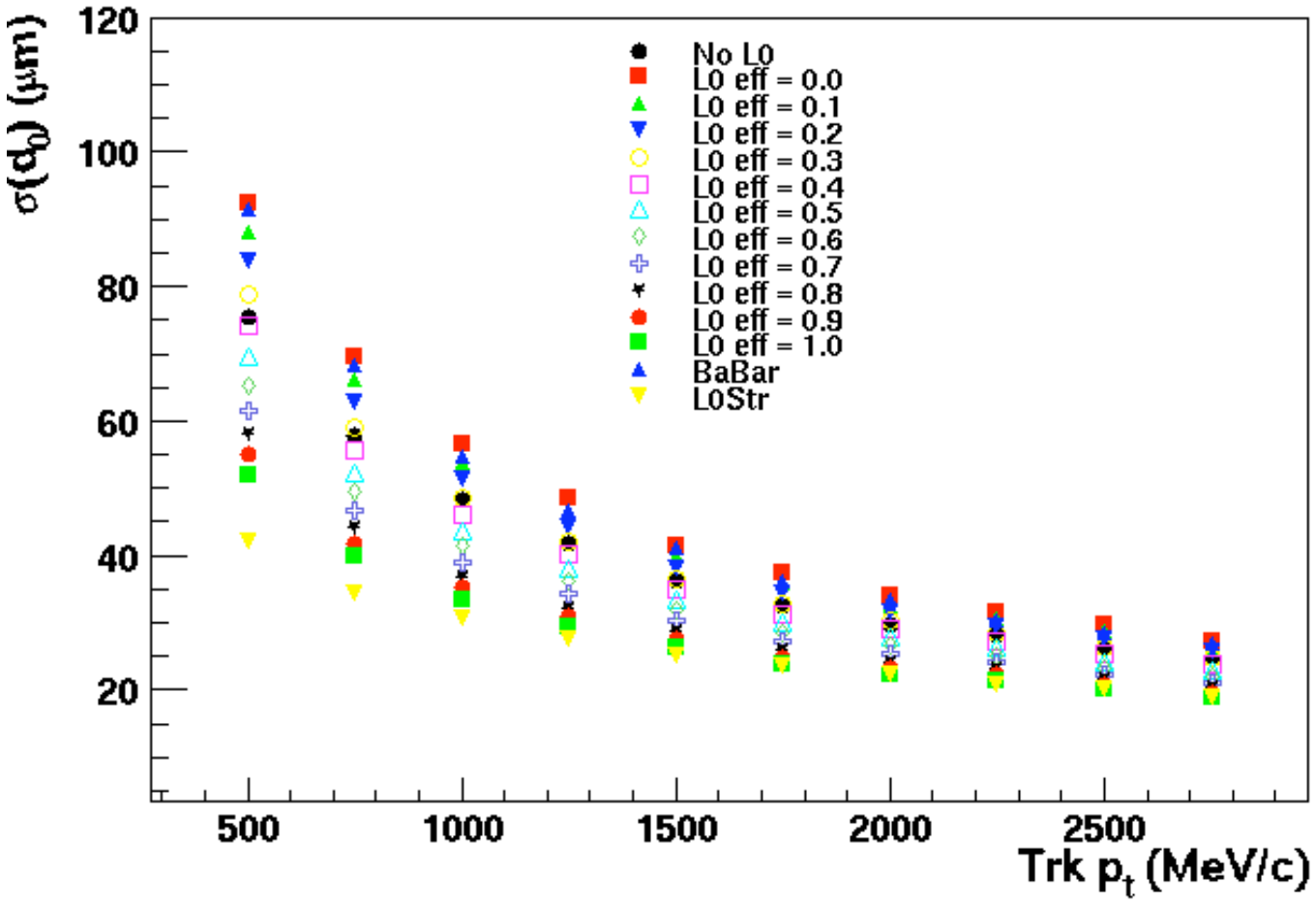


BaBar



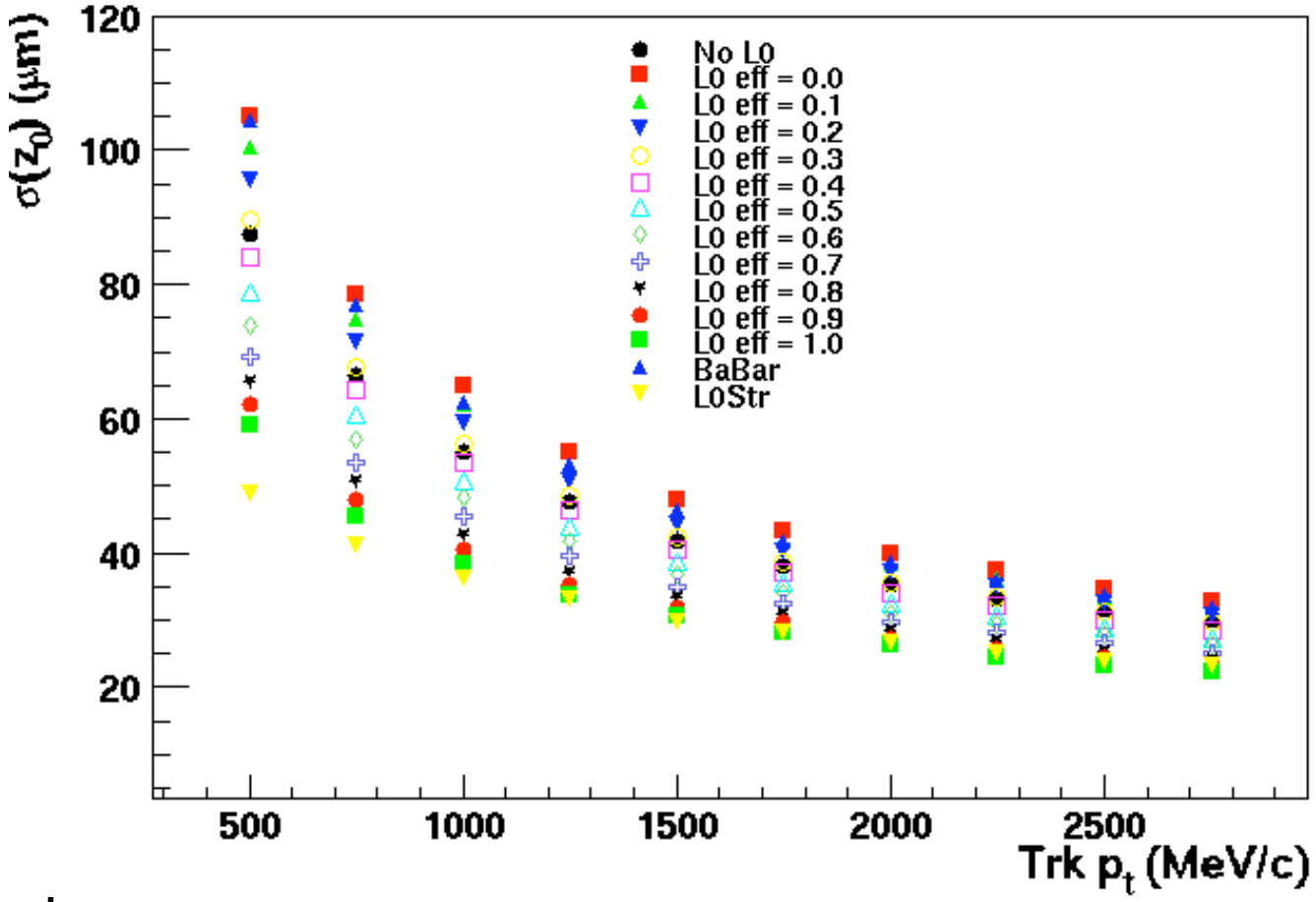
Total amount of L0 material is ~1.36% X_0 considering overlap of passive material.
Relative amount of material for Al bus and support-cooling requires small adjustments.

d_0 resolution



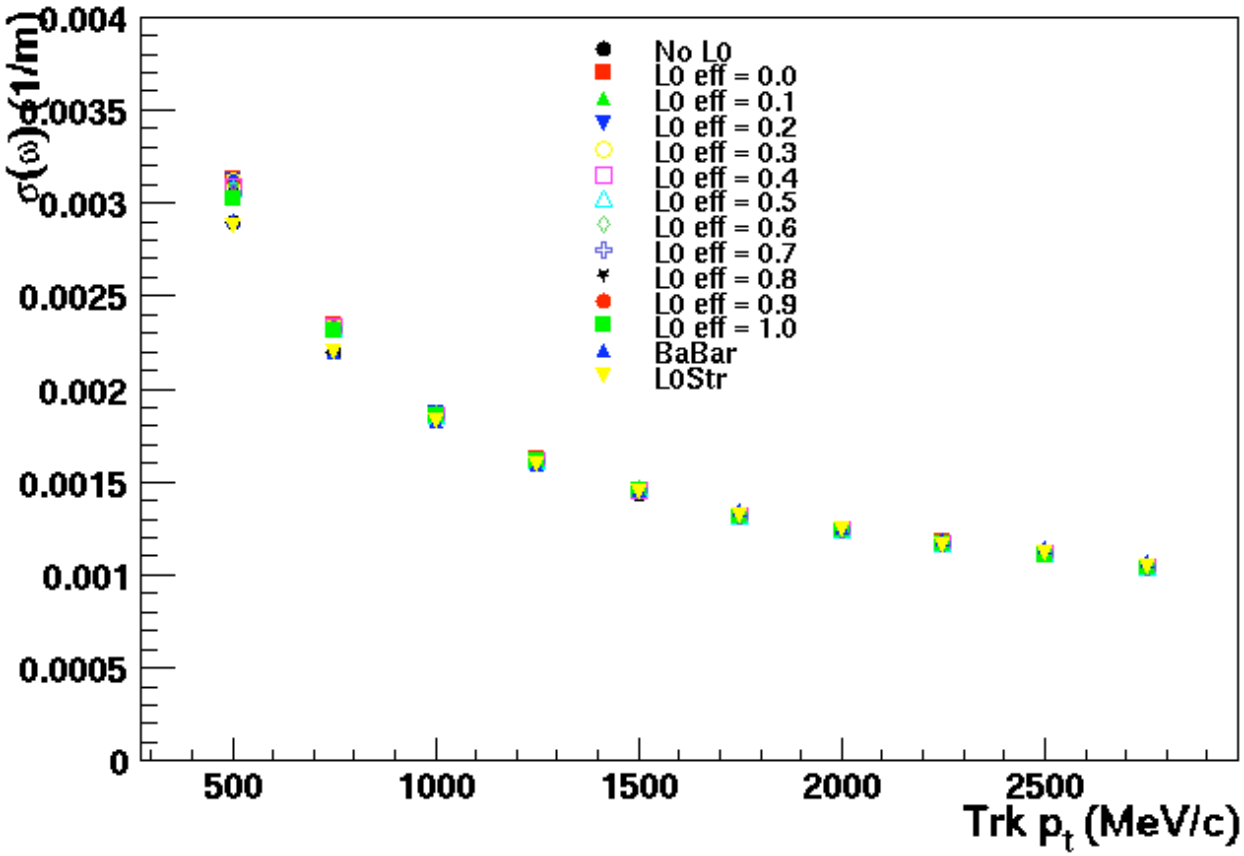
Legenda:
L0Str = L0 Strip detector

z_0 resolution



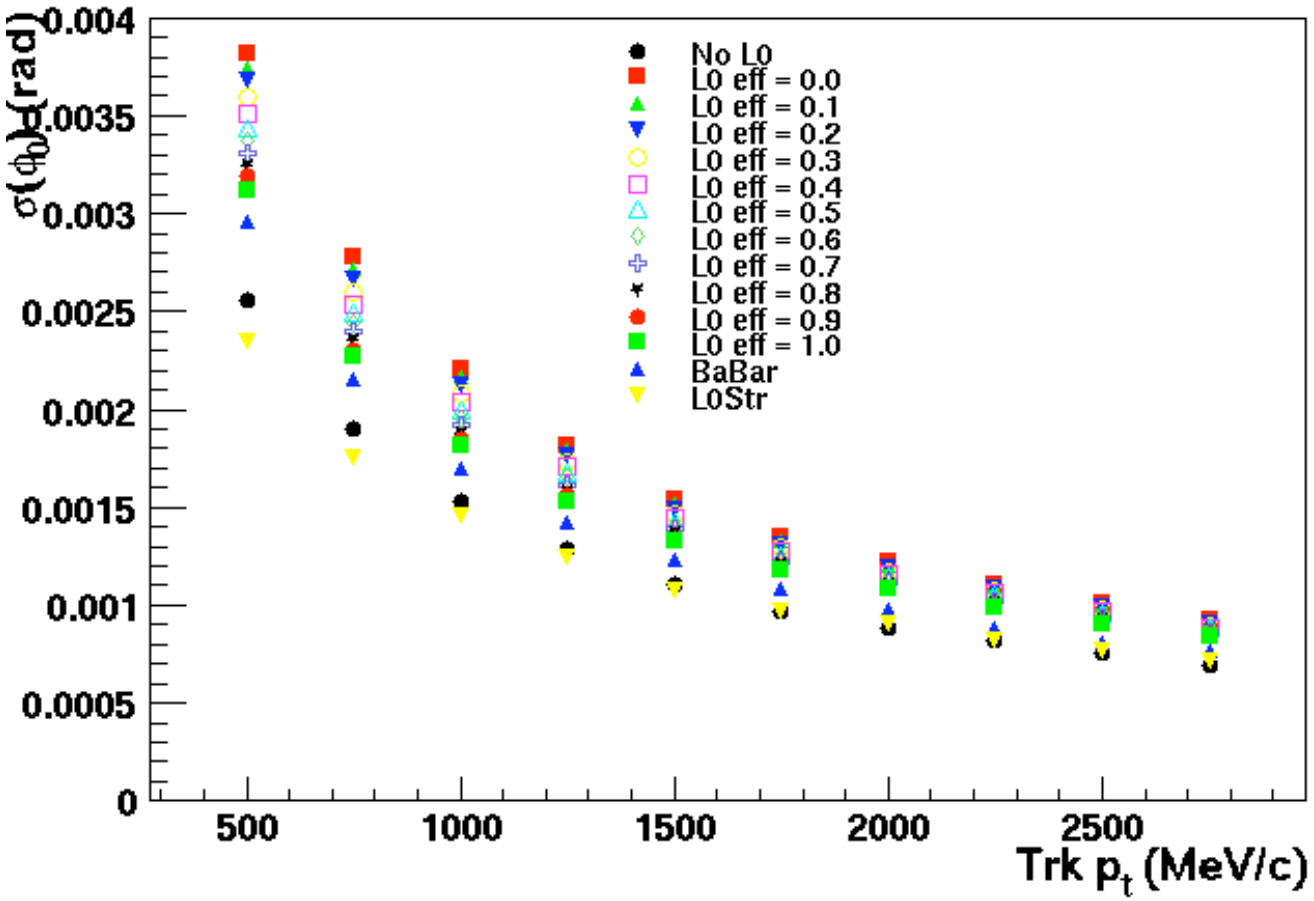
Legenda:
L0Str = L0 Strip detector

ω resolution



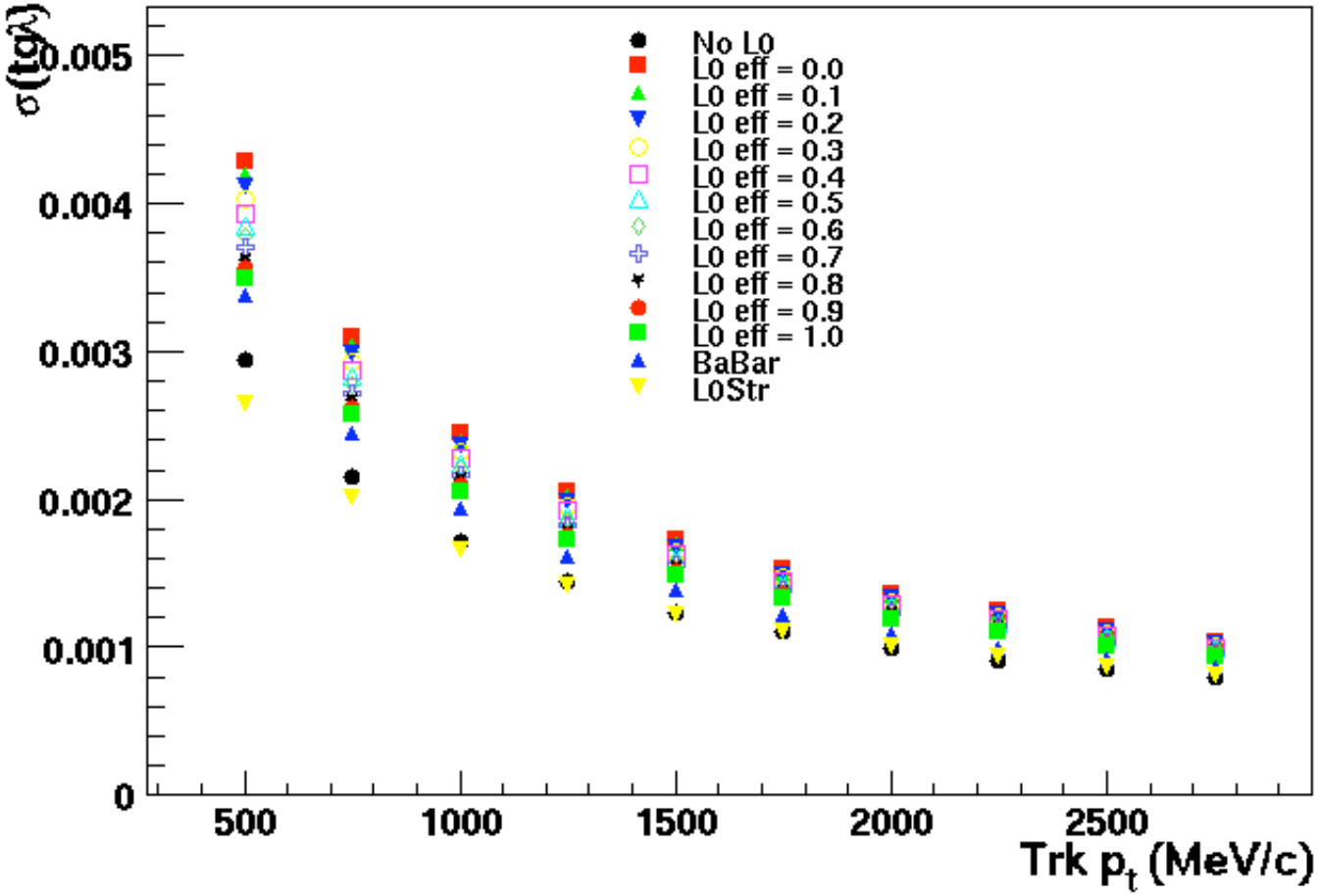
Legenda:
L0Str = L0 Strip detector

ϕ_0 resolution



Legenda:
L0Str = L0 Strip detector

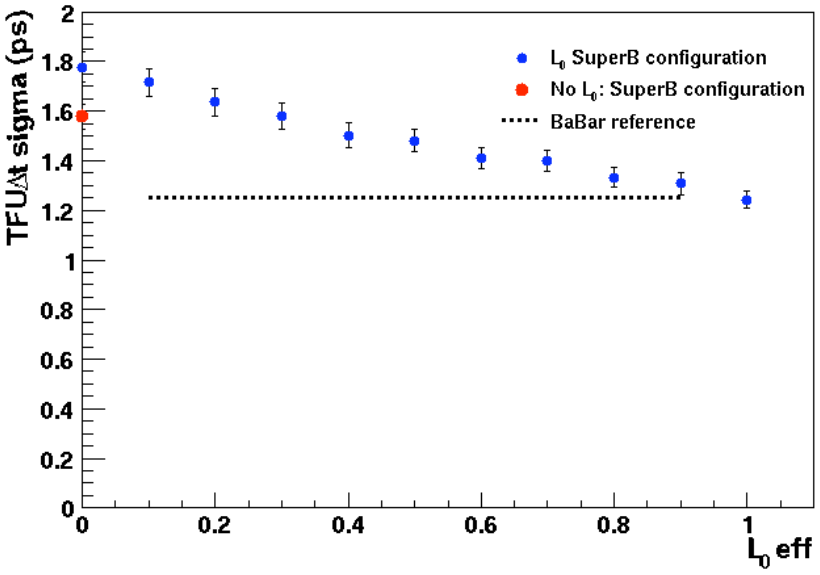
tgλ resolution



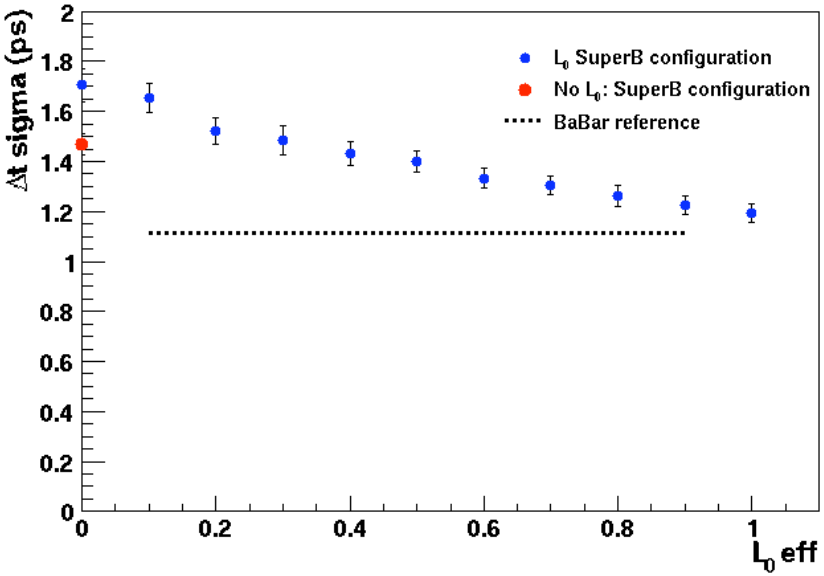
Legenda:
L0Str = L0 Strip detector

DeltaT resolution

TreeFitter Upsilon



Standard BaBar algorithm



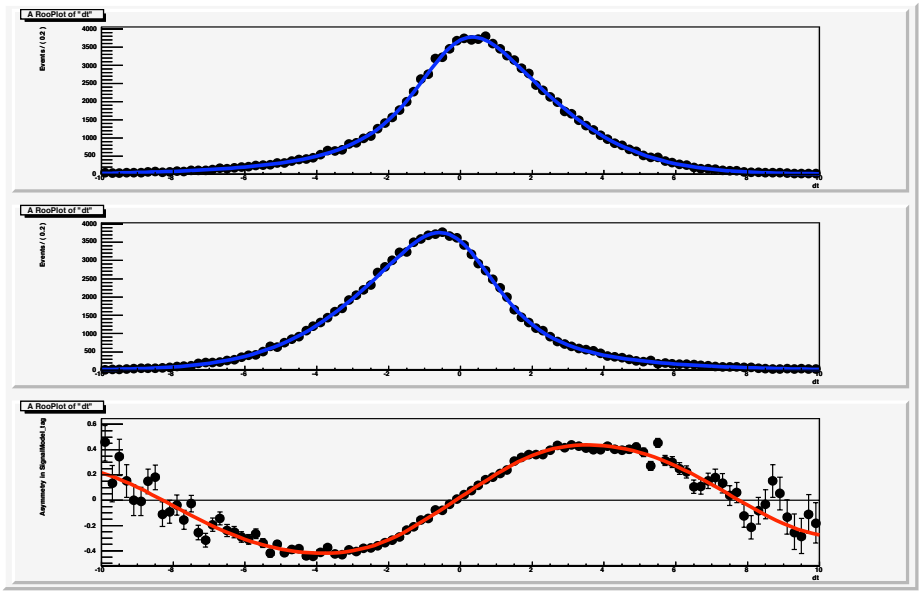
TreeFitter has worst resolution wrt the standard algorithm which is against the expectation. Needs to be further investigated.

It is worth to keep the Hybrid Pixel L_0 inside the tracking volume if efficiency > 40%.

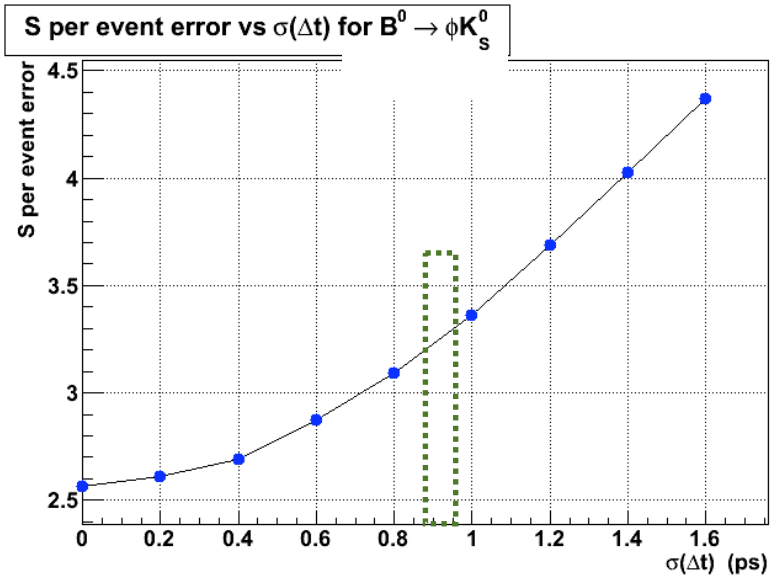
Impact on TD measurement

ToyMC fit with perfect tagging: use 2 Gaussian proper time resolution function tuned to FastSim residual.

100K signal Evts. S_{GEN}=0.70

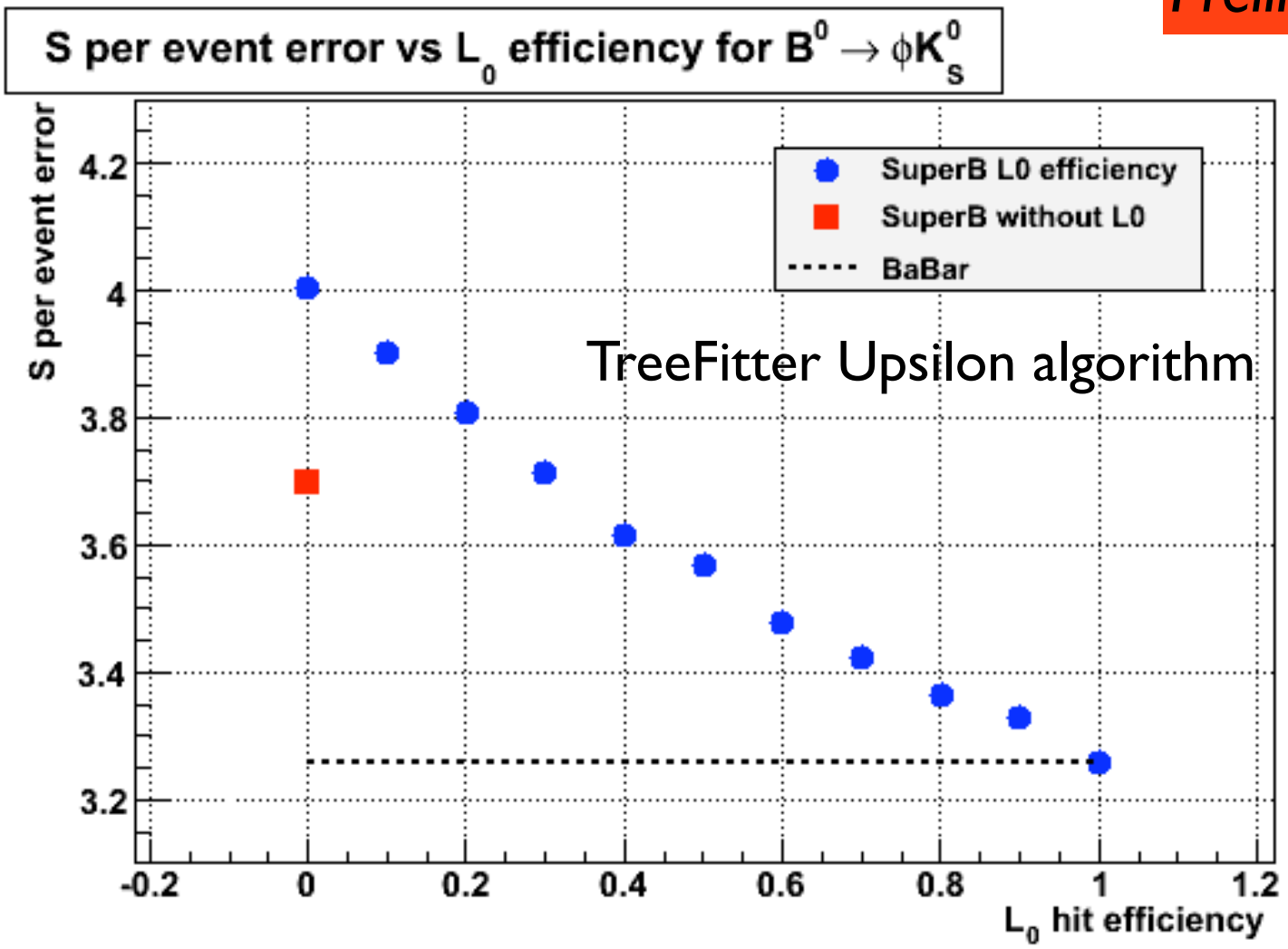


S per event error normalized to BaBar result:
Phys.Rev.D71:091102,2005.



From "AFit" Toy MC

Preliminary

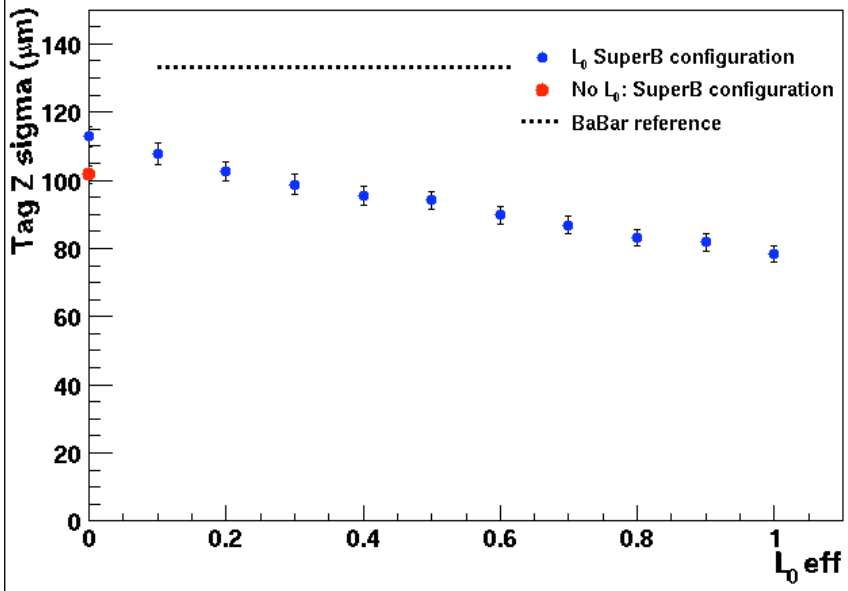


It is worth keeping Hybrid Pixel L_0 inside SVT

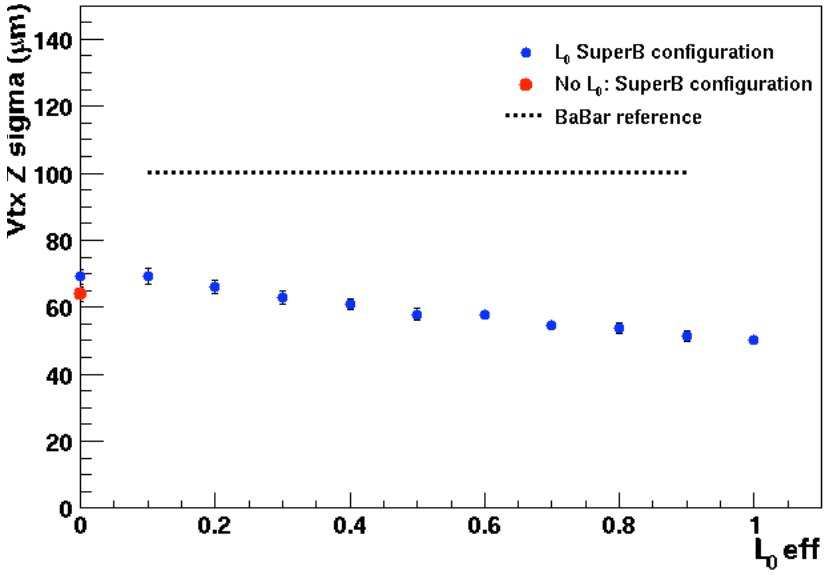
if efficiency is greater than 40%

Tag and CP vertex

Tag vertex



CP vertex



Better resolution with respect to BaBar even when No L0 configuration.

Impact of beampipe radius on Vtx resolution

- No sizable change in Vtx resolution due to beampipe radius variation (same amount of radial material)