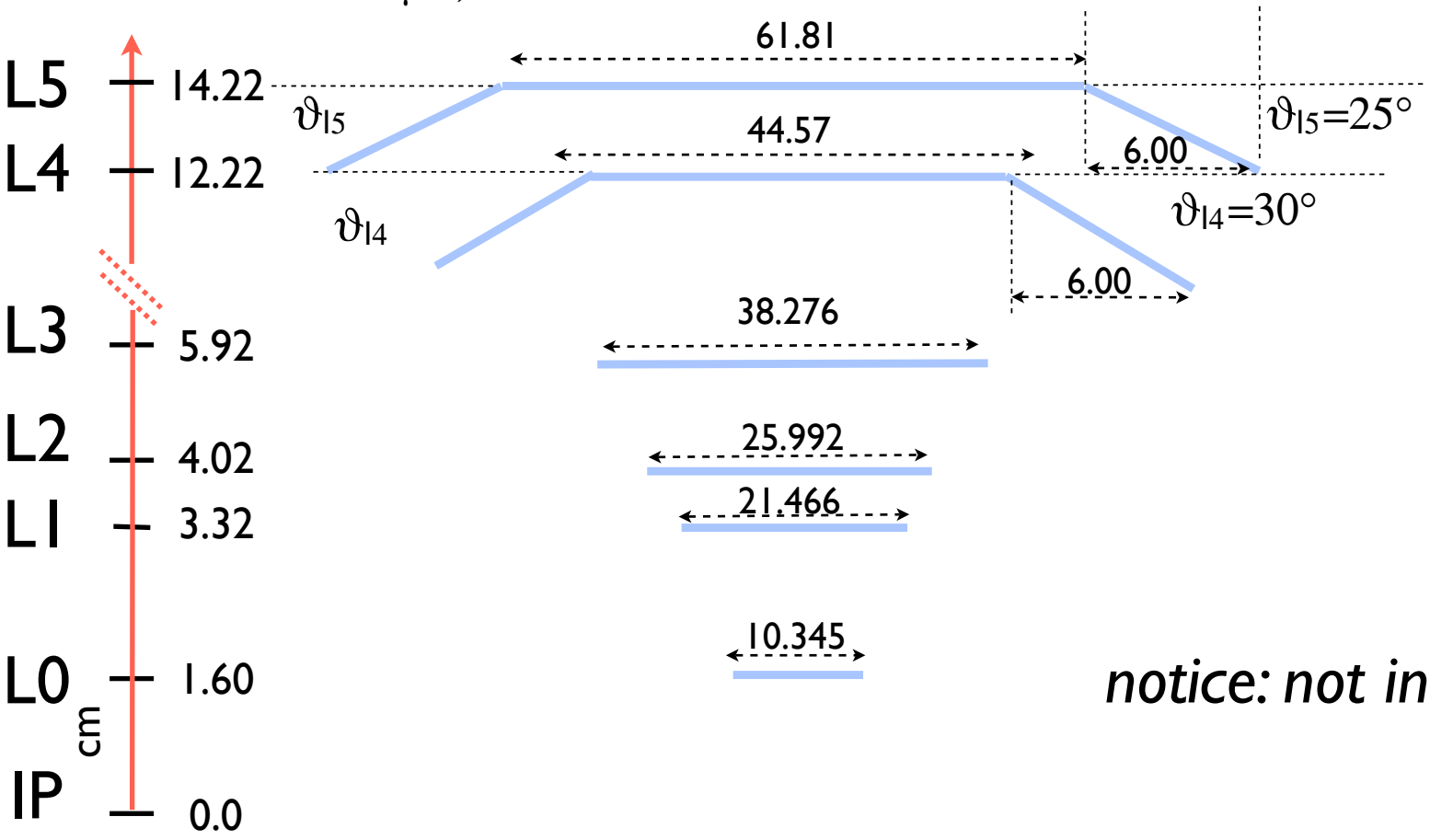
# $L_0$ solutions and impact on time-dependent measurements

Nicola Neri
Università di Pisa & INFN

XI SuperB General Meeting
Frascati, 1- 4 Dec 2009

# 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

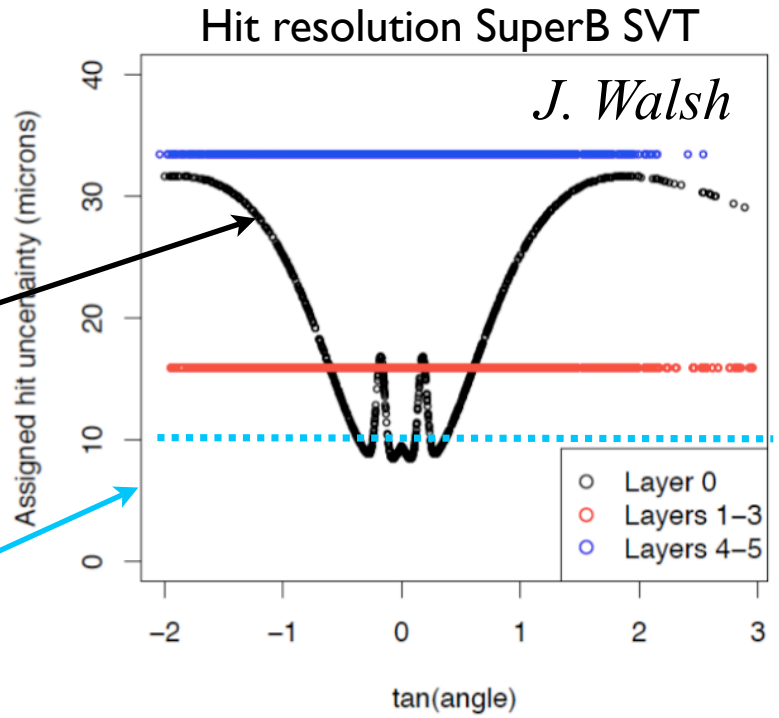
Decision will be based on bkg rates on $L_0$, dominated by pair production process $e^+e^- \rightarrow e^+e^-e^+e^-$. According to recent bkg simulations, (see Riccardo Cenci's talk) hit rate on $L_0$ is reduced compared to previous estimates and a striplet $L_0$ solution looks viable in terms of occupancy.

## Hybrid Pixel

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

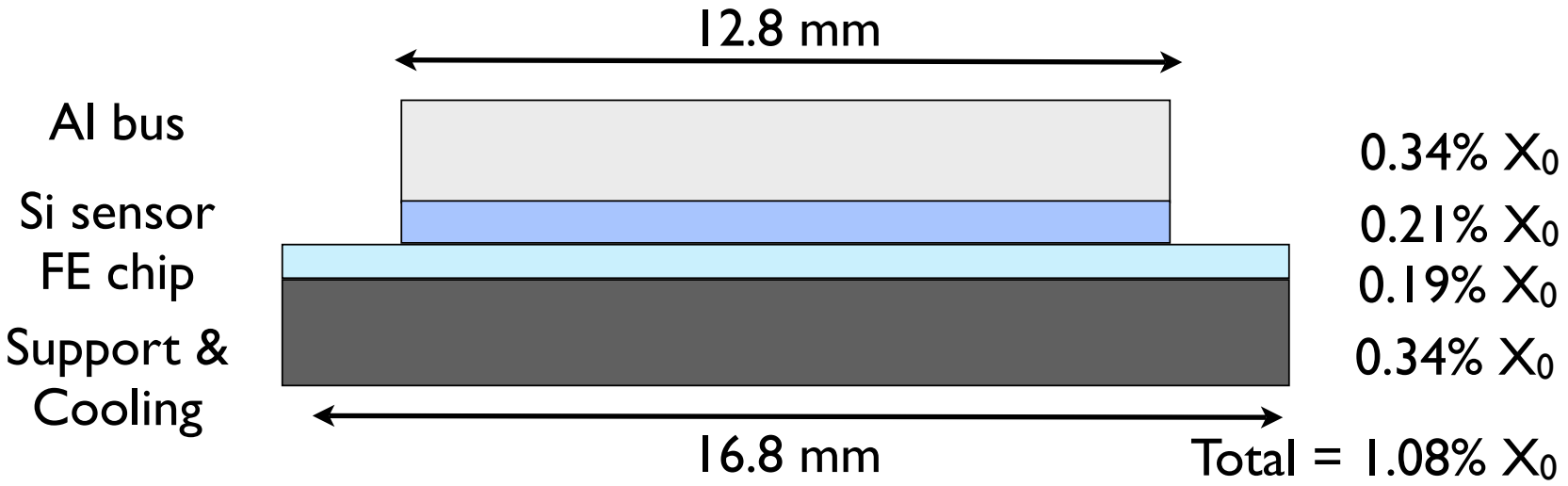
## Striplets

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



# Hybrid pixel solution

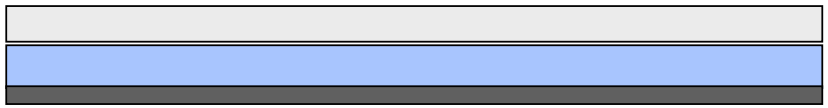
- Module cross section



# Striplet solution

- Module cross section

Fan out
Si sensor
Support

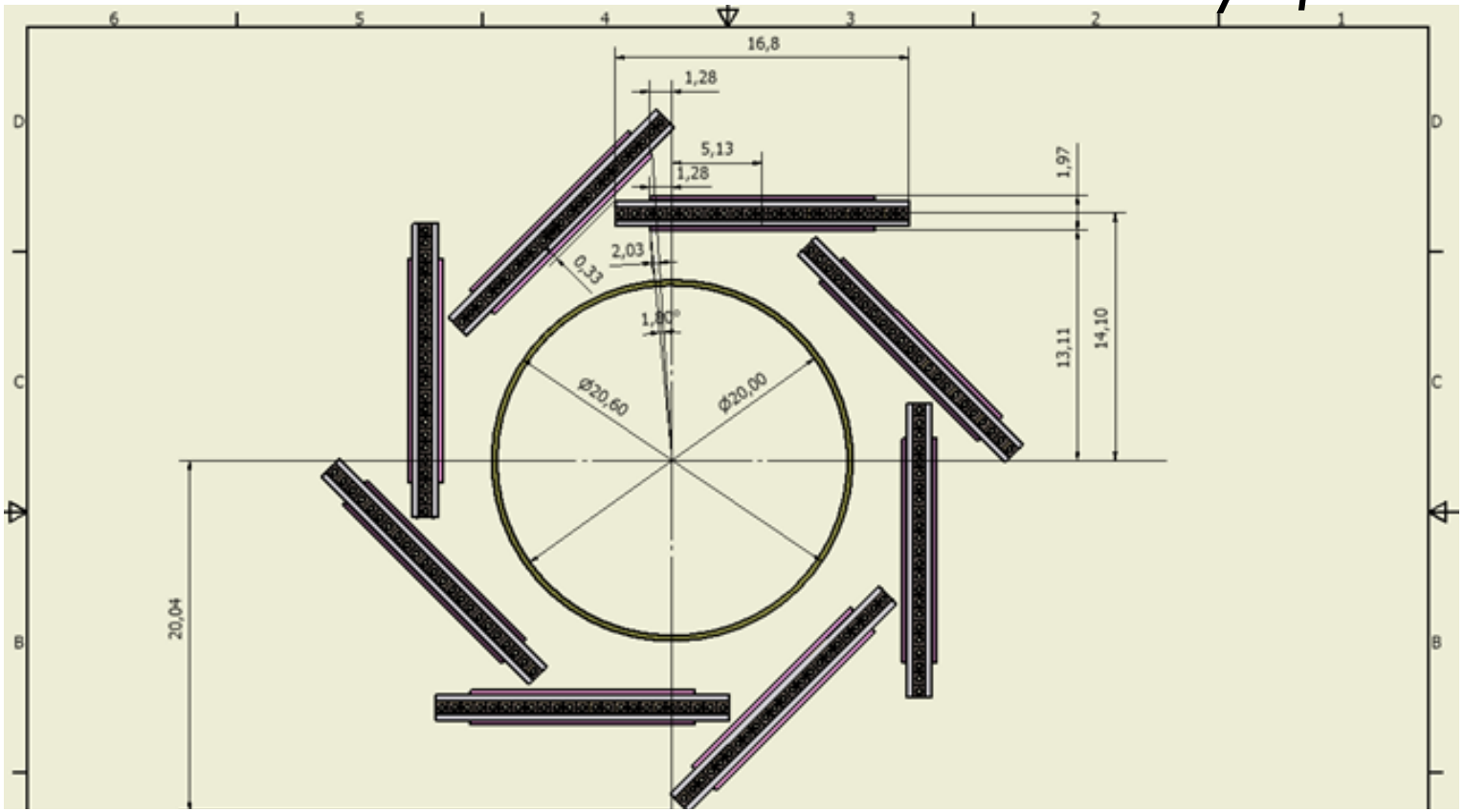


Si sensor overlap 3.4%

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

# Pinwheel layout for $L_0$

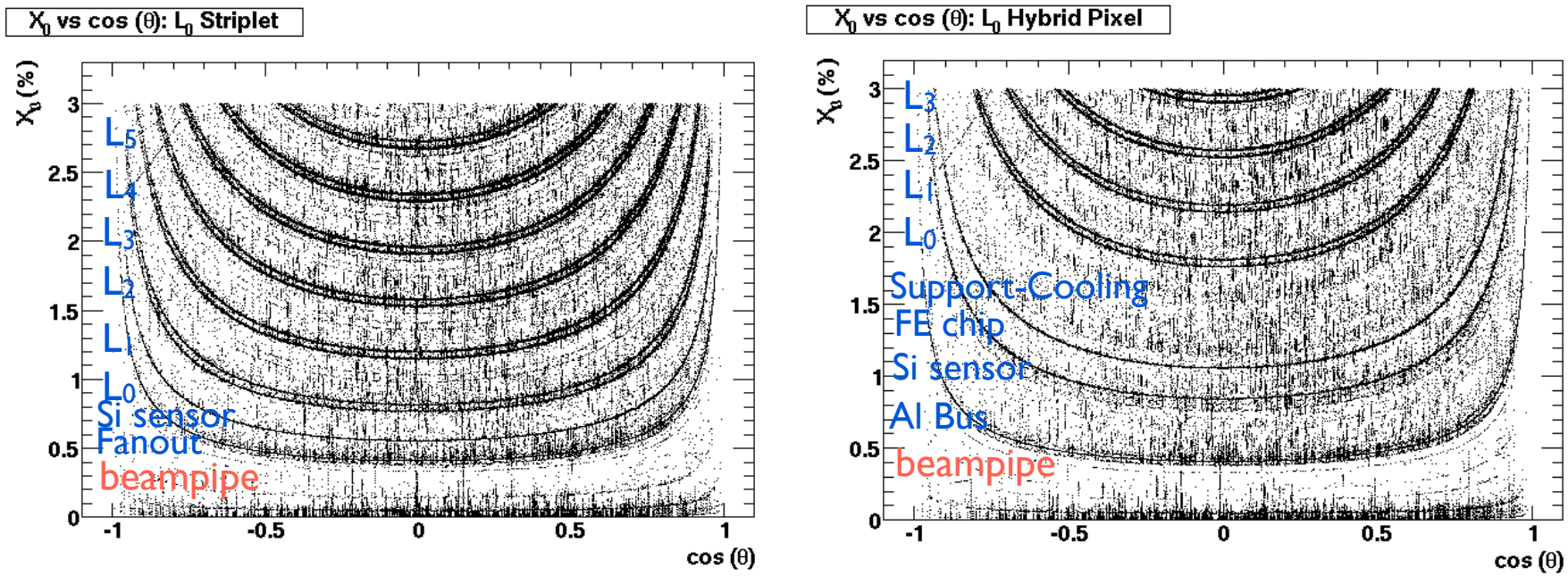
*courtesy of F. Bosi*




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 $\Delta t$ resolution for $B^0 \to \varphi K_S$, $B^0 \to \pi^+\pi^-$

- $B^0 \to \varphi K_S$, $\varphi \to K^+K^-$, $K_S \to \pi^+\pi^-$ and $B^0 \to \pi^+\pi^-$
  - $\Delta t$ 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, $\Delta t$ 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 $\beta\gamma = 0.56$

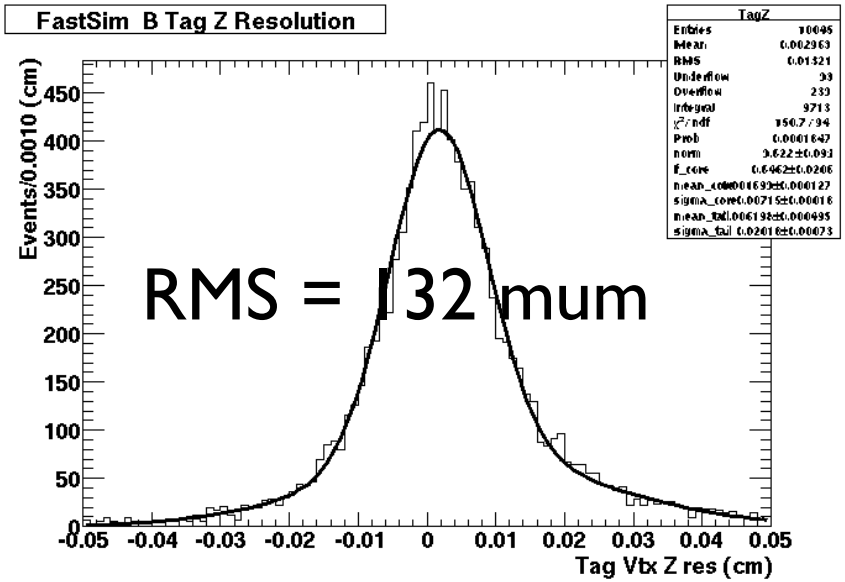
# Effect of beamspot constraint

BaBar SVT detector:

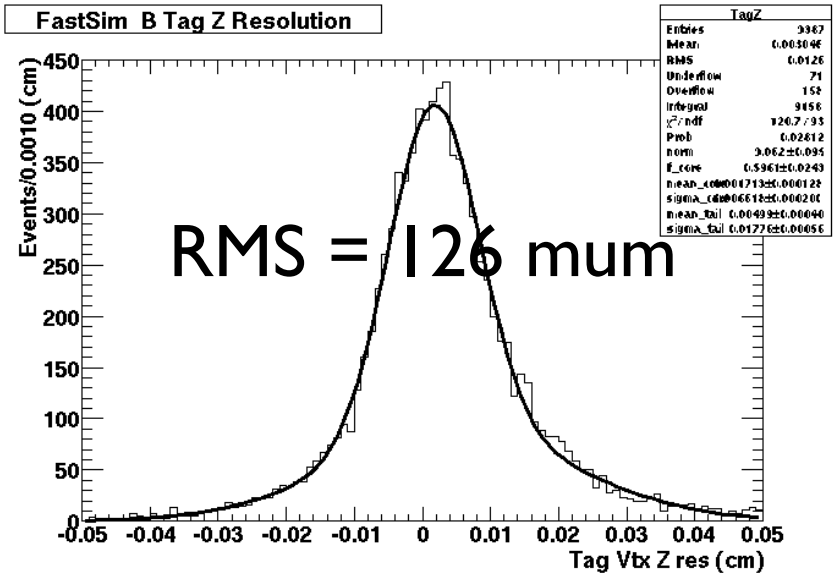
- BaBar beams and beamspot
- BaBar beams and SuperB beamspot
- SuperB beams and beamspot

# Tag vertex test

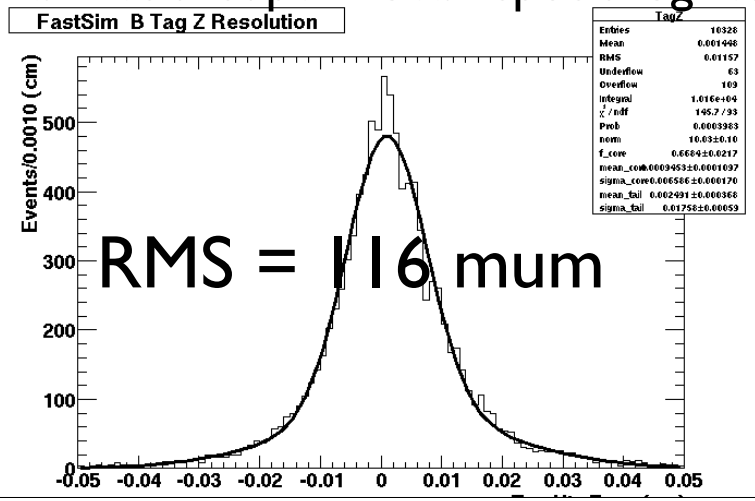
BaBar detector




BaBar det & SuperB beamspot



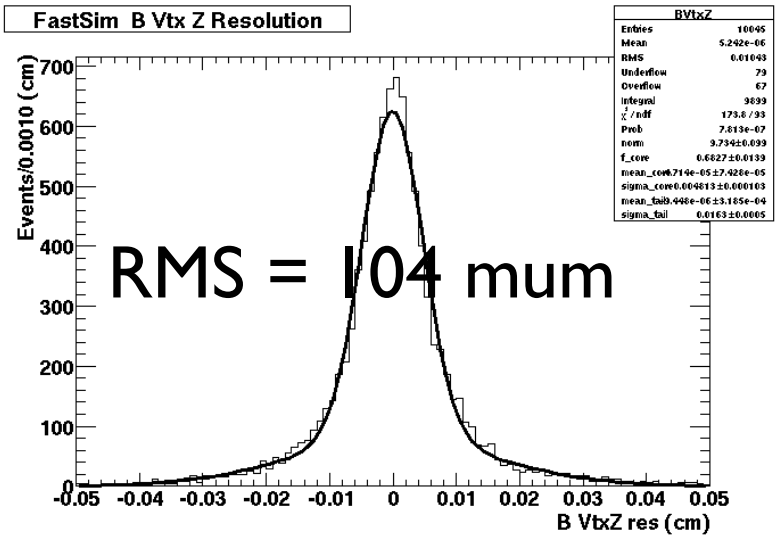

BaBar det & SuperB beamspot & bg=0.28




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

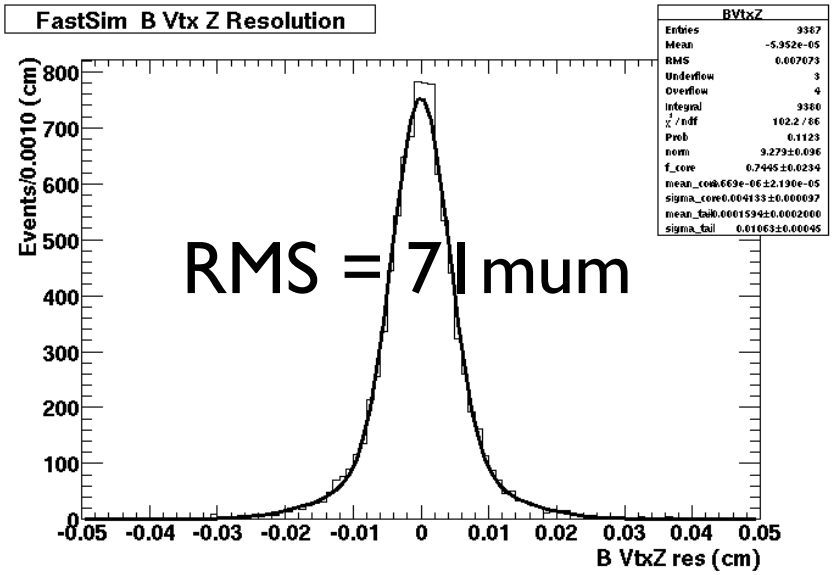
# $B_{rec}$ vertex test: $B^0 \rightarrow \varphi K_S$

BaBar detector



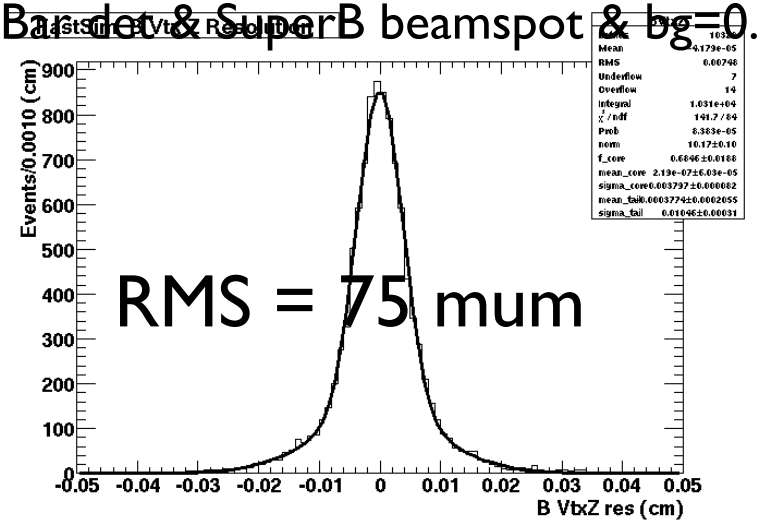

RMS = 104 mum

BaBar det & SuperB beamspot




RMS = 71 mum

BaBar det & SuperB beamspot & bg=0.28




RMS = 75 mum

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

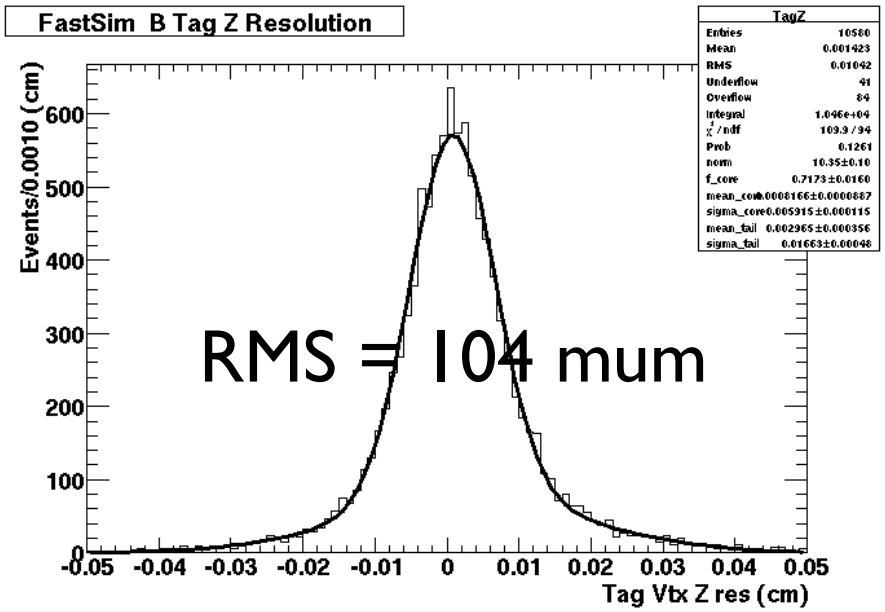
# Effect of reduced material beampipe

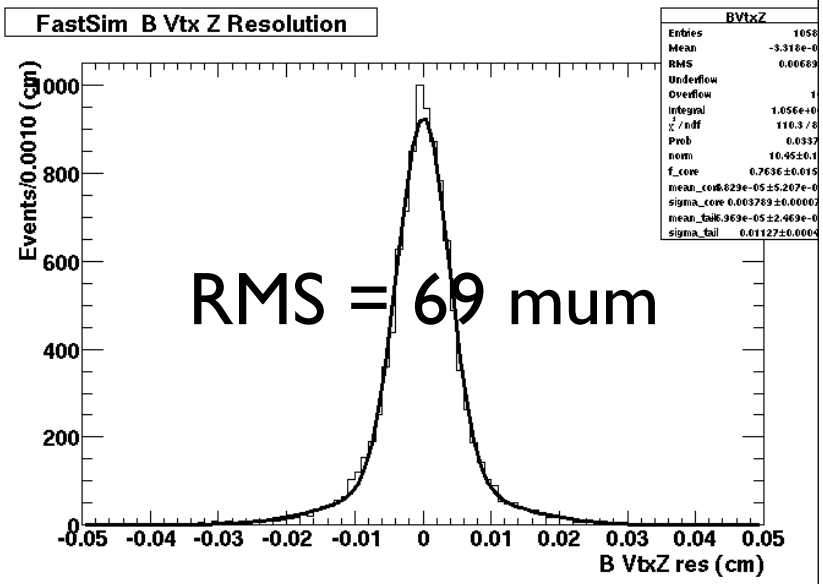
BaBar SVT detector:

- SuperB beams, beamspot and beampipe

# $B_{tag}$ and $B_{rec}$ vertex

$B^0 \rightarrow \varphi K_S$




BaBar SVT detector and SuperB beams and beampipe

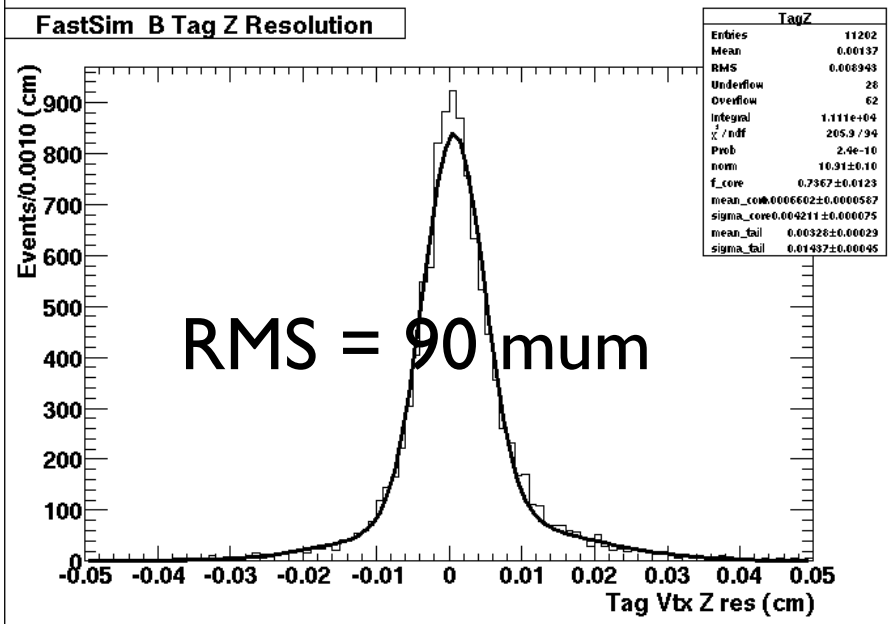
# Effect of additional $L_0$ hit measurement

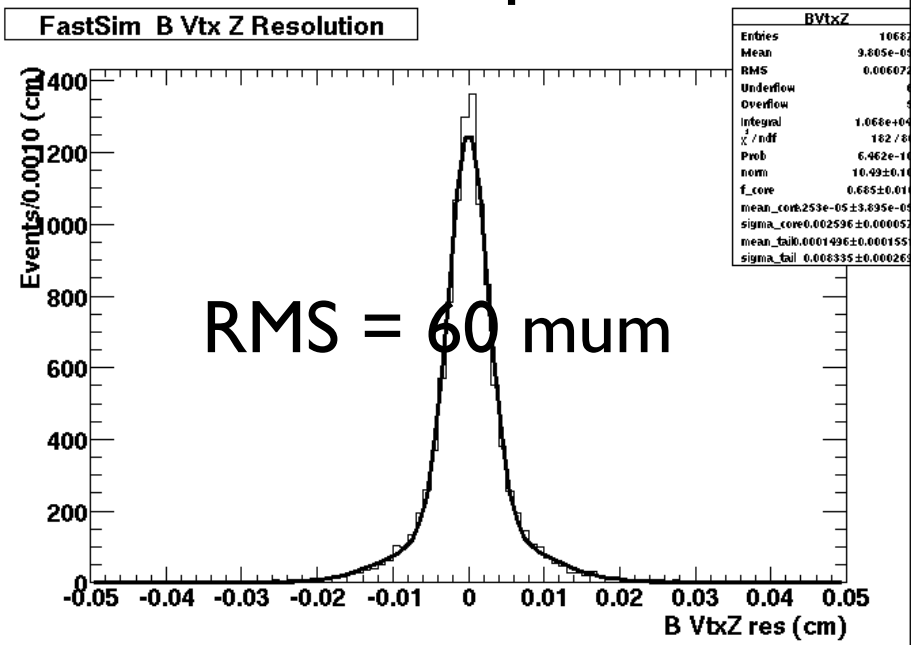
SuperB SVT detector (Hybrid Pixel $L_0$):

- SuperB beams, beamspot and beampipe

# $B_{tag}$ and $B_{rec}$ vertex

$B^0 \rightarrow \varphi K_S$




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

$B^0 \to \varphi K_S$

| $L_0$ | 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 |

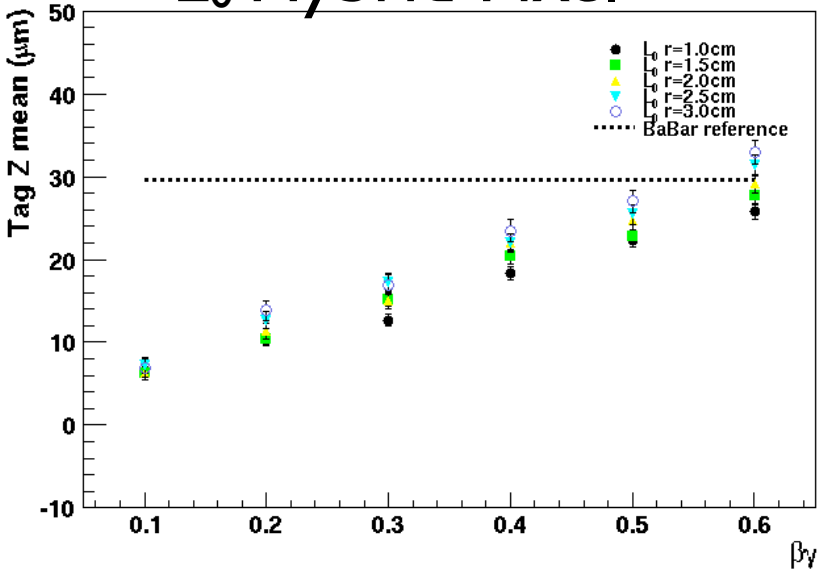
$B^0 \to \pi^+\pi^-$

| $L_0$ | boost | beamspot | beampipe | Tag res(μm) | Reco res(μm) | Δt(ps) |
|---|---|---|---|---|---|---|
| no | 0.56 | BaBar | BaBar | 127±1 | 55±1 | 1.08±0.01 |
| no | 0.56 | SuperB | BaBar | 122±1 | 40±1 | 1.02±0.01 |
| no | 0.28 | SuperB | BaBar | 116±1 | 53±1 | 1.62±0.01 |
| no | 0.28 | SuperB | SuperB | 103±1 | 48±1 | 1.43±0.01 |
| HP | 0.28 | SuperB | SuperB | 89±1 | 42±1 | 1.23±0.01 |
| Str | 0.28 | SuperB | SuperB | 71±1 | 30±1 | 1.00±0.01 |

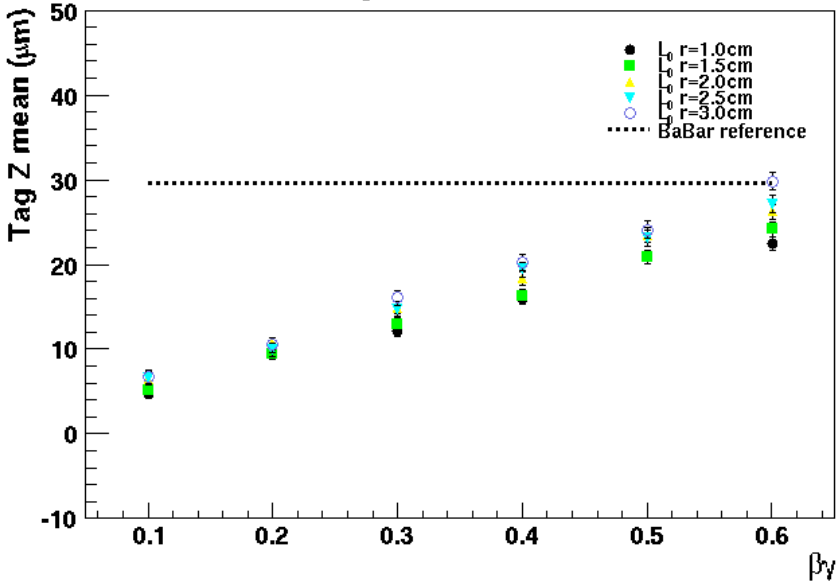
# Effect of boost and $L_0$ radius

# Tag vertex bias vs boost

## $L_0$ Hybrid Pixel



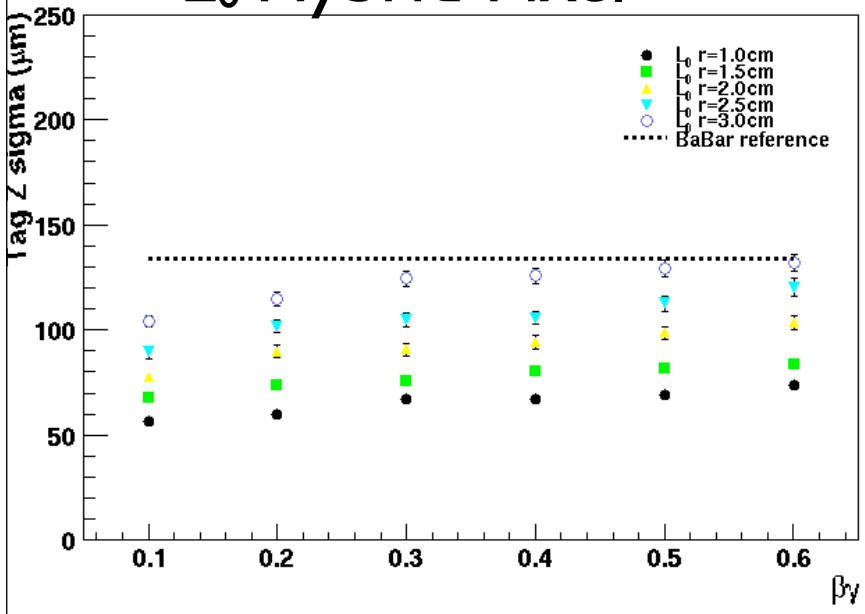

## $L_0$ striplet



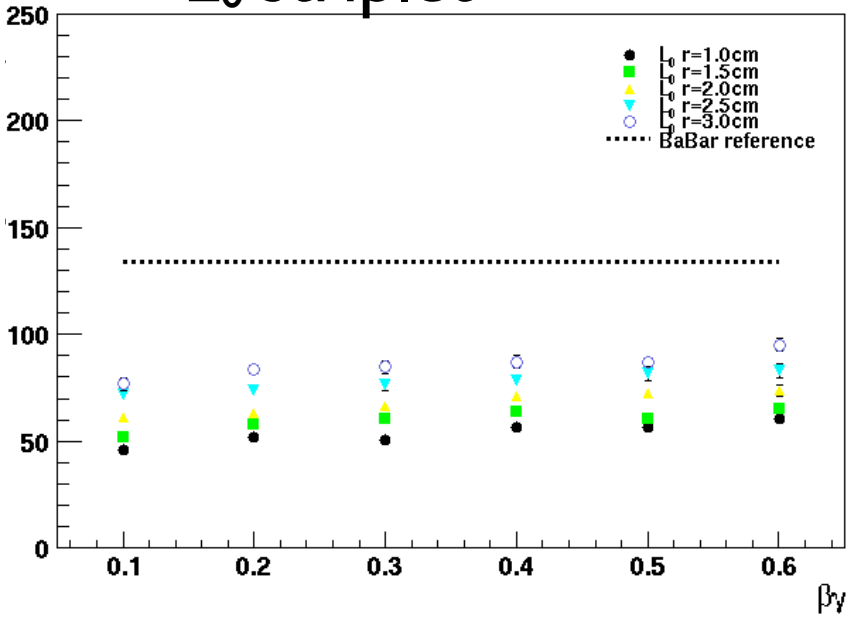

Tag vertex bias increases with boost (and $L_0$ radius).
Positive effect of boost reduction on vtx resolution.
Reduction charm vertex bias.

# Tag vertex resolution

## $L_0$ Hybrid Pixel




## $L_0$ striplet

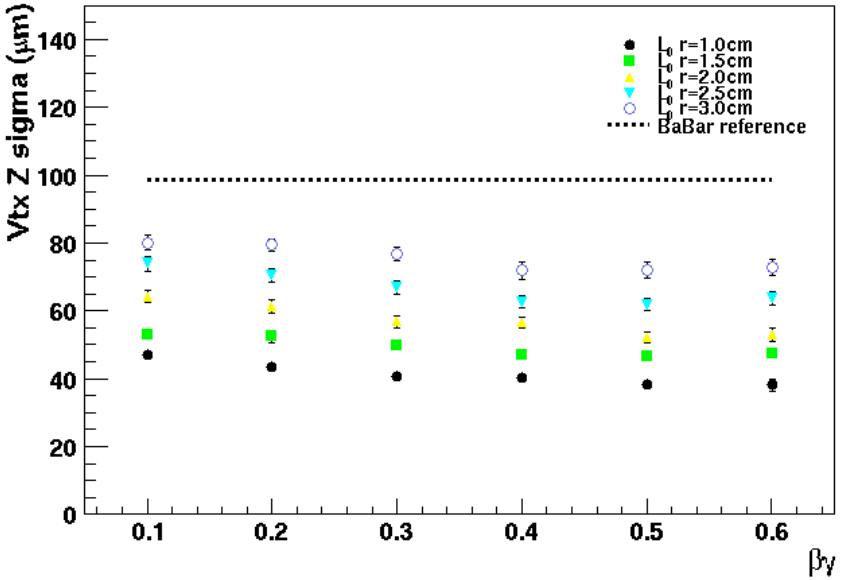



Tag vertex sigma increases with boost oppositely to $B_{rec}$ vertex resolution.
Tag vertex resolution correlated with Charm vertex bias.
Positive effect of boost reduction.

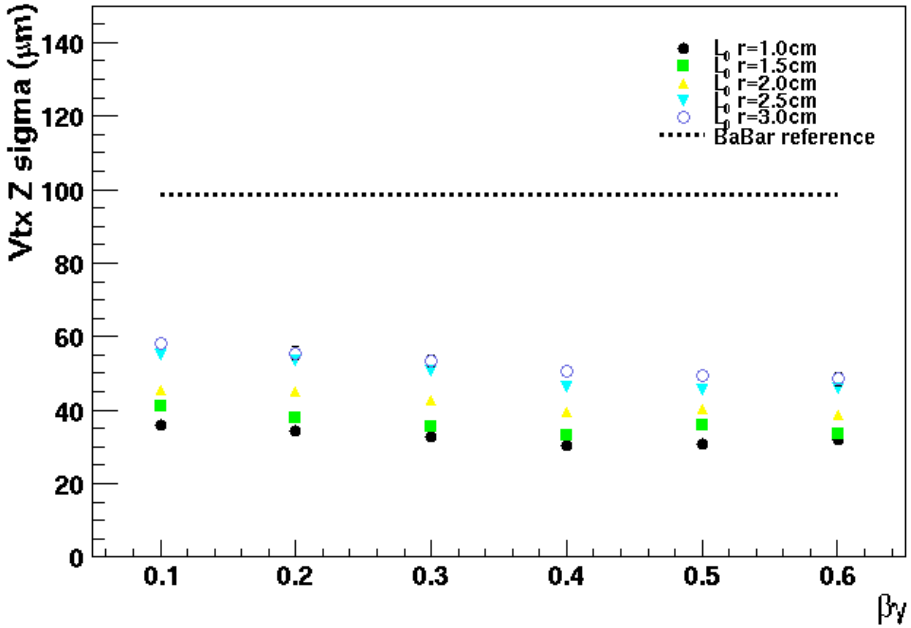
# $B_{rec}$ vertex resolution

$B^0 \rightarrow \varphi K_S$

## $L_0$ Hybrid Pixel




## $L_0$ striplet

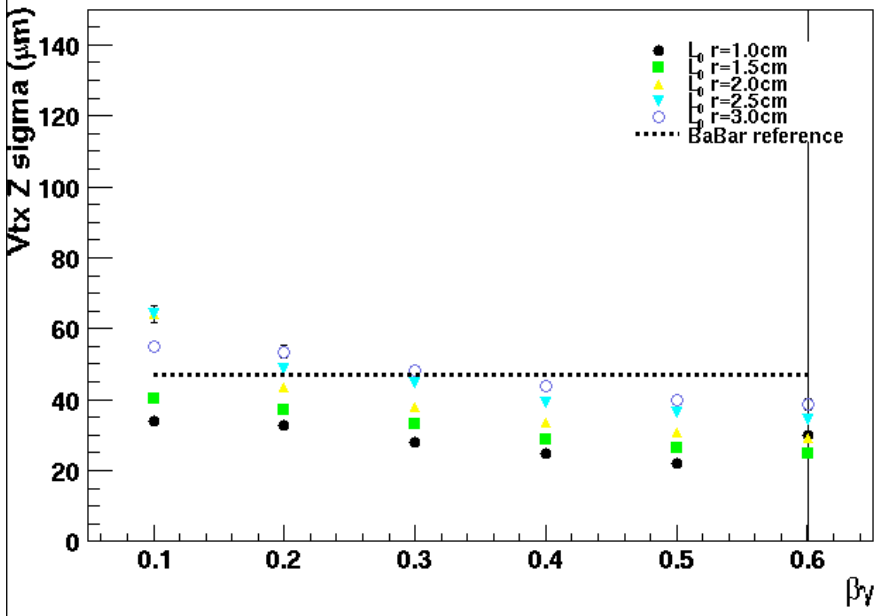



$B_{rec}$ vertex resolution slightly decreases with boost: reduction of multiple scattering by increasing the average track momentum

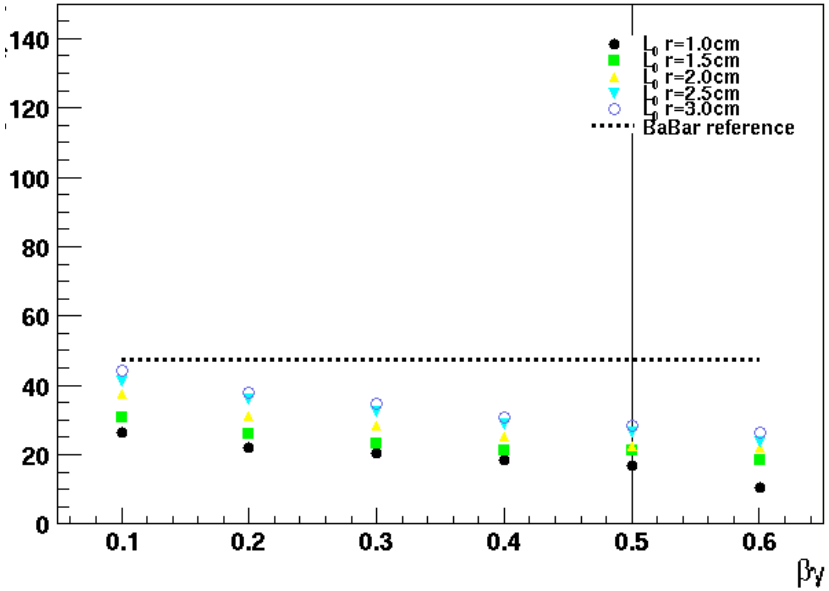
# $B_{rec}$ vertex resolution

$B^0 \rightarrow \pi^+\pi^+$

## $L_0$ Hybrid Pixel



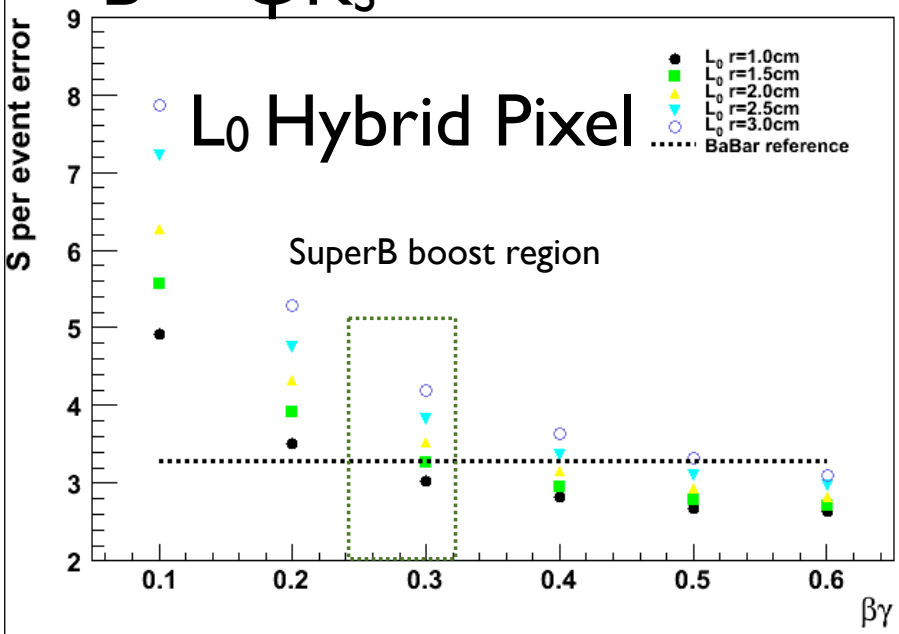

## $L_0$ striplet

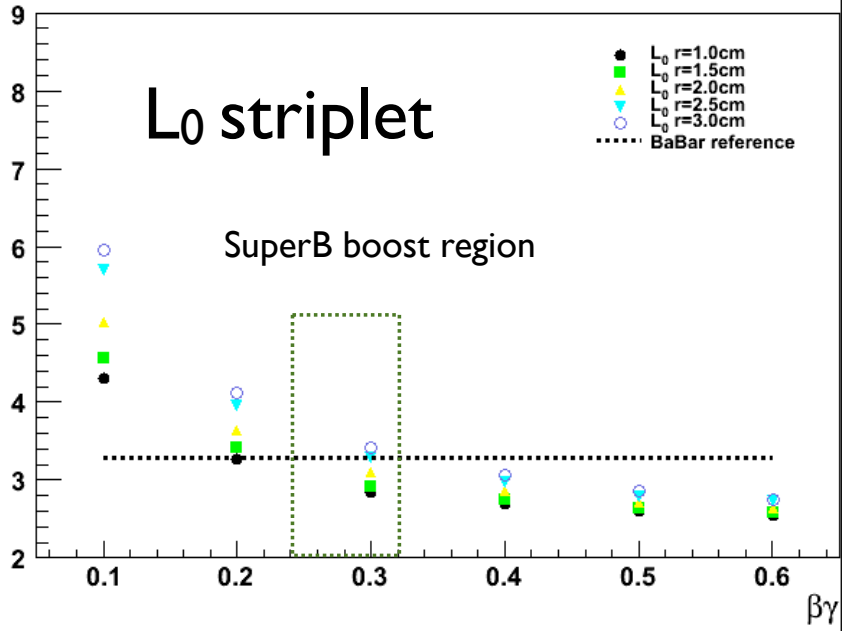



$B_{rec}$ vertex resolution slightly decreases with boost: reduction of multiple scattering by increasing the average track momentum

# Striplet vs Hybrid Pixel: S per event error

$B^0 \rightarrow \varphi K_S$

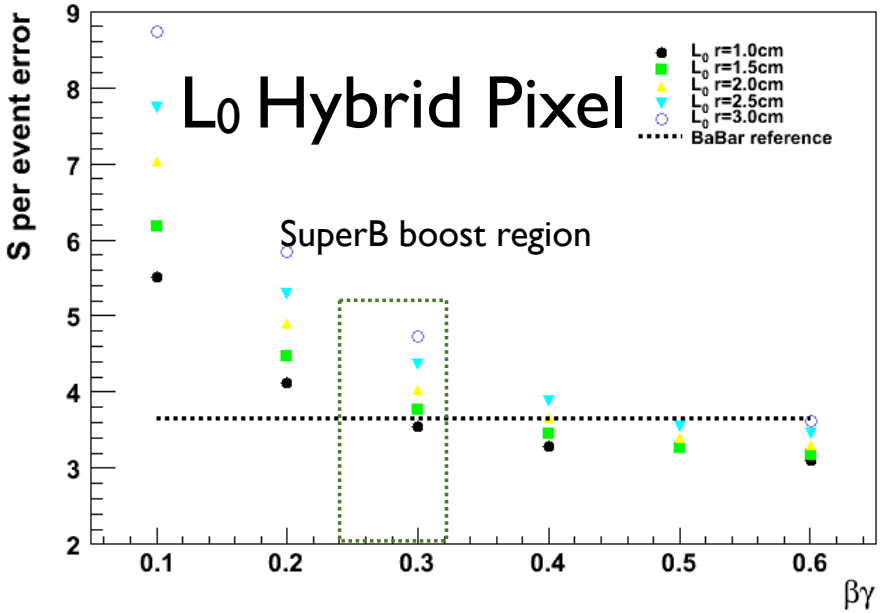


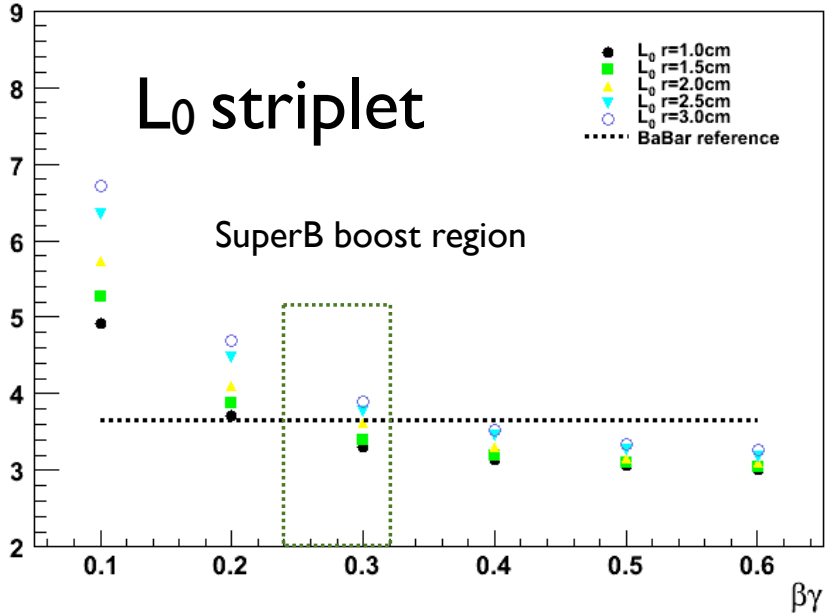




*Hybrid Pixel solution is reaching BaBar reference for S (sin(2β)) per event sensitivity with $L_0$ radius ~1.5 cm. Striplet solution can afford a larger $L_0$ radius ~2 cm where bkg is much lower.*

# Striplet vs Hybrid Pixel: S per event error

$B^0 \rightarrow \pi^+\pi^+$

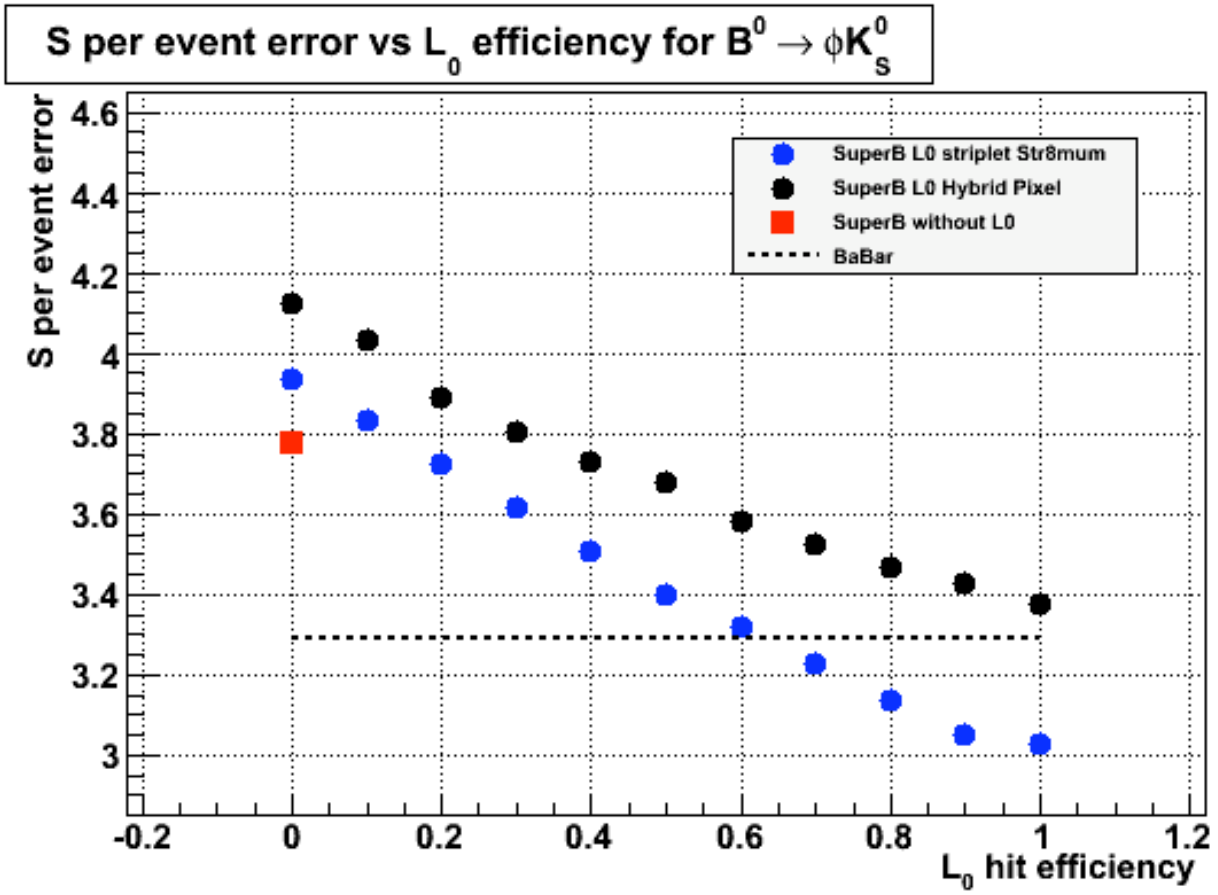


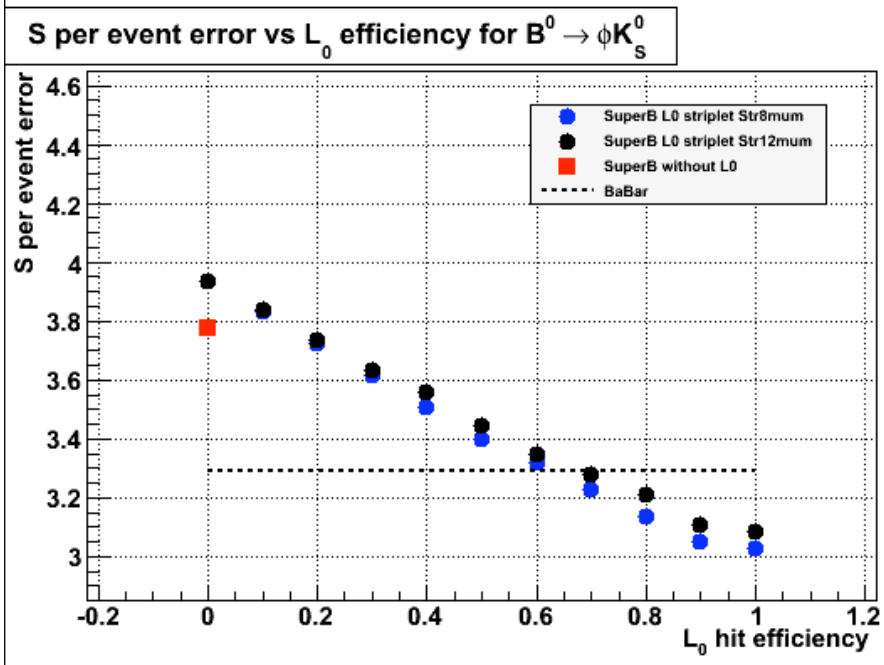

*Hybrid Pixel solution is slightly below BaBar reference for S (sin(2β)) per event sensitivity with $L_0$ radius ~1.5 cm. Striplet solution is reaching BaBar reference at $L_0$ radius ~2 cm.*

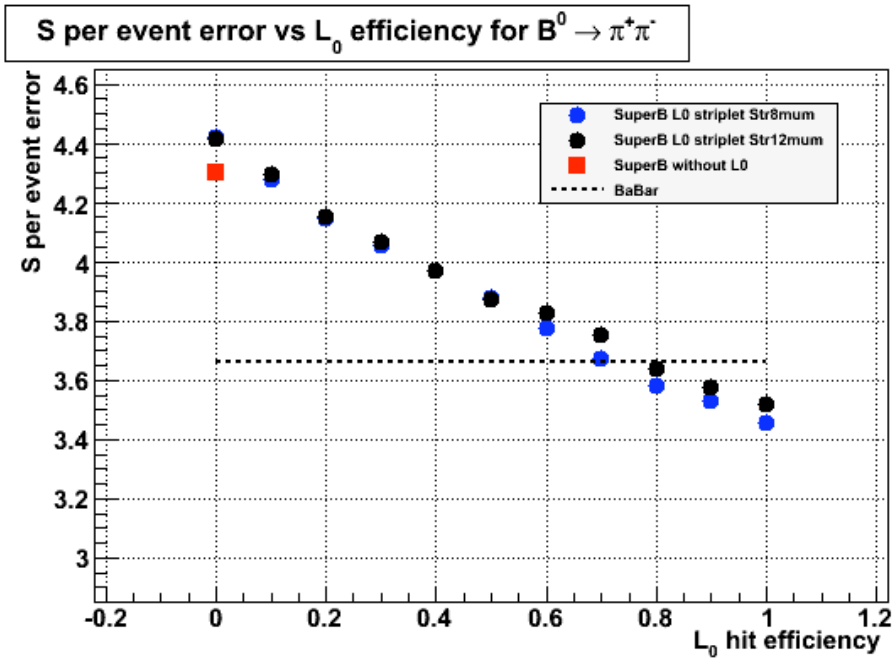
# Effect of $L_0$ efficiency and hit resolution

# Striplet vs Hybrid Pixels



# Striplet performance vs degraded hit resolution



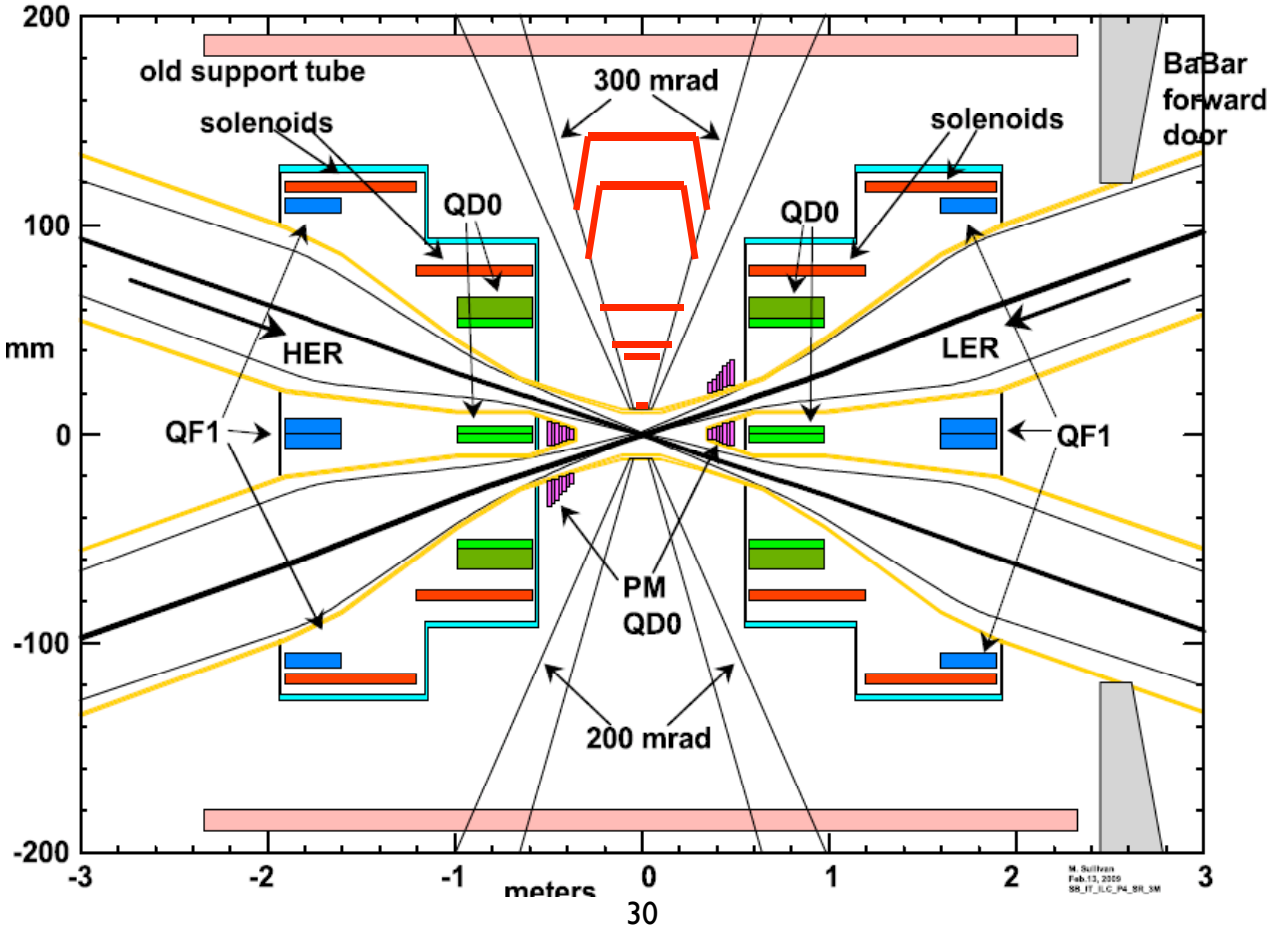

*Nominal resolution 8 μm.*
*Considering 50% worsening (12 μm) from high occupancy in $L_0$.*
*Rough estimate to be studied in detail.*

# Conclusions

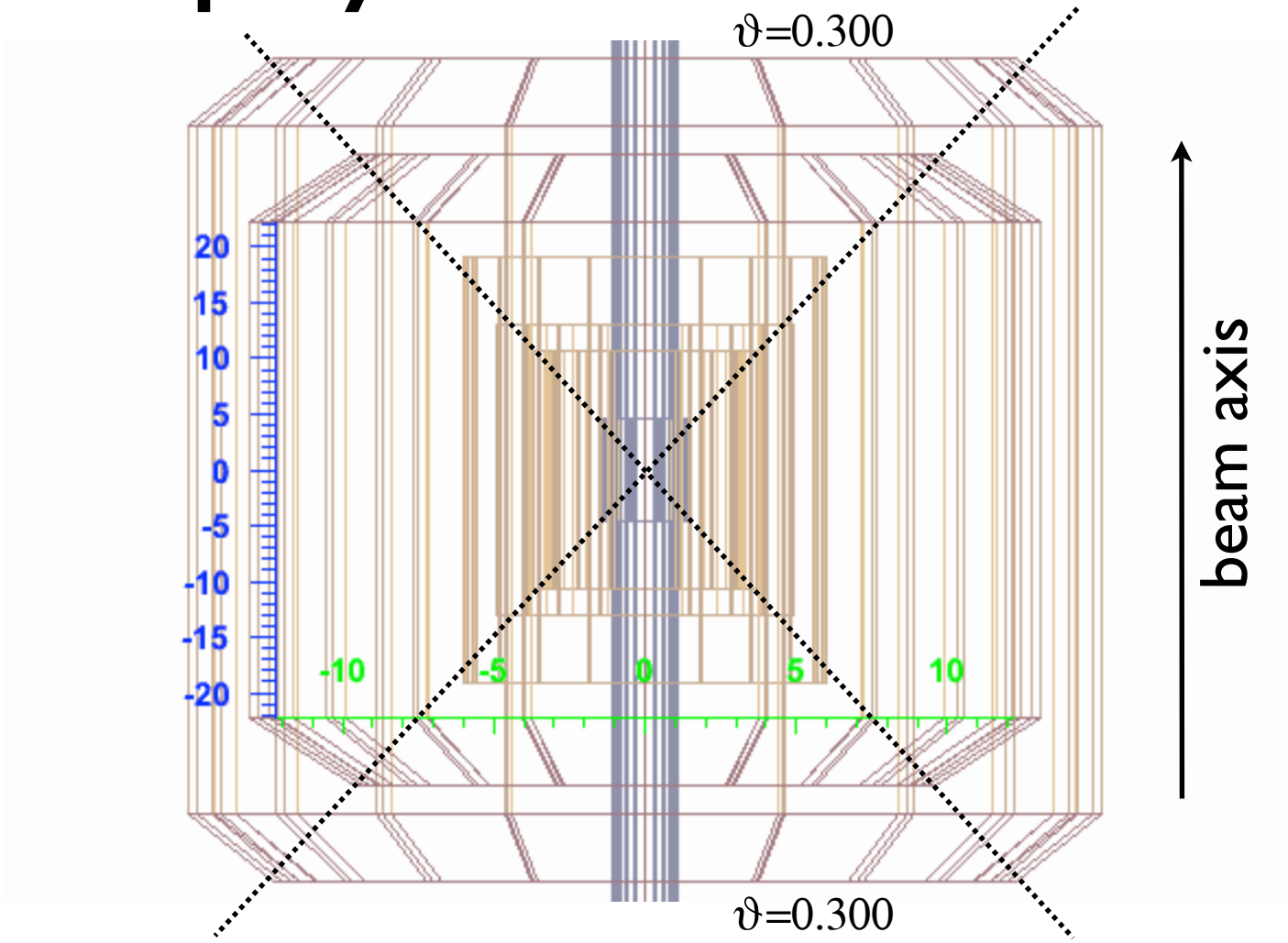
- Striplet detector seems to represent a viable solution for $L_0$ in terms of vertex and proper time resolution for time-dependent measurements in alternative to Hybrid Pixel or Maps detectors (assuming current bkg estimates on $L_0$ are robust).
- Some increase of the $L_0$ radius with respect to the nominal 1.60 cm value is possible if required for bkg reduction, up to ~2 cm, maintaining comparable $\Delta t$ resolution with BaBar.
- Studied effect of efficiency on $\Delta t$ resolution. Striplet detector maintains better or comparable $\Delta t$ resolution with BaBar down to ~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



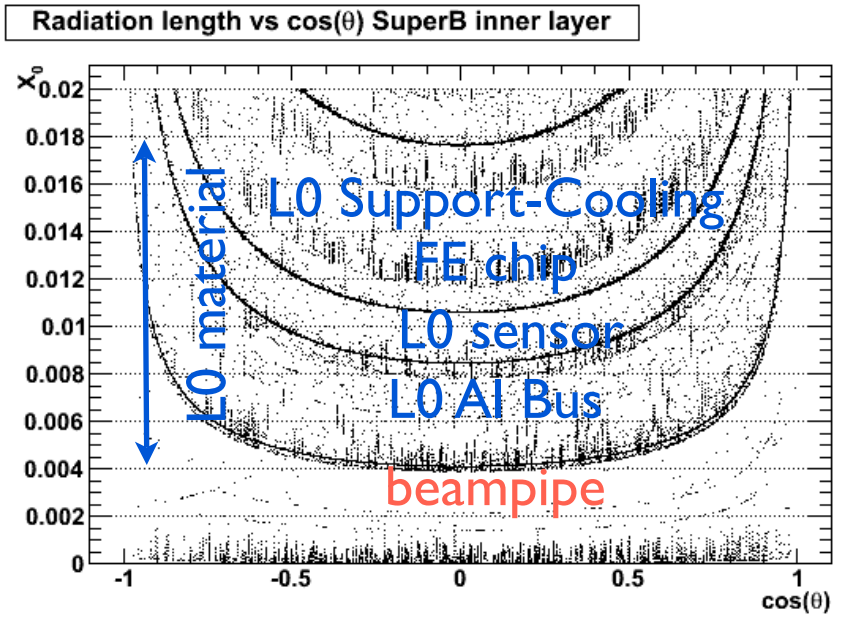
# Display of SVT modules



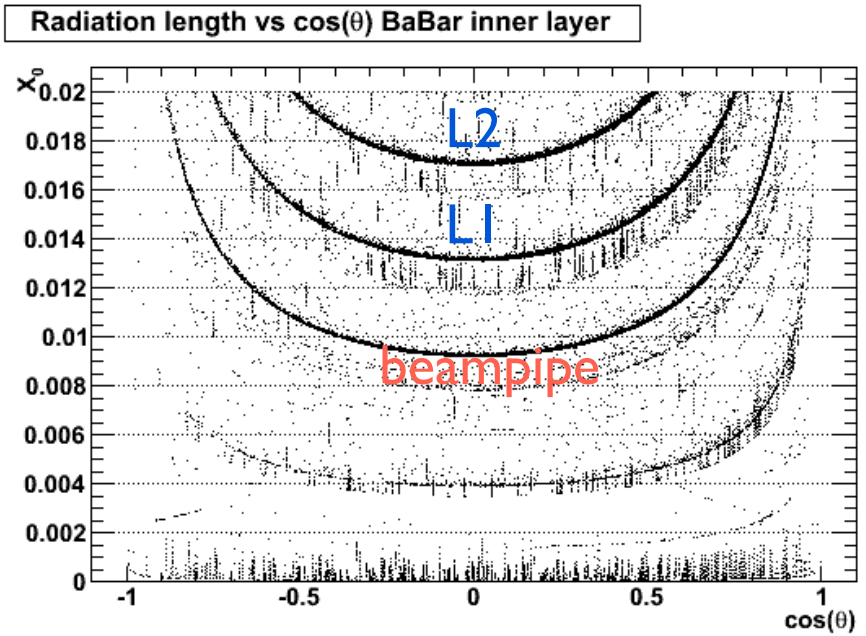

angular coverage in $CM_3$~ 95% (BaBar SVT ~89%)

# Radiation length vs cos(theta) in FastSim

## SuperB

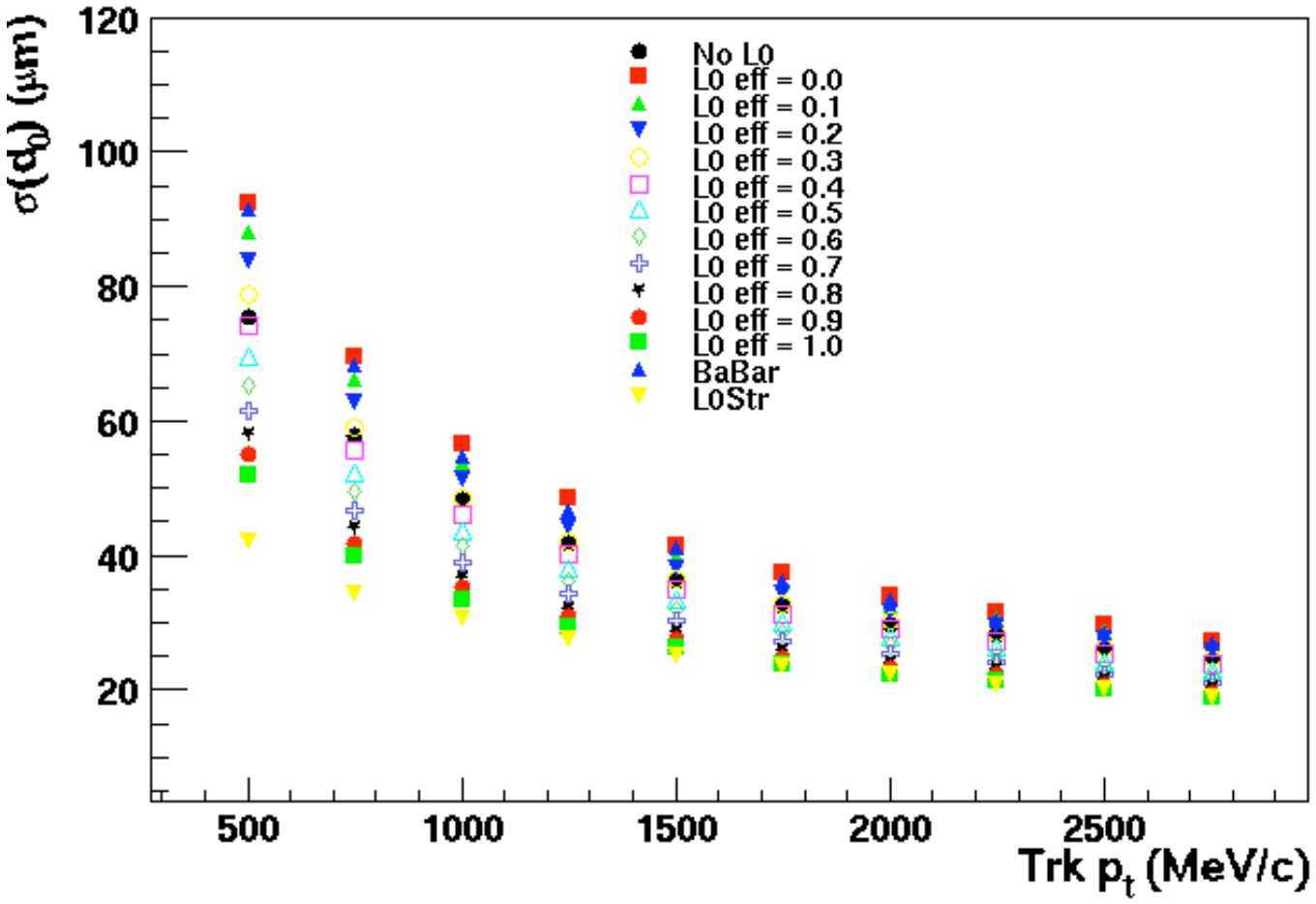



## BaBar



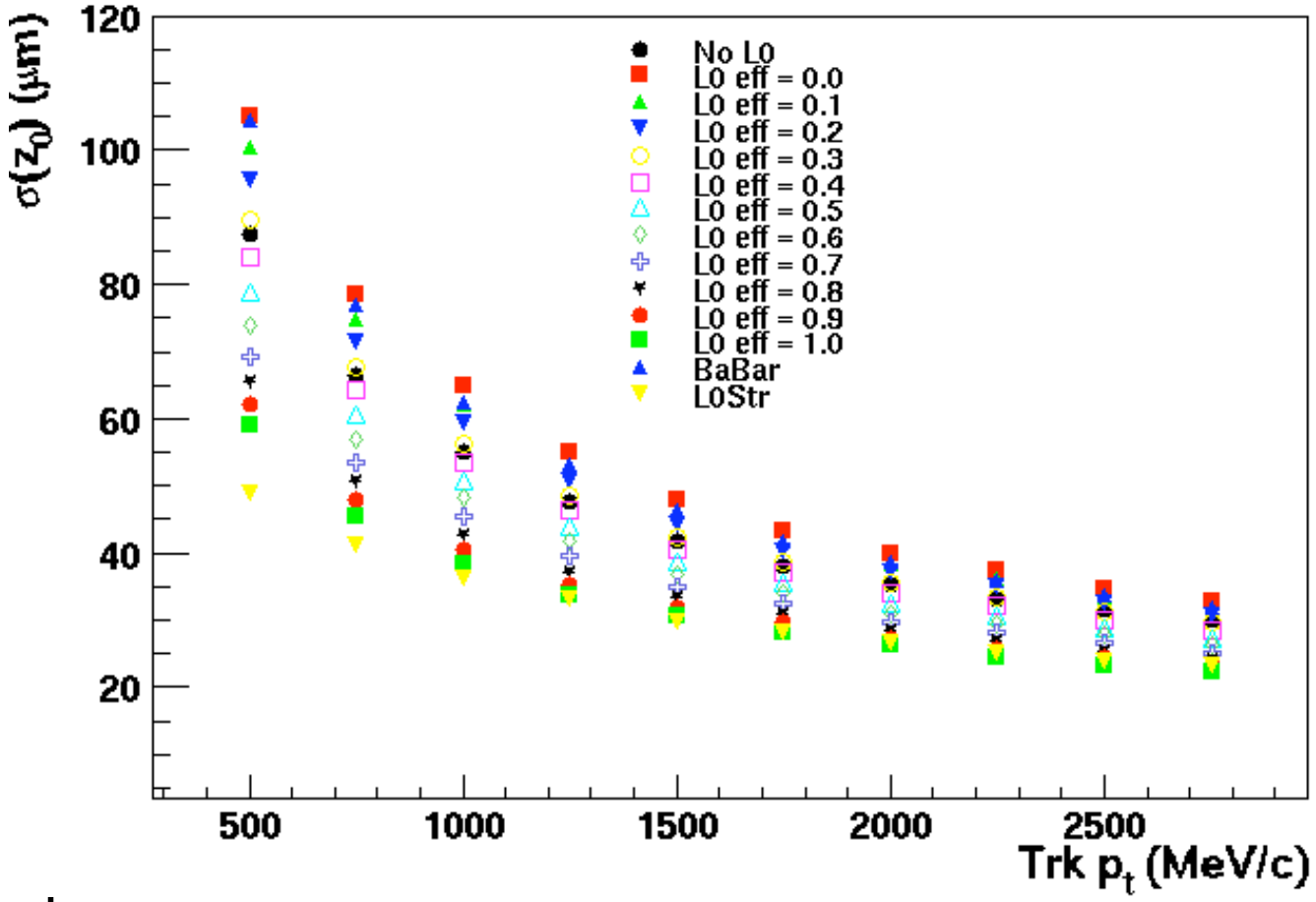

Total amount of L0 material is ~1.36% $X_0$ considering overlap of passive material.
Relative amount of material for Al bus and support-cooling requires small adjustments.

# $d_0$ resolution



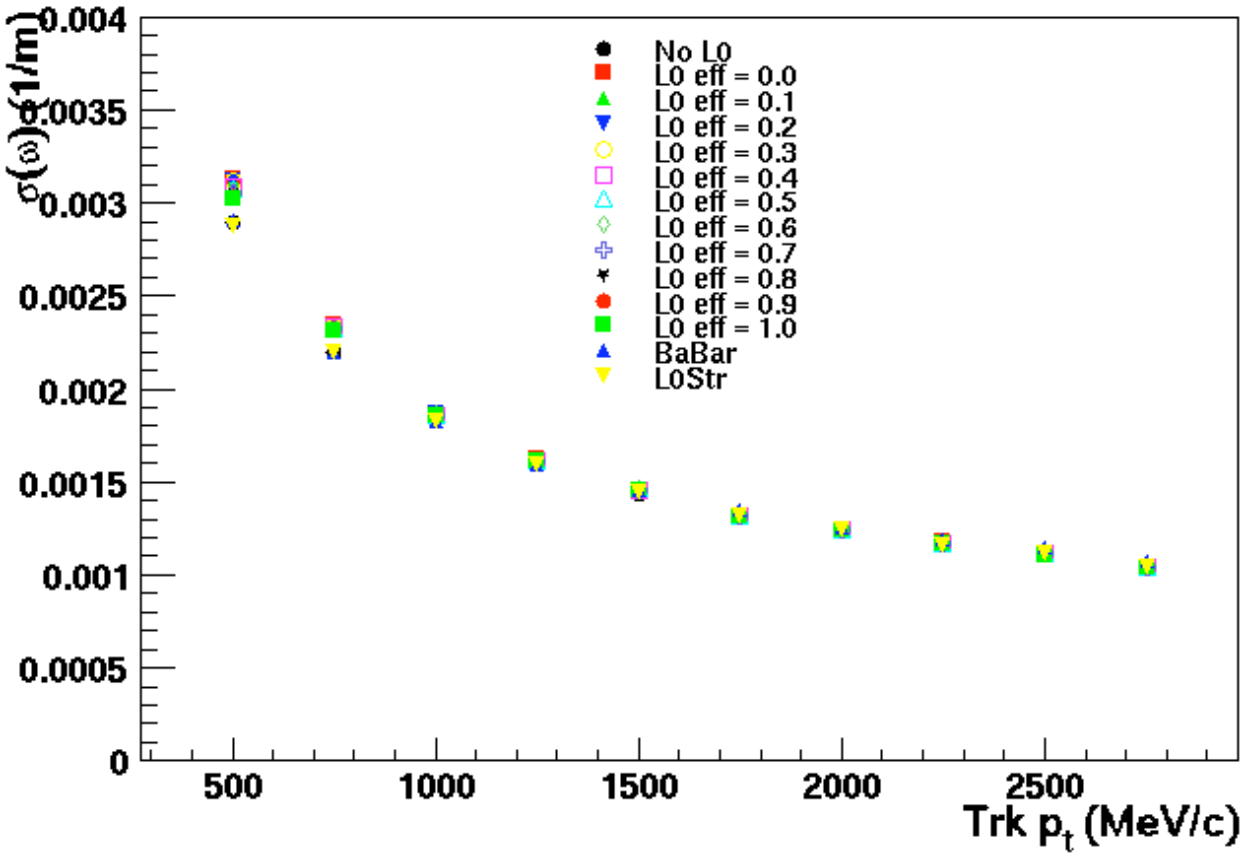

Legenda:
L0Str = L0 Strip detector

# $z_0$ resolution



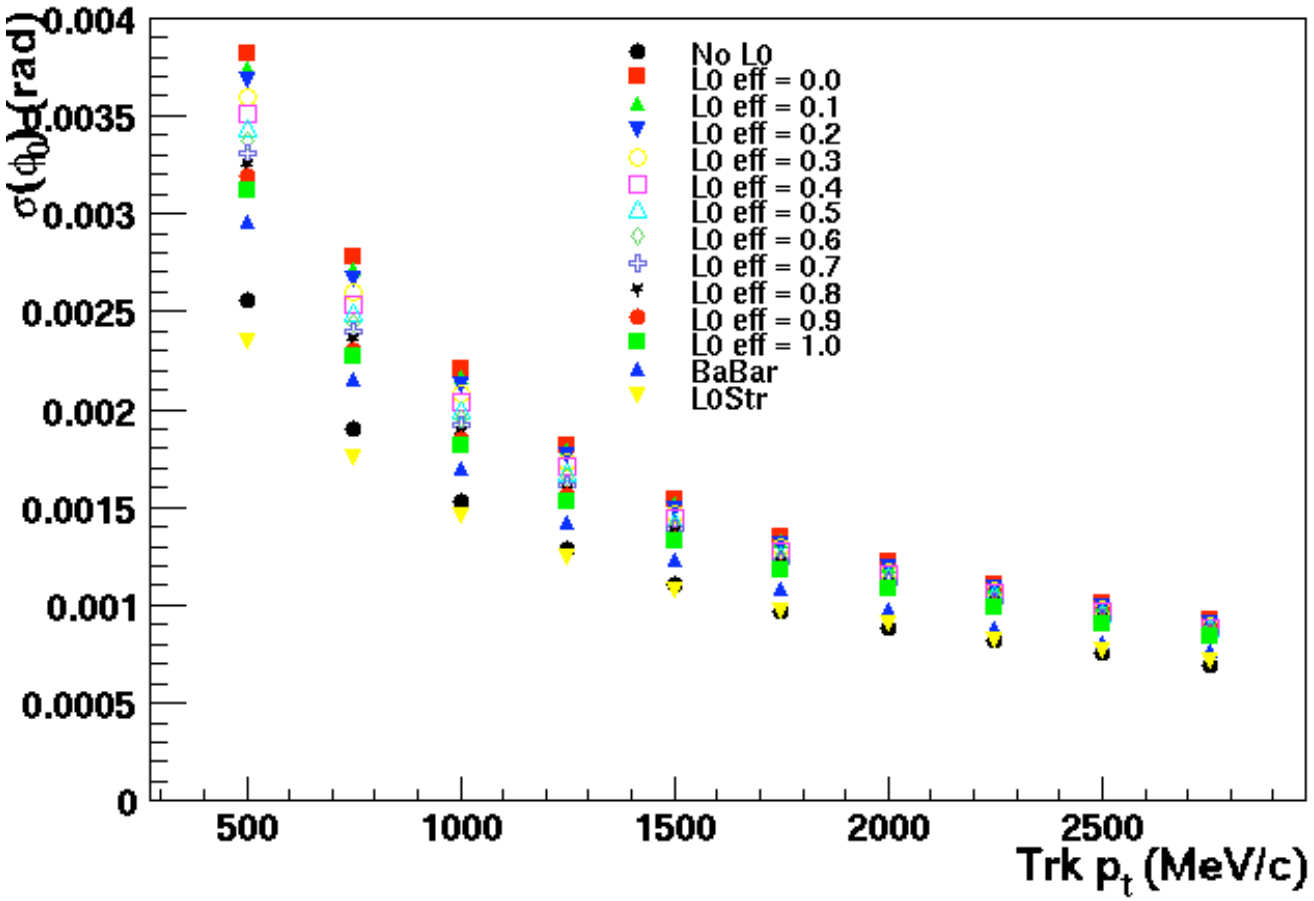

Legenda:
L0Str = L0 Strip detector

# ω resolution



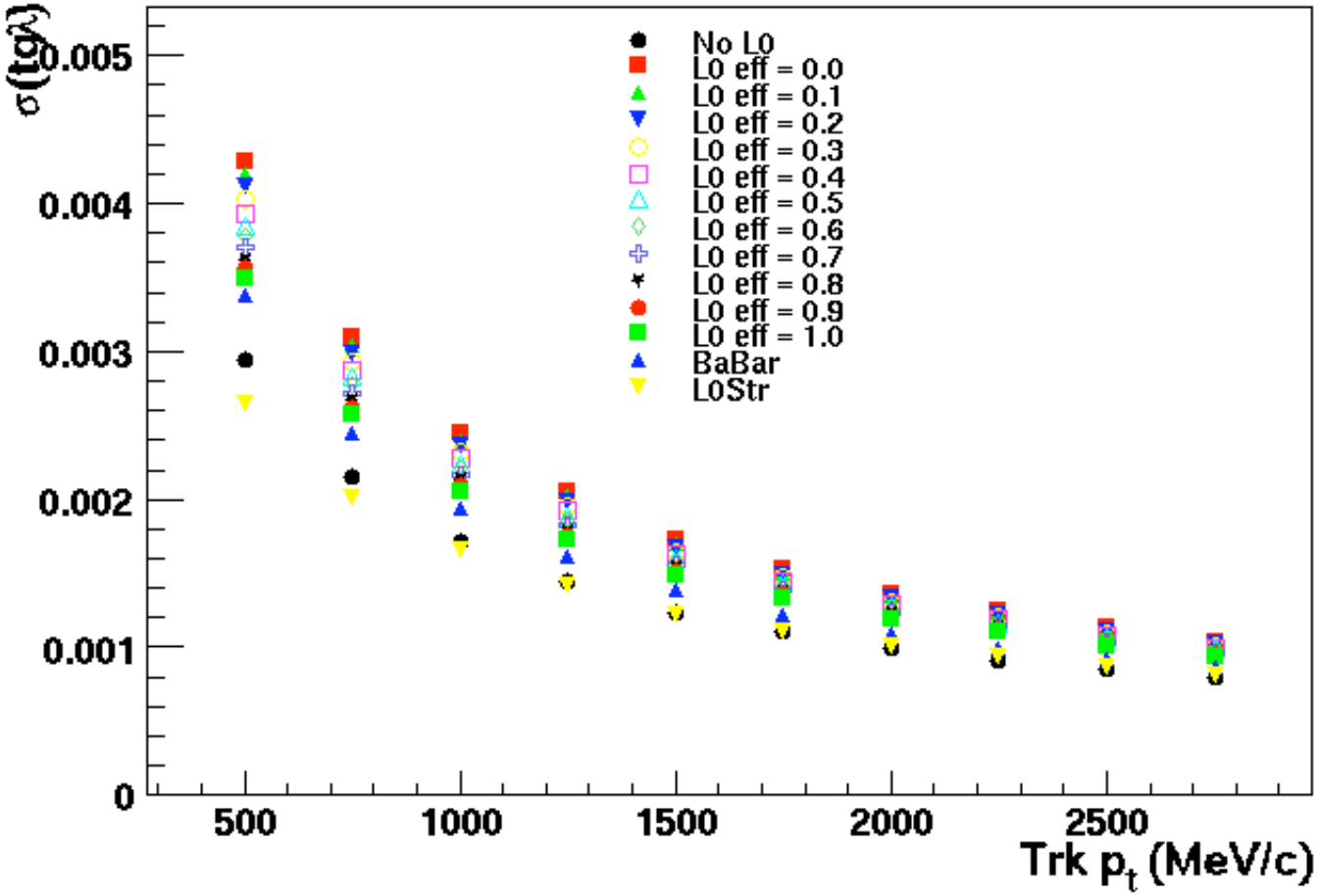

Legenda:
L0Str = L0 Strip detector

# $\phi_0$ resolution




Legenda:
L0Str = L0 Strip detector

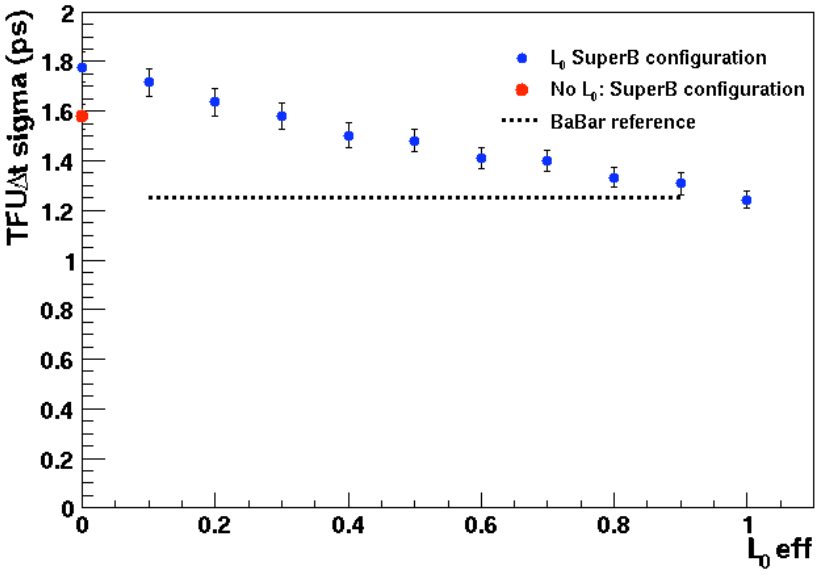
# tgλ resolution



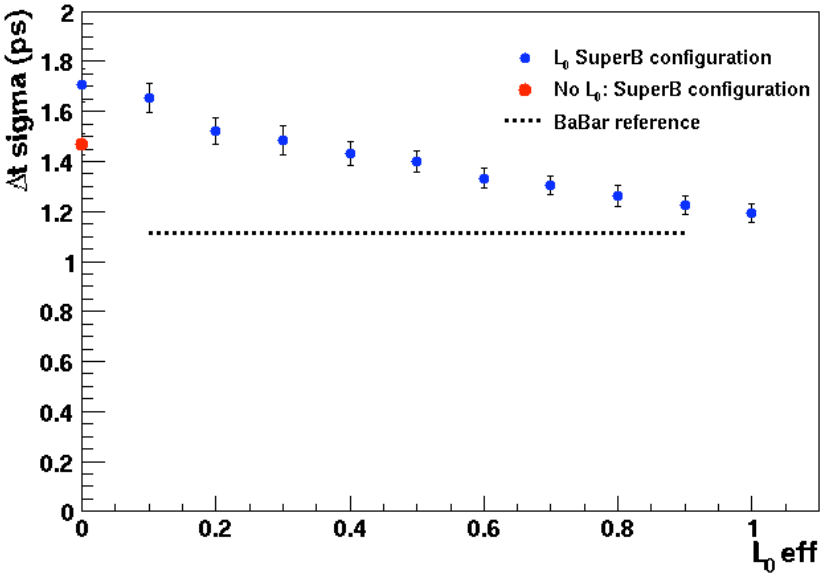

Legenda:
L0Str = L0 Strip detector

# DeltaT resolution

## TreeFitter Upsilon




## Standard BaBar algorithm



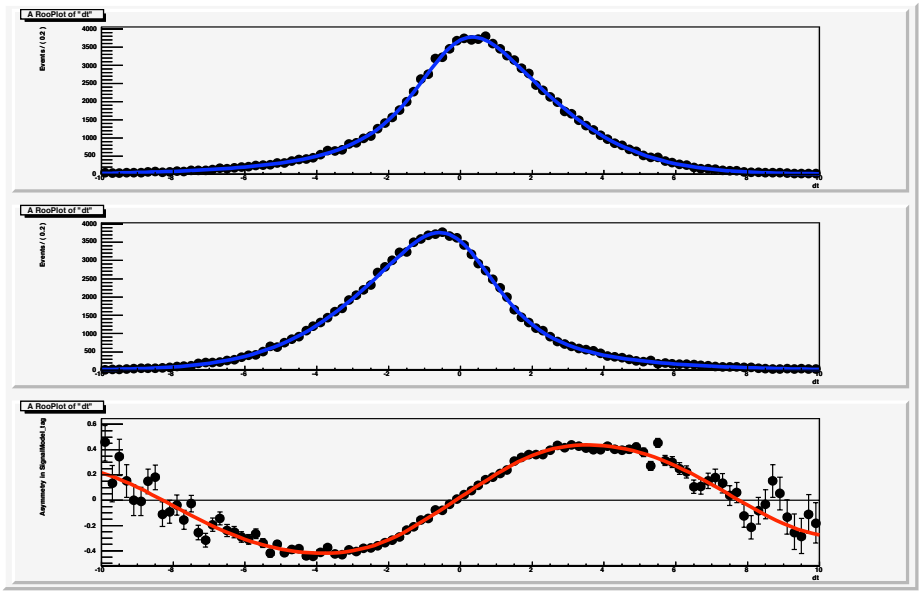

*TreeFitter has worst resolution wrt the standard algorithm which is against the expectation. Needs to be further investigated.*

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

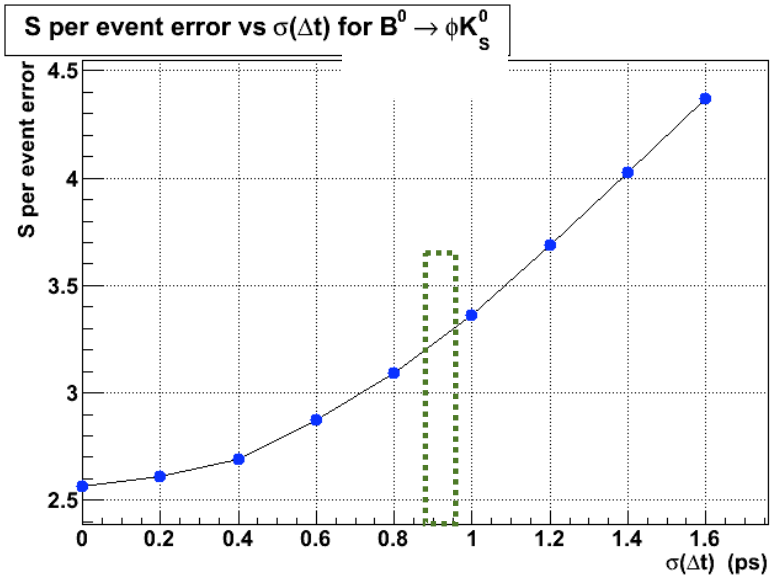
# Impact on TD measurement

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

100K signal Evts. $S_{GEN}$=0.70

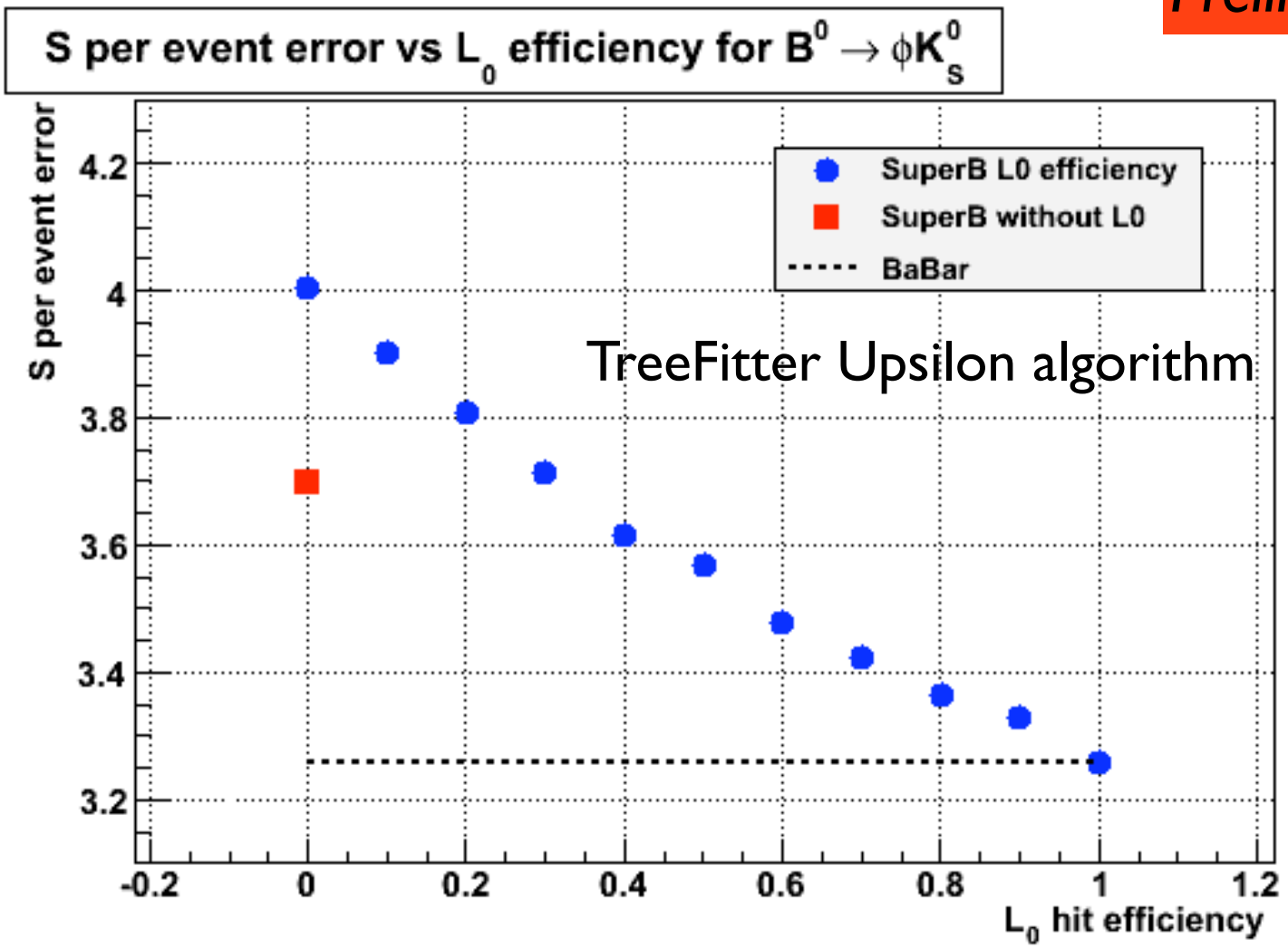


S per event error normalized to BaBar result:
Phys.Rev.D71:091102,2005.




From "AFit" Toy MC

*Preliminary*

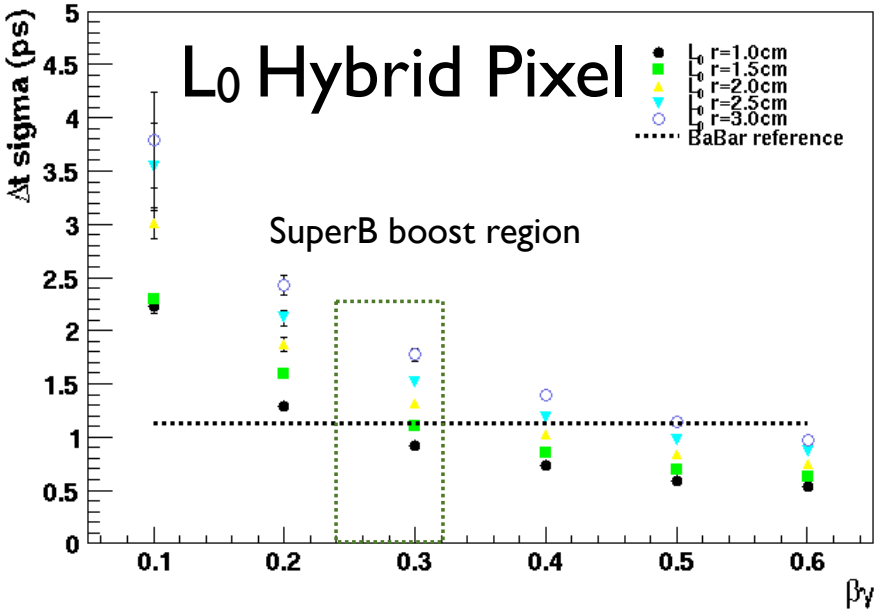



*It is worth keeping Hybrid Pixel $L_0$ inside SVT*

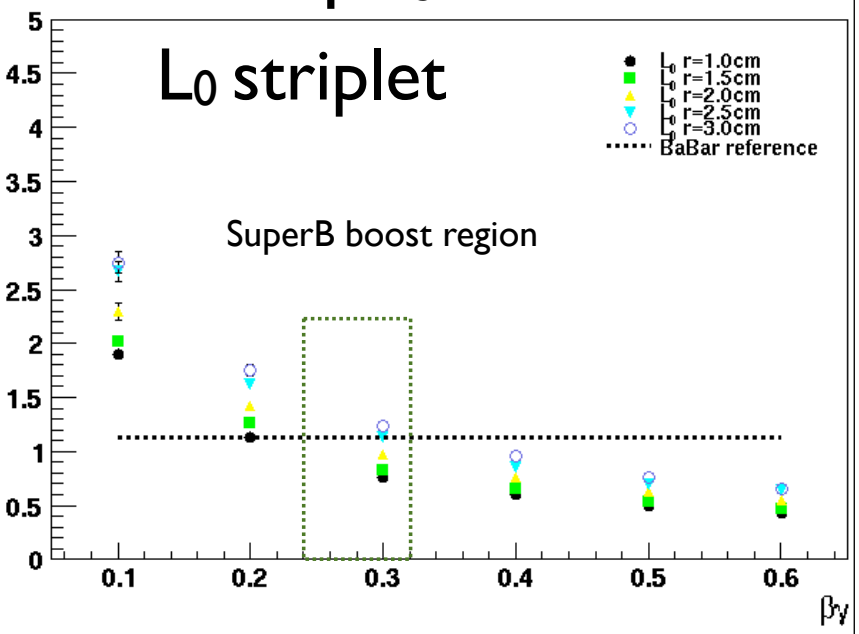
*if efficiency is greater than 40%*

# Striplet vs Hybrid Pixel: Δt resolution

$B^0 \rightarrow \varphi K_S$



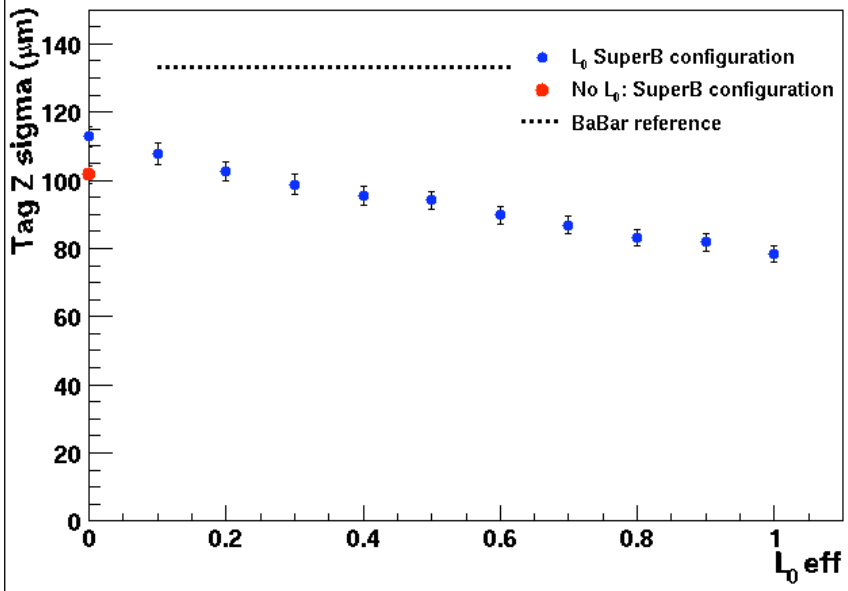

$B^0 \rightarrow \varphi K_S$



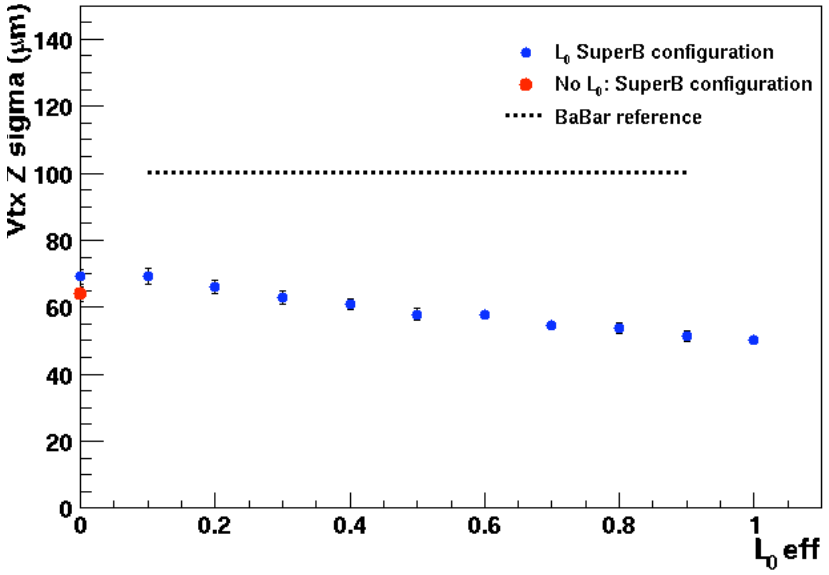

*Hybrid Pixel solution is reaching BaBar reference of Δt resolution with $L_0$ radius ~1.5 cm. Striplet solution can afford a larger $L_0$ radius ~2.0 cm where bkg is much lower.*

# 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)