Impact of high QED background on time-dependent measurements

Nicola Neri
INFN - Sezione di Milano
London - 13 September 2011

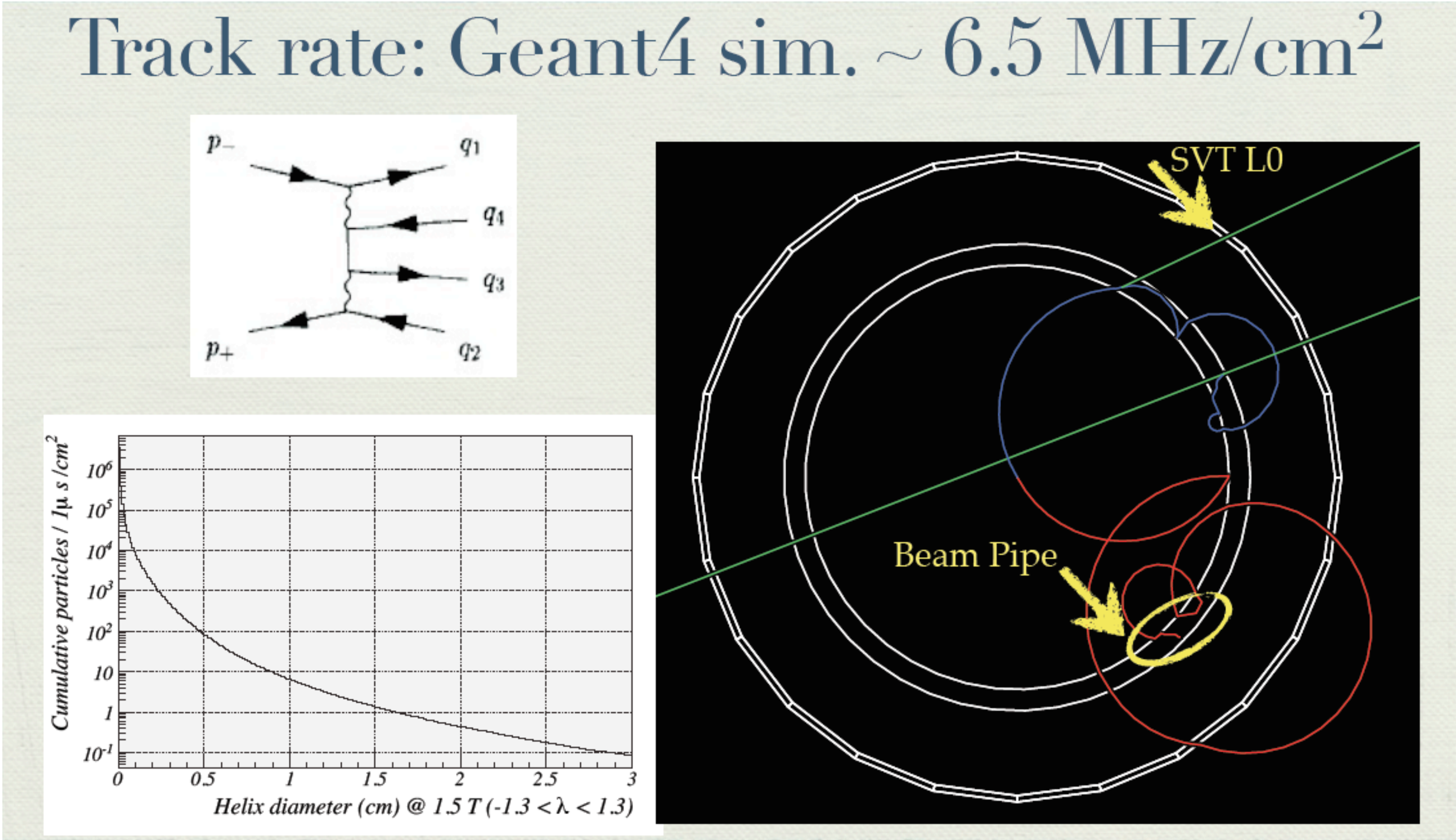
Outline

- Introduction
- FastSim setup
- First results
- Summary

Introduction

- According to our FullSim studies, QED bkg (aka Pairs) is the dominant bkg in the inner layer of the SVT. For details see R. Cenci and E. Paoloni talks at recent SuperB workshops.

From E. Paoloni talk



Belle II studies disagree

- According to Belle II studies QED bkg is about a factor 15 smaller.

❑ BUT: there is also a prediction from SUPERB which deviates strongly

from Elena Nedelkovska talk
at 6th DEPFET workshop (Feb 2011)

MC generator	SuperB (BDK)	BDK	KoralW
Tracks	13800	~ 710	~ 800
Occupancy	1.3%	0.07%	**0.1%**

a factor of 15 difference

- Belle II performed "QED experiments" directly on data, using latest Belle runs. Idea: vary luminosity, look at change in #hits in SVT, extrapolate to L0 and estimate luminosity driven (QED) bkg.

From Elena Nedelkovska talk:

The expectation form SuperB is completely excluded

There is an MDI ongoing effort to understand the disagreement

- As far as I know, Cecile Rimbault (LAL, Orsay) volunteered to understand the discrepancy at simulation level. She is an expert of machine related background.
- I am not sure if it is possible to extract some information on QED bkg using BaBar data. Any thought about it?

FastSim setup

- FastSim is able to deal with simulated bkg hits and estimate their impact on Hit reconstruction and track pattern recognition. D. Roberts and D. Brown have implemented those functionalities. See D. Roberts talk at Paris SuperB workshop (2009) for details.

- I applied few trivial changes to the code in order to make it work with Silicon Striplets detectors in FastSim V0.2.7_test. Changes not available on svn yet.

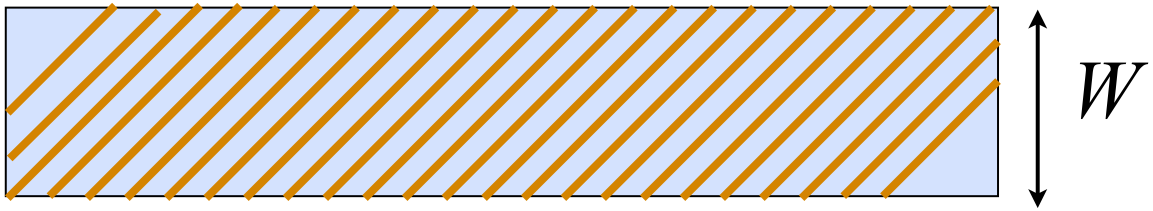
- I generated 10^6 QED pair events and then merged to $2 \cdot 10^3$ signal $B^0 \rightarrow J/\Psi K_S$ events.

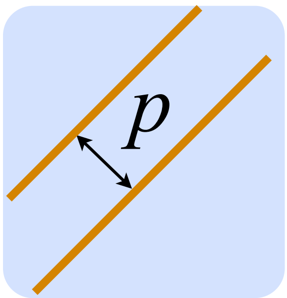
- I realized severe memory leaks in the PacMCApp executable when running the reconstruction of signal+bkg events. Needed to run several small jobs of 200 events each to prevent crashes or hanging the system. Also very slow the reconstruction. Need to be fixed.

Bkg parameters

- Bunch crossing frequency: 200 MHz
- Instantaneous Luminosity: $10^{36} cm^{-2} s^{-1}$
- Use Diag36 generator with QED pairs cross section 7.3 mbarn
- For Diag36 generators parameters use the default :
    - $p_t > 2$ MeV/c (for e^+, e^- tracks)

Estimate for L0 striplets Occupancy





$Occ = B\cdot T\cdot p\sqrt{2}\cdot W = 2\%$ at radius 1.5 cm

B = hit rate/Area = 25 MHz/cm^2 *from R. Cenci studies*

T = 100 ns (L0 sensitive window)

p = 50 μm (pitch)

W = 1.2 cm (detector width)

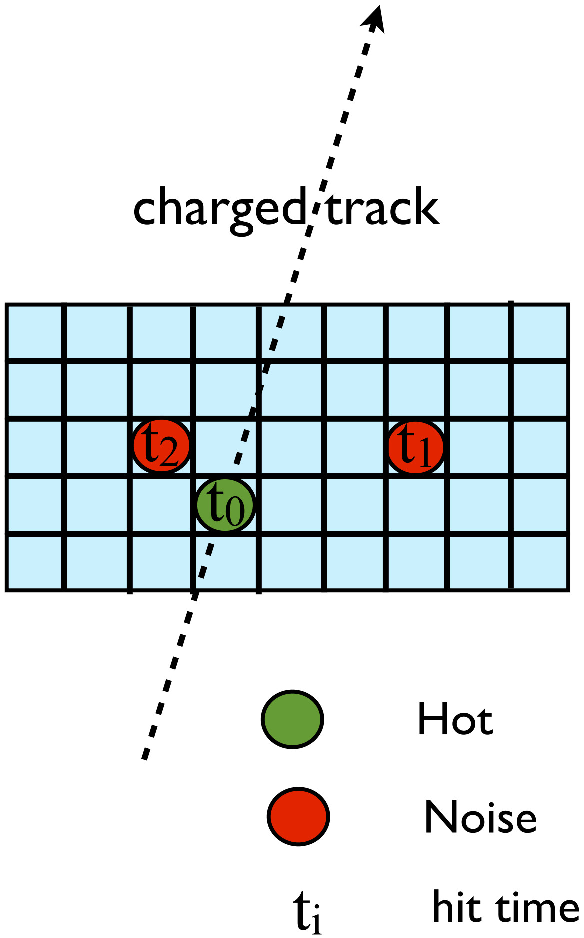
I still need to setup the code in order to evaluate the occupancy for L0 directly from root files.

Safety factor on QED pairs process

- $e^+e^- \rightarrow e^+e^-e^+e^-$ is a well known QED process originated at the IP and proportional to the luminosity. In this sense it differs from a "generic" machine bkg, since it is a "physics" bkg.
- Some uncertainties in the generator algorithm are due to some "operative" approximations. Two different generators: BDK and KoralW agree at the level of 30%.
- Other uncertainties might arise in the propagation of low momentum (MeV) electron/positrons in the tracking volume. Interaction with the material, propagation in the magnetic field, etc. Do we have an estimate for this uncertainty?
- Currently we are prosing 500% uncertainty on this process. (Belle II is not considering to apply a safety factor).
- How is the safety factor being determined for QED bkg? It may be worth it to discuss about it.

Hit Merging

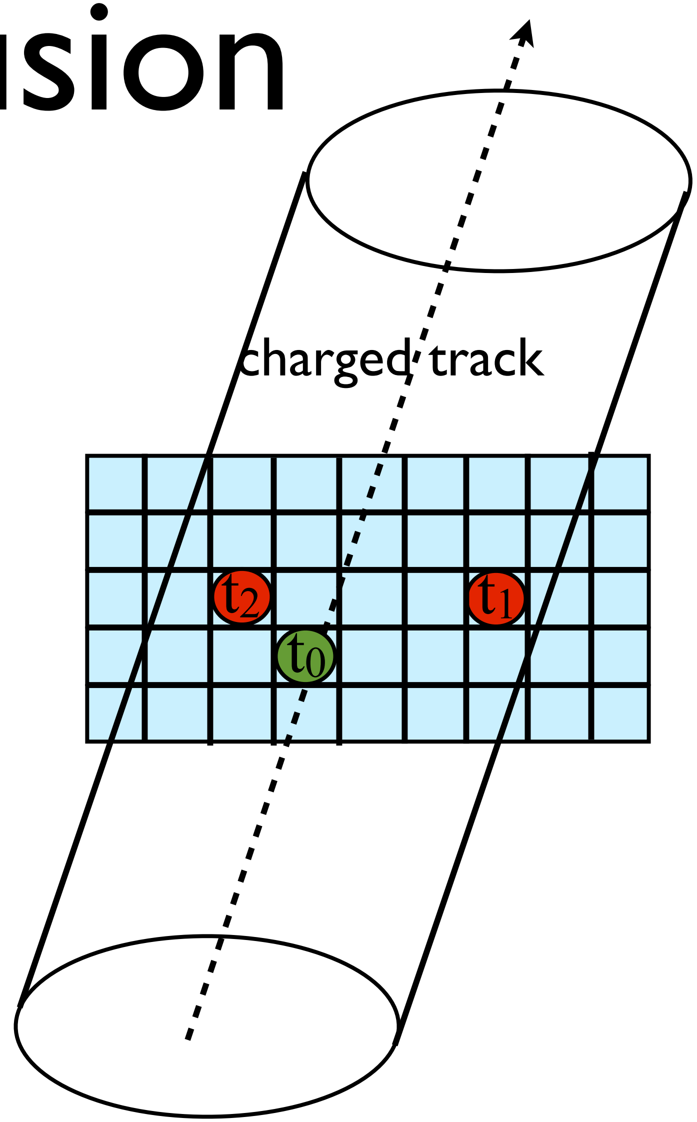
- It works for DCH wires and Si strip/striplets detectors. Not working for Si pixel detector at present.
- Hit merging based on hit timing (sensitive time window 400 ns L1-L5 and 100 ns for L0) and for spatial informations (hit distance vs pitch and wafer size) on a chi2 basis.
- If a pair of hit passes the chi2 cut a new average hit position is determined.
- Several tunable parameters: chi2 value, sensor separation (1mm L1-L5, 0.5 mm L0) , sensor size (5 cm), sensitive time window.




```
double _sensorSeparation; // rough measure of how far apart active elements are in the measurement direction
double _sensorSize; // rough measure of sensor size perpendicular to measurement direction;
```

PatRec confusion

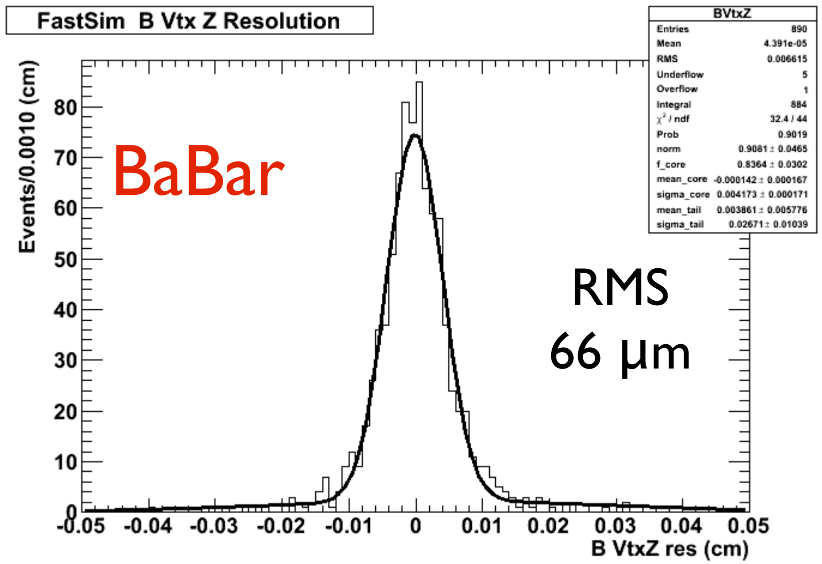
- The effect is driven more by the track resolution.
- This is probably a bigger effect than HitMerging in presence of bkg. It is included in the simulation but not evaluated yet the relative contribution.
- To be studied for L0 pixel.

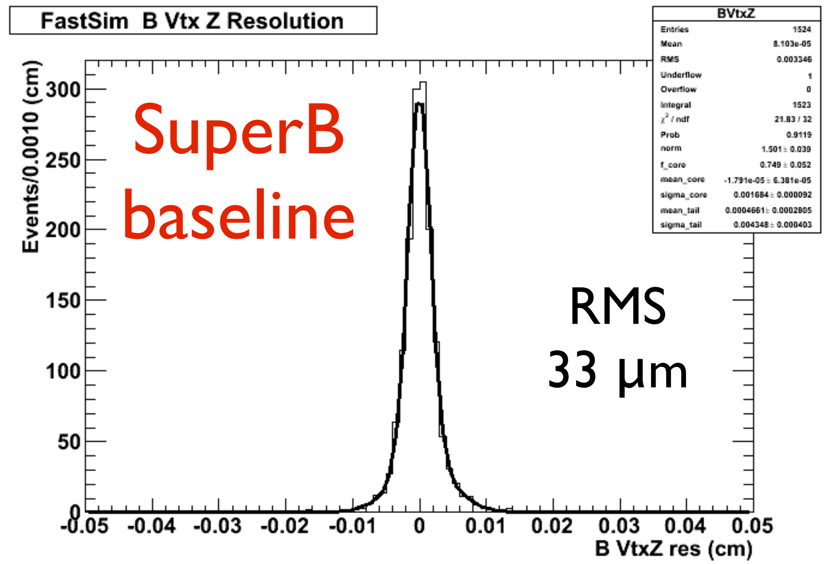


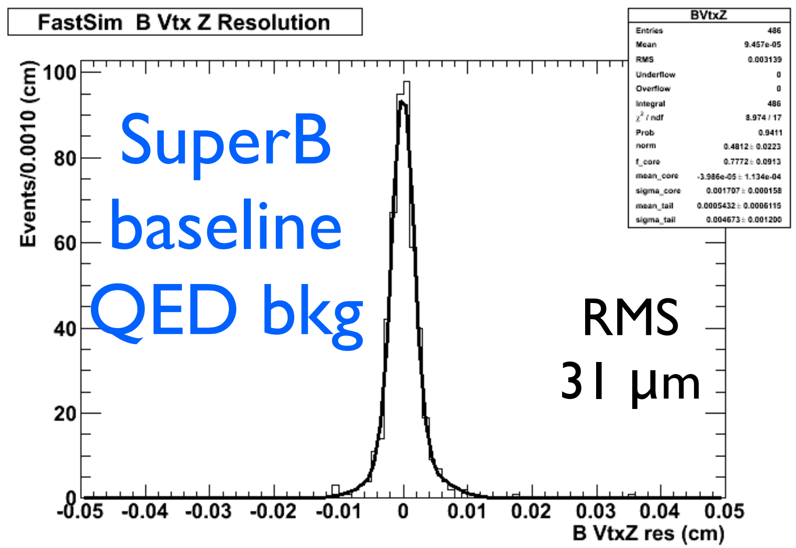
Some caveats

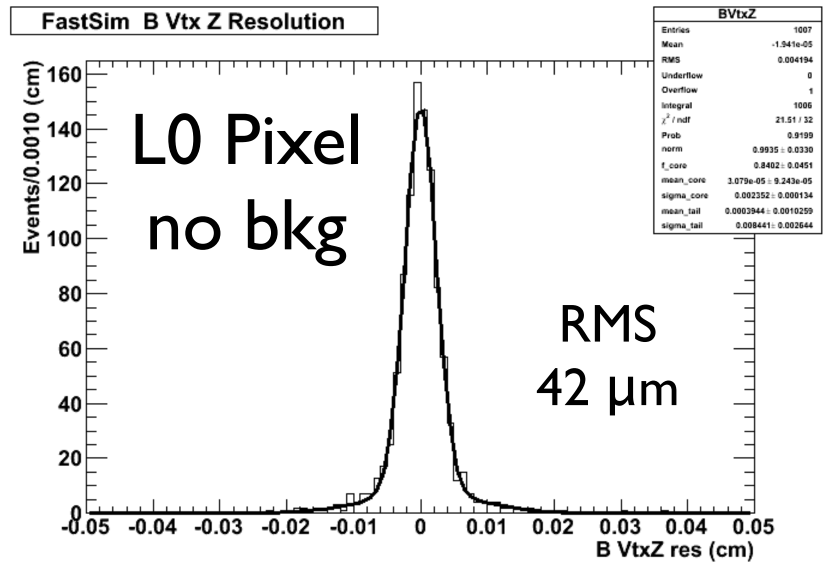
- The results that follow have to be considered as preliminary results. Still have to double check occupancy values from output files. Need to properly configure rootuples.
- To be reviewed after some fixes to the executable that process signal+bkg events in order to allow the necessary flexibility for performing systematic studies. In particular: fix memory leak, improve cpu time, additional configurations.
- No estimate of the impact of QED bkg for L0 pixel results that follow.

Decay vertex resolution

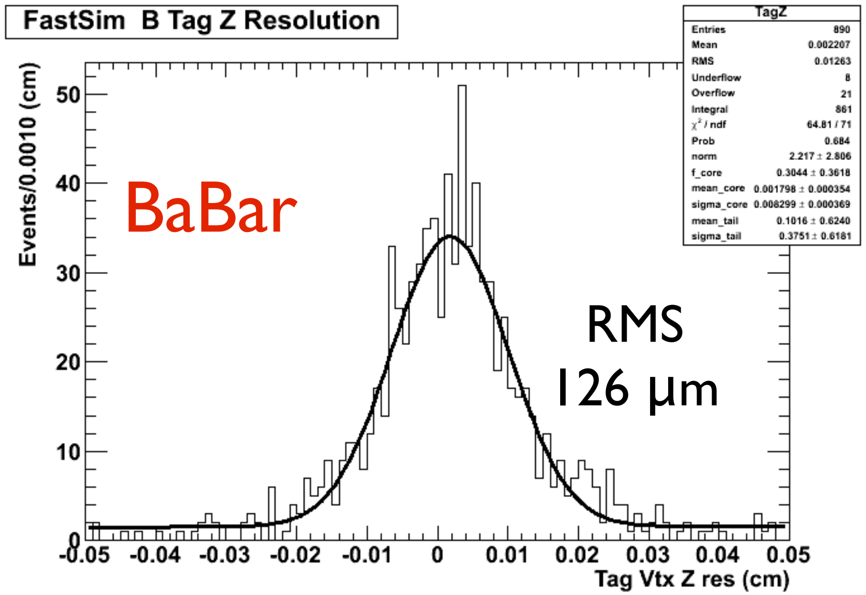


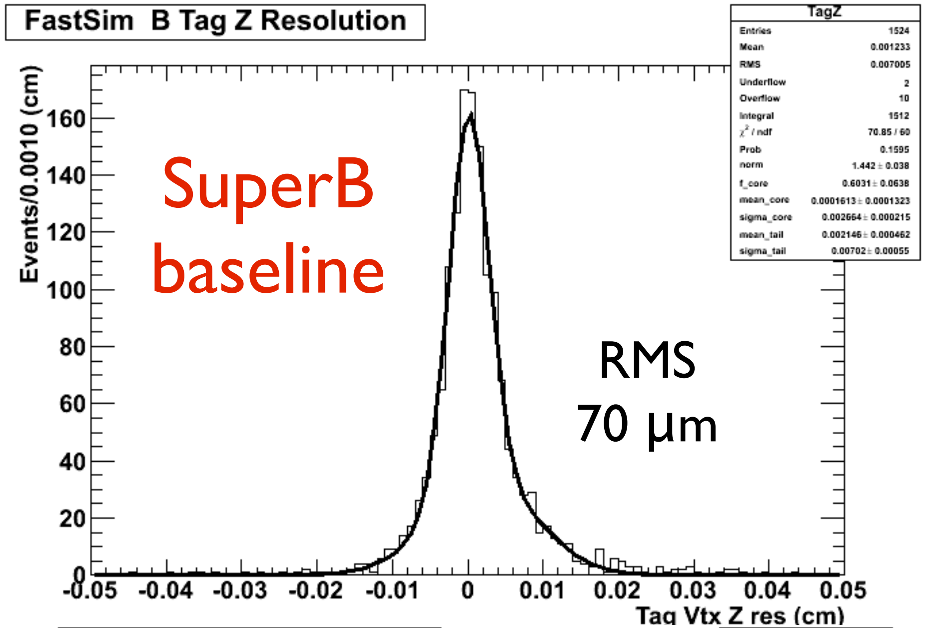


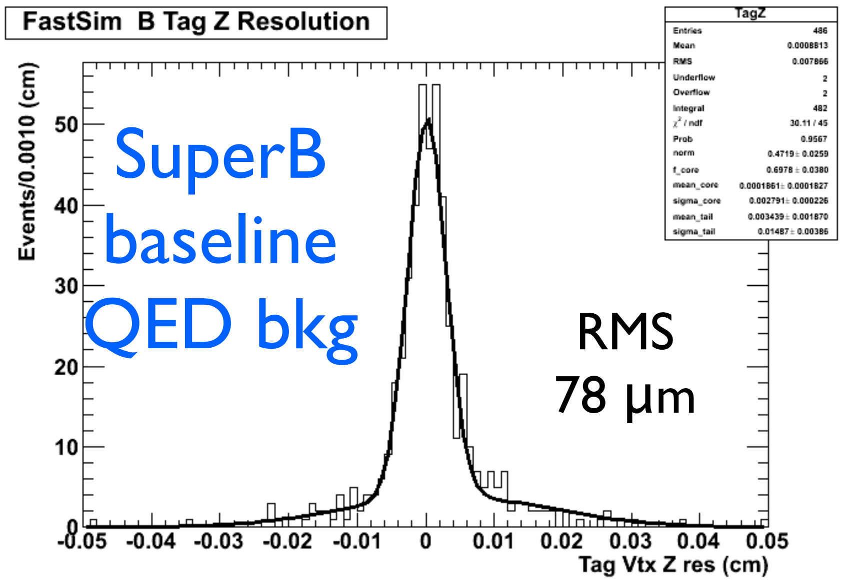


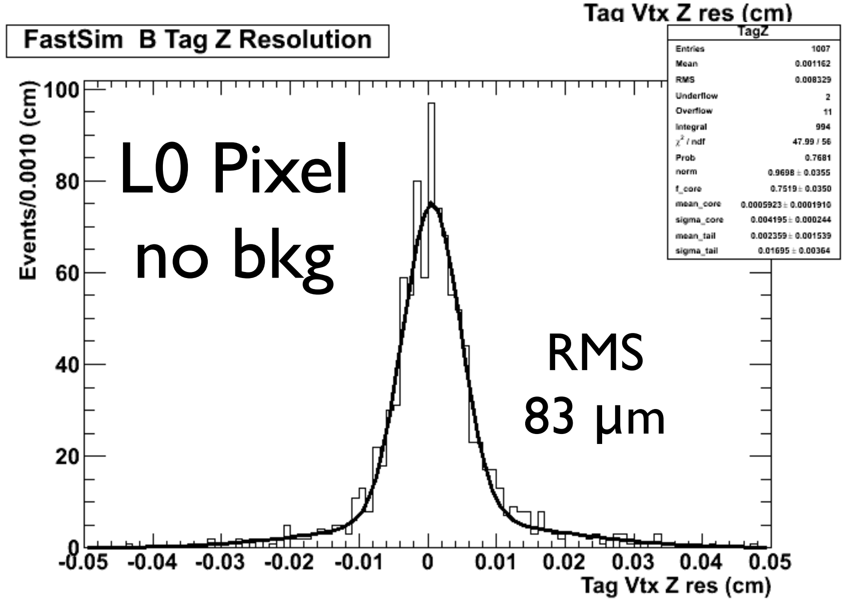


Tag side vertex resolution

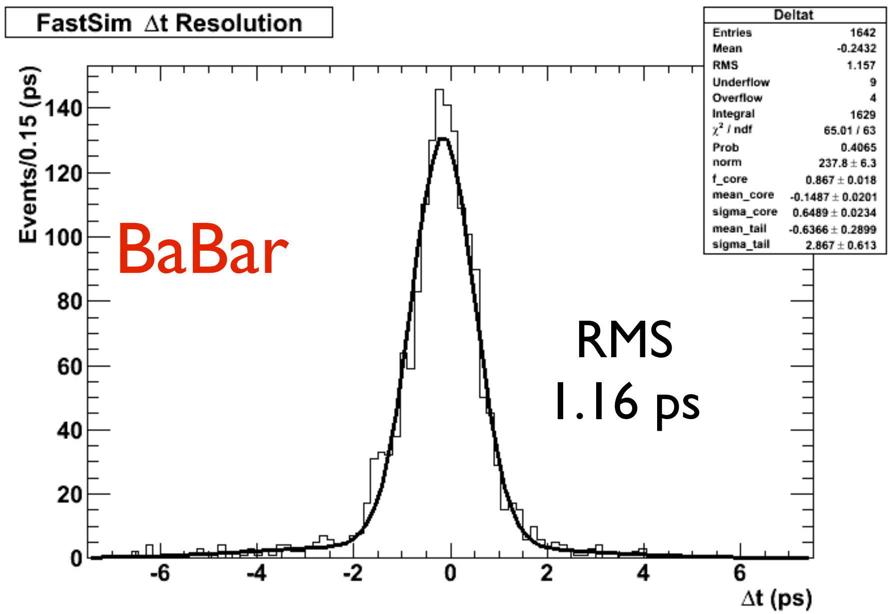


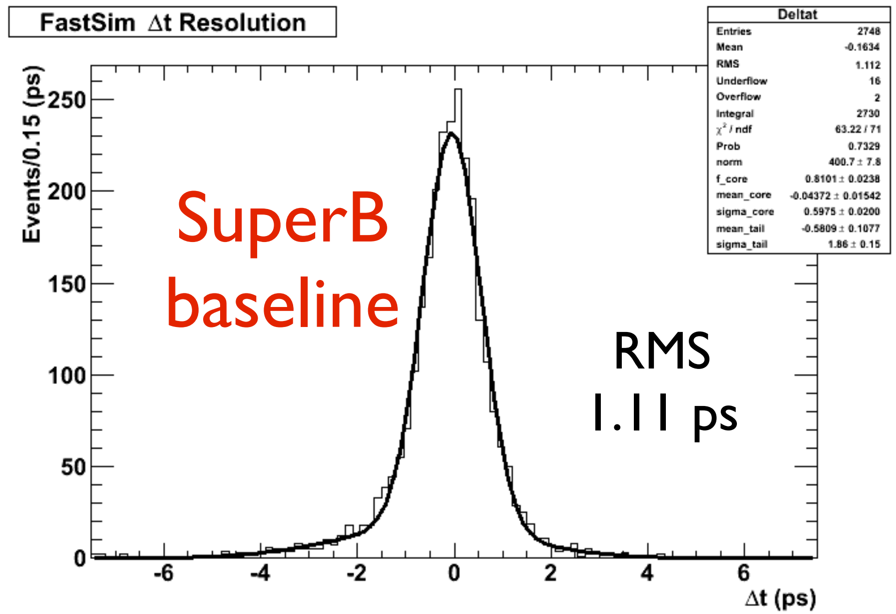


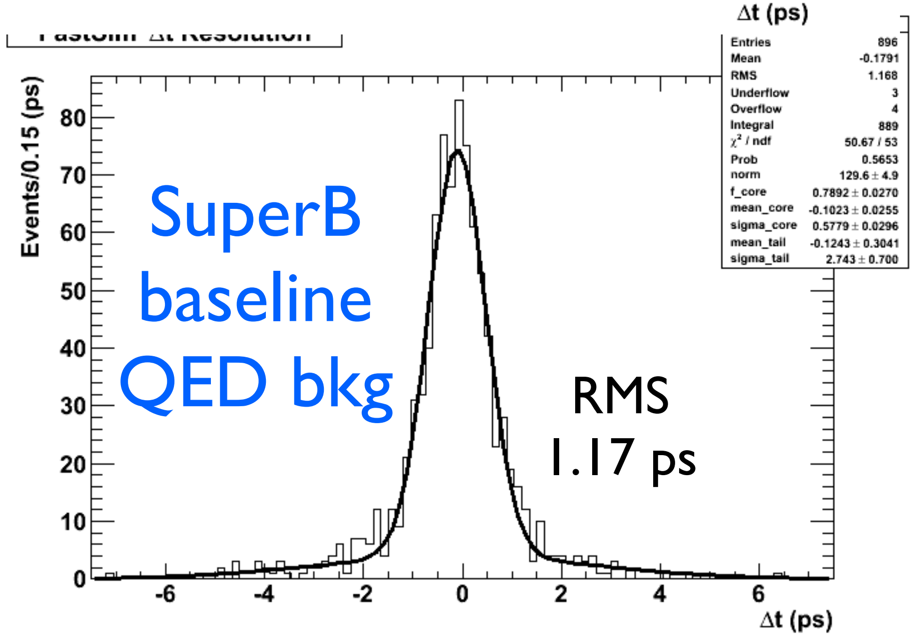


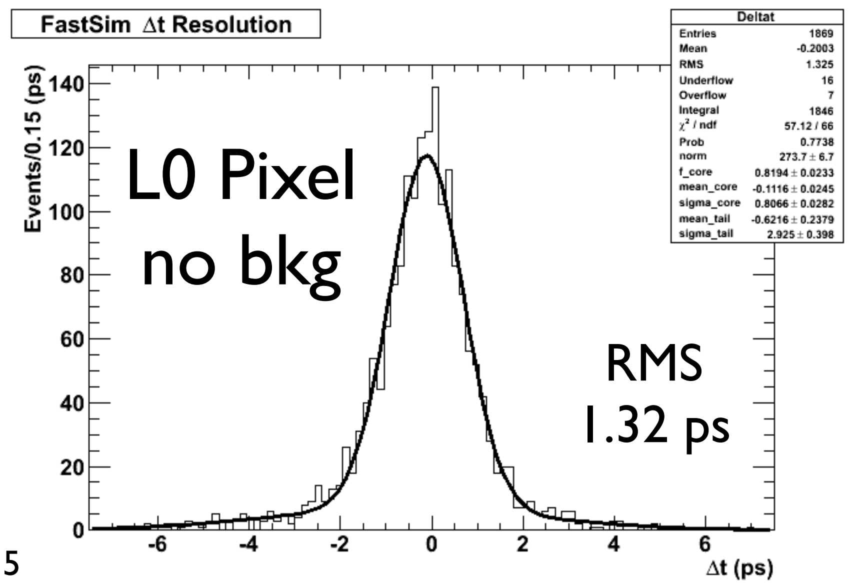


Δt resolution

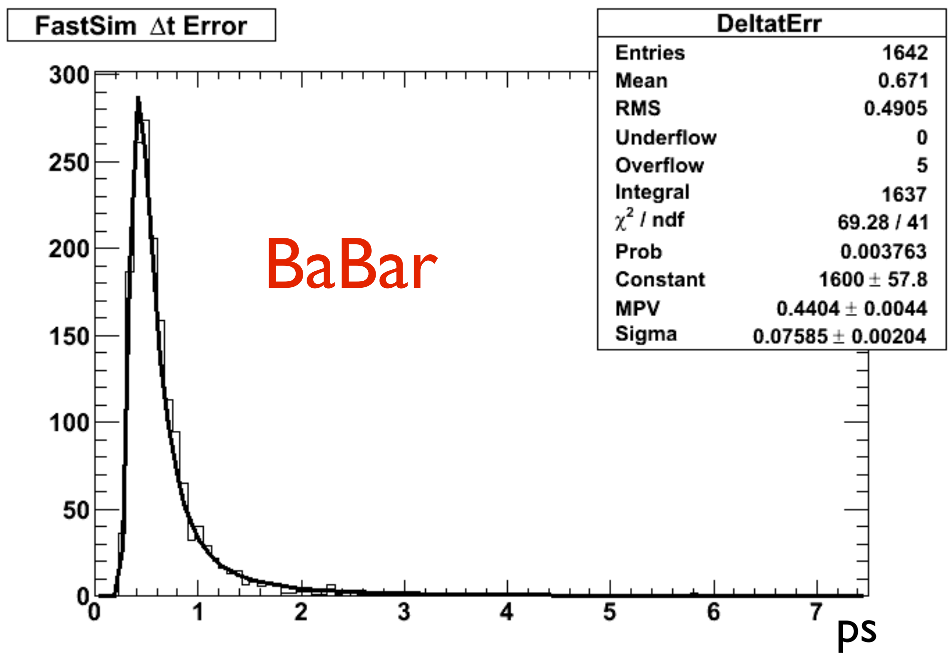


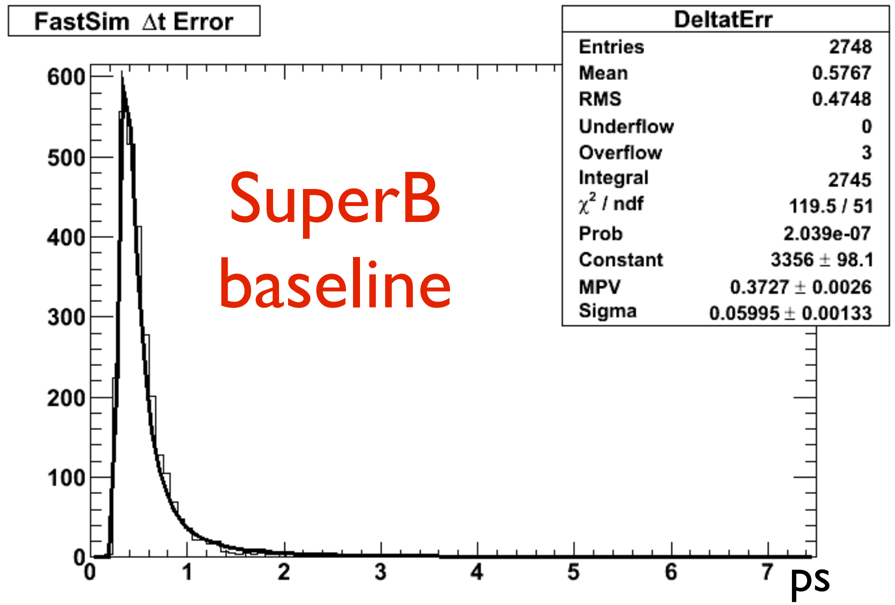


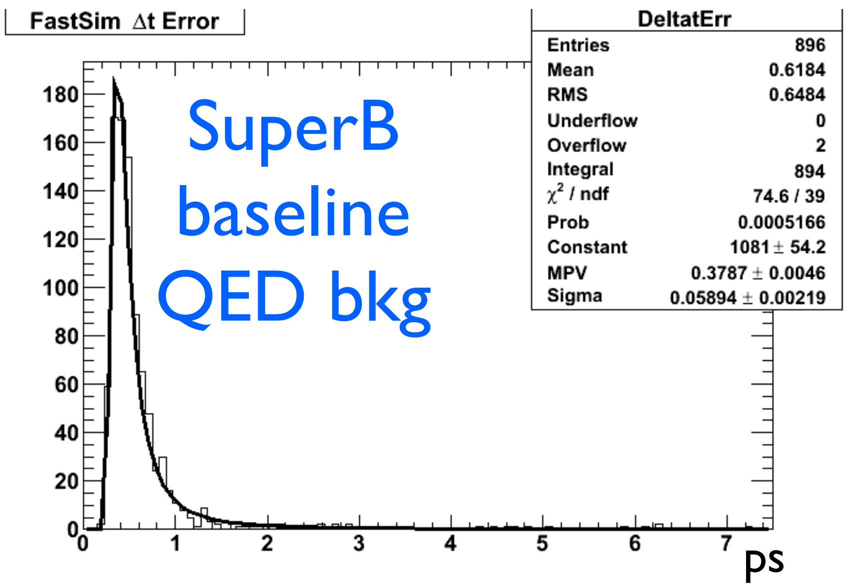


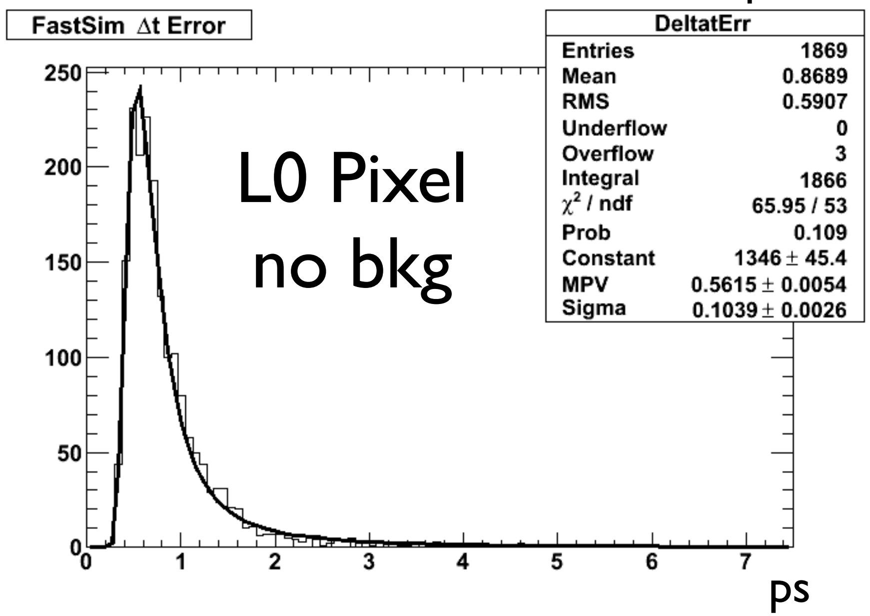


Δt error distribution

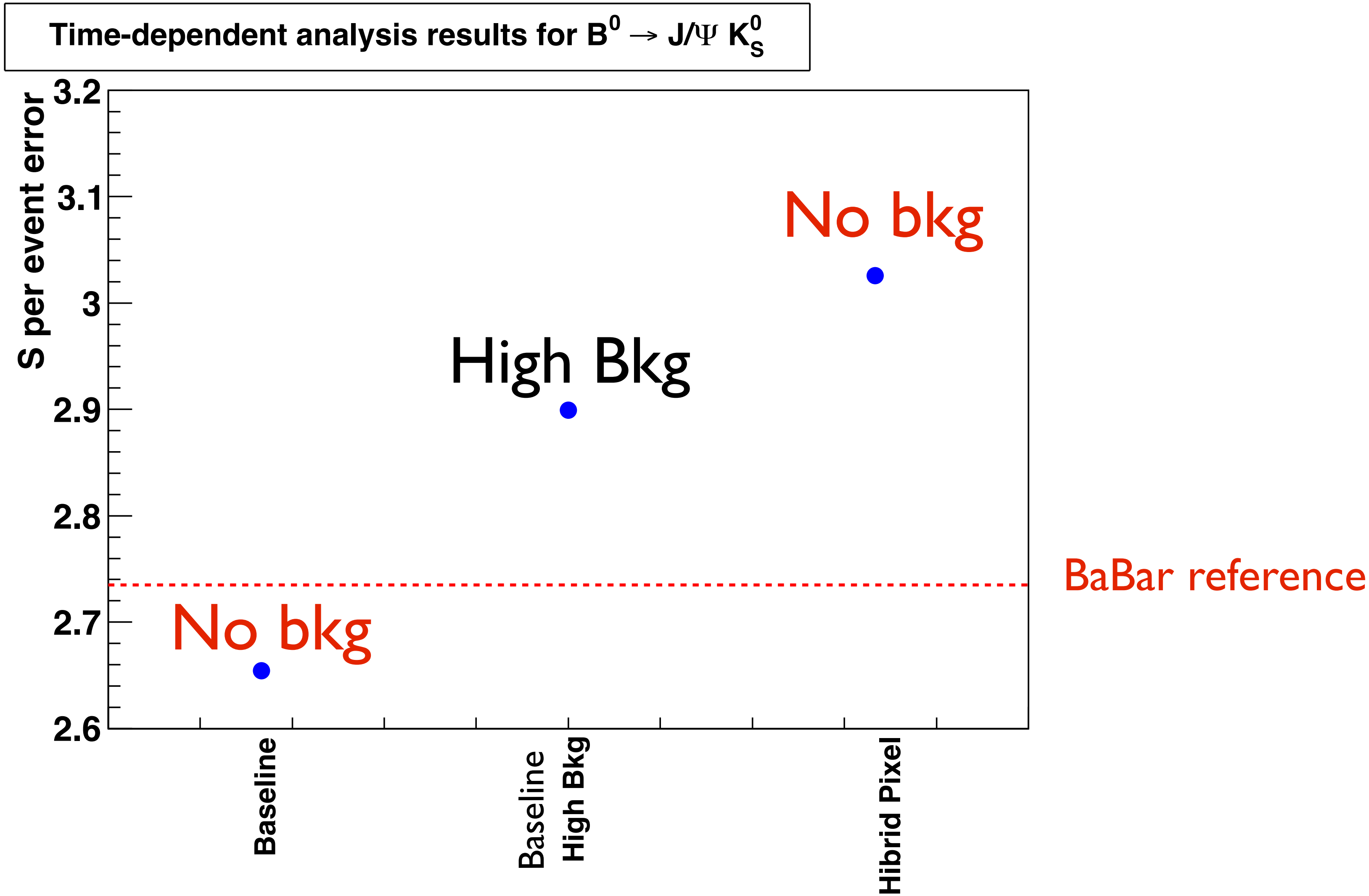








Impact on S per event error



Summary

- According to SuperB studies bkg in L0 is dominated by QED pairs bkg. Belle II studies are in disagreement with SuperB ones by a factor 15 less.
- Simulated with FastSim the impact of QED pairs bkg on vertex resolution, proper time error and S sensitivity for the L0 baseline: striplets solution.
- Preliminary results show that there is a sizable impact but moderate on S per event error. Further studies are needed for a better understanding.
- Still better sensitivity wrt pixel solution with no background. Not evaluated yet the impact of QED bkg for L0 pixel solution.

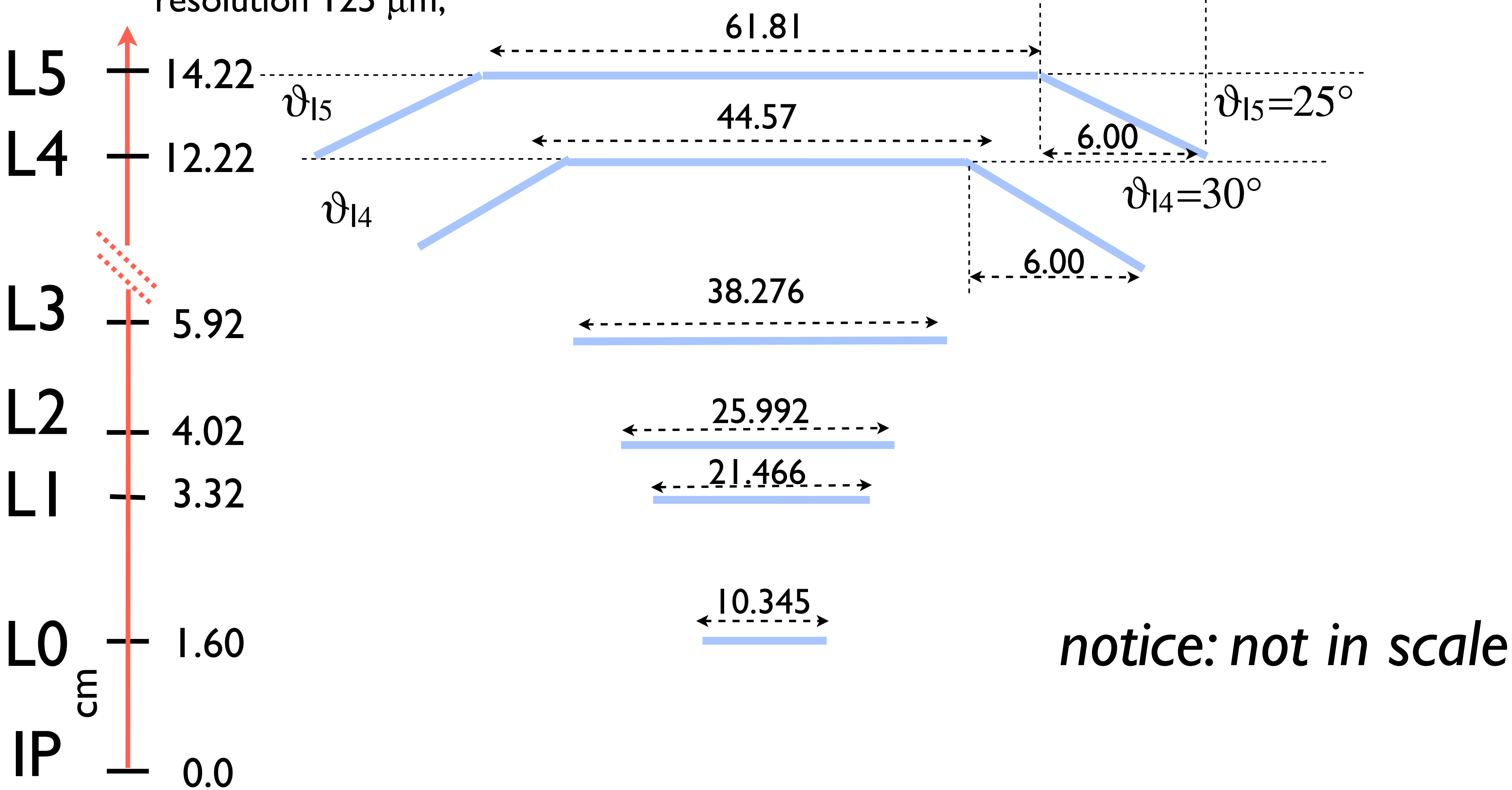
Backup slides

Introduction

- The baseline in FastSim for the Silicon Vertex Tracker (SVT) of SuperB consists in a 6 layer silicon detector;
- an additional Layer0 (L_0), at smaller radius, was introduced in order to maintain adequate proper-time resolution for B decays, in presence of a reduced center-of-mass boost: in BaBar was $\beta\gamma$=0.56, in SuperB will be $\beta\gamma$=0.24;
- the angular coverage of the SVT will reach ±300 mrad in the FW-BW direction;
- the outer layers (L_4-L_5) will have similar arch shape as in BaBar, and L_1-L_5 layers will be placed at almost identical radial position as in BaBar;
- the layer L_0 solution for the SVT baseline in FastSim *(as today)* is striplets: 200μm silicon, 0.4 % X_0, 8μm hit resolution.

1. SuperB baseline in Fast Sim:

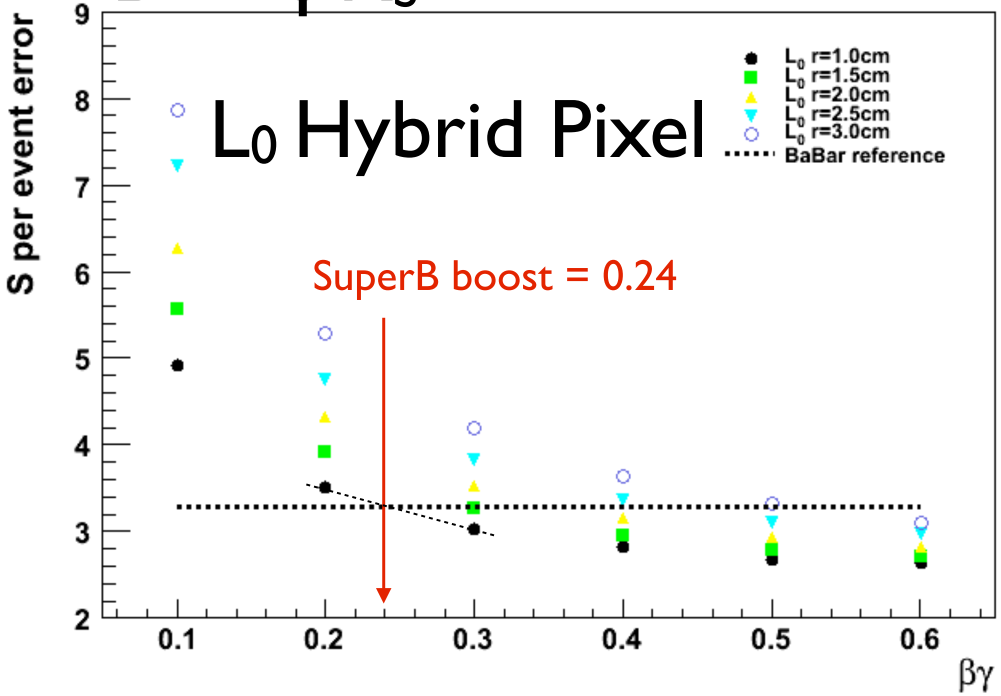
- SVT baseline: L0 + L1-L5 strip detectors, ±300 mrad angular coverage;
- DCH baseline: 10 SuperLayers (4 cell layers per SL); inner radius 23.6 cm, spatial resolution 125 μm;

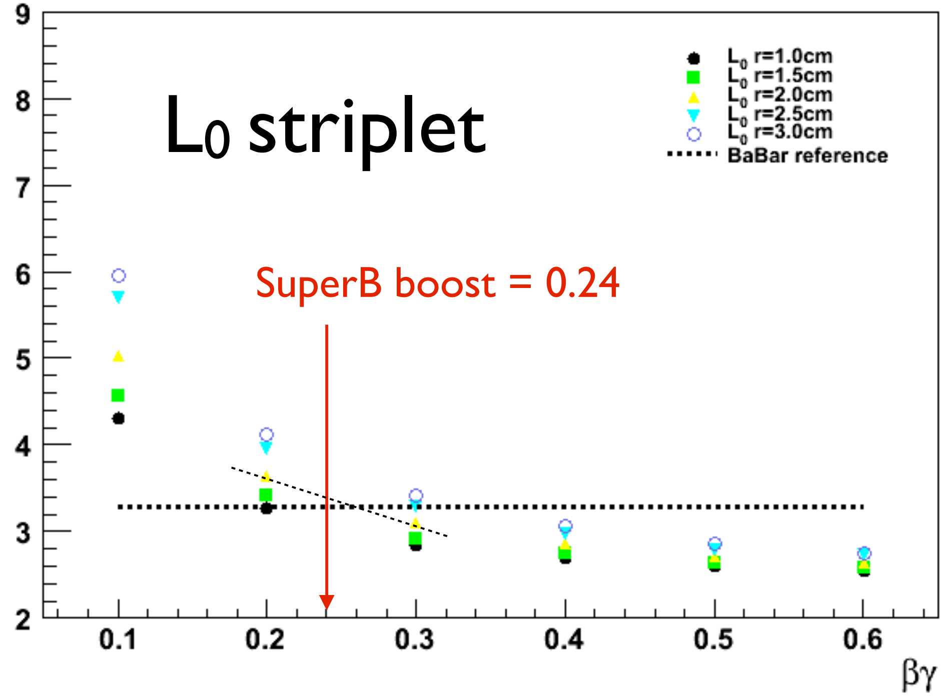


Coverage down to 300 mrad FW and BW

Striplet vs Hybrid Pixel: S per event error

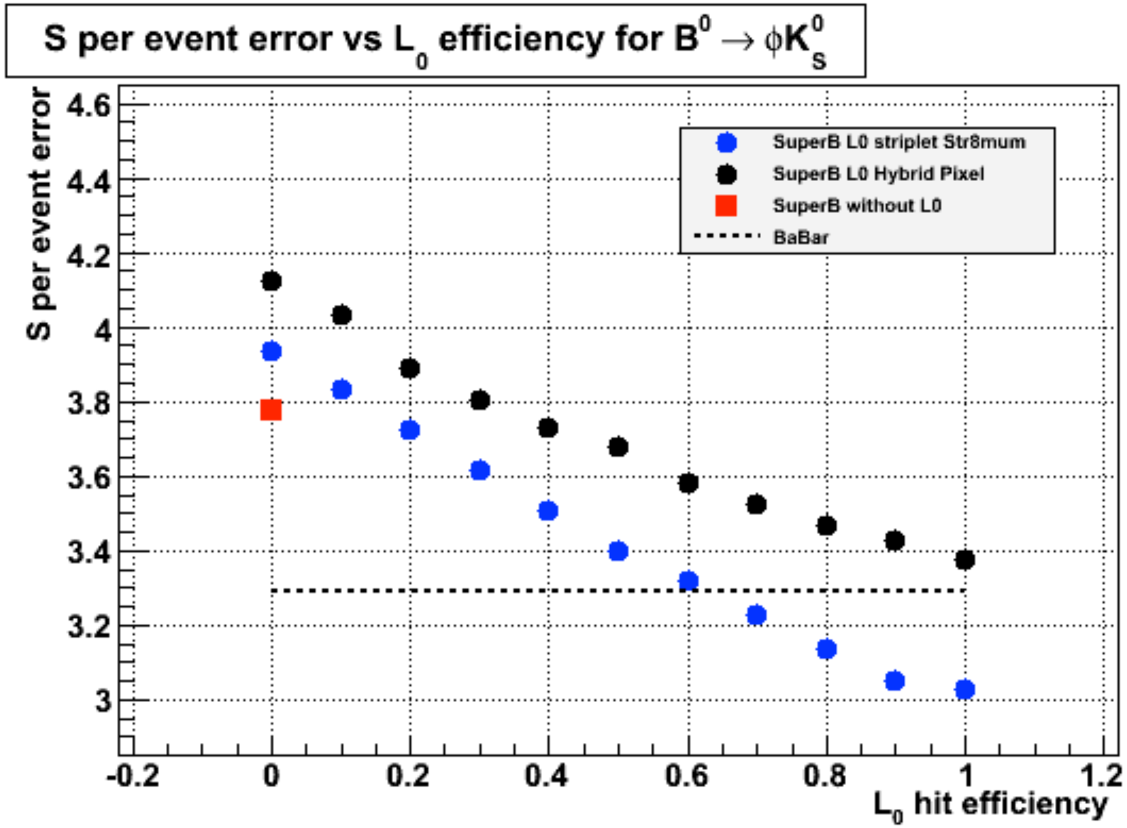
$B^0 \rightarrow \varphi K_S$



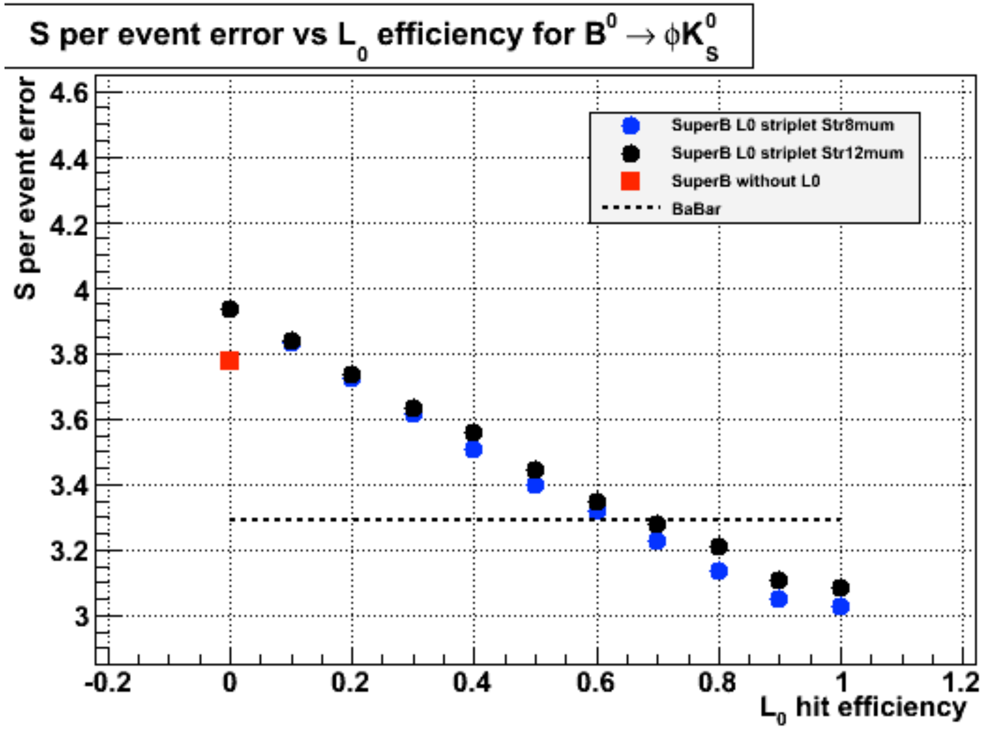


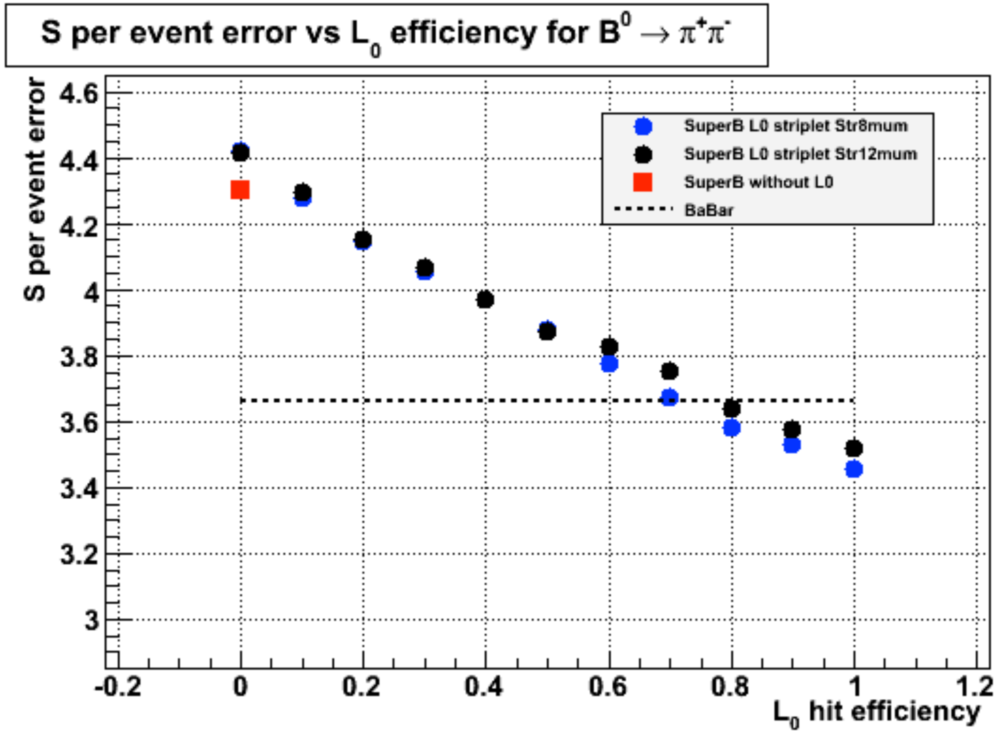
Hybrid Pixel solution is reaching BaBar reference for S (sin(2β)) per event sensitivity with L_0 radius ~1.0 cm. Striplet solution can afford a larger L_0 radius ~2.0 cm where bkg is lower.

Striplet vs Hybrid Pixels vs degraded hit efficiency



Striplet performance vs degraded hit resolution



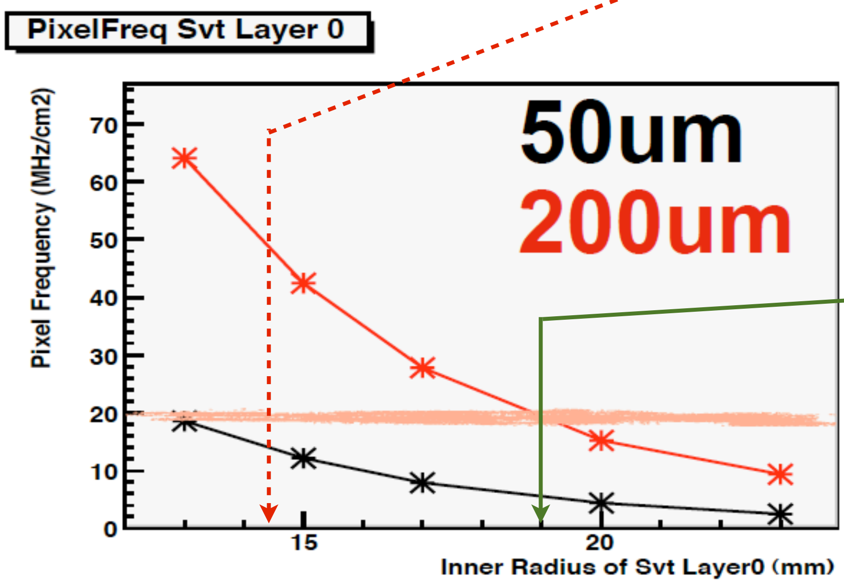


Nominal resolution 8 μm.

Considering 50% worsening (12 μm) from high occupancy in L_0. Rough estimate (to be studied in detail) but seems to be a second order effect.

Background rate in L_0

Max rate: 20 MHz/cm^2
50um @ <13mm
200um @ ~19mm



R. Cenci

In pinwheel geometry average radius <r> is about 1.12×min(radius).
Riccardo found with L_0 min(radius)=1.3 cm (<r>~1.45) a bkg rate of ~56MHz/cm^2 in his latest bkg study presented at Caltech meeting, Dec 2010).

Striplet solution with <r>=1.9cm (min(radius) =1.7cm) seems to satisfy both proper-time resolution and bkg rate requirements.

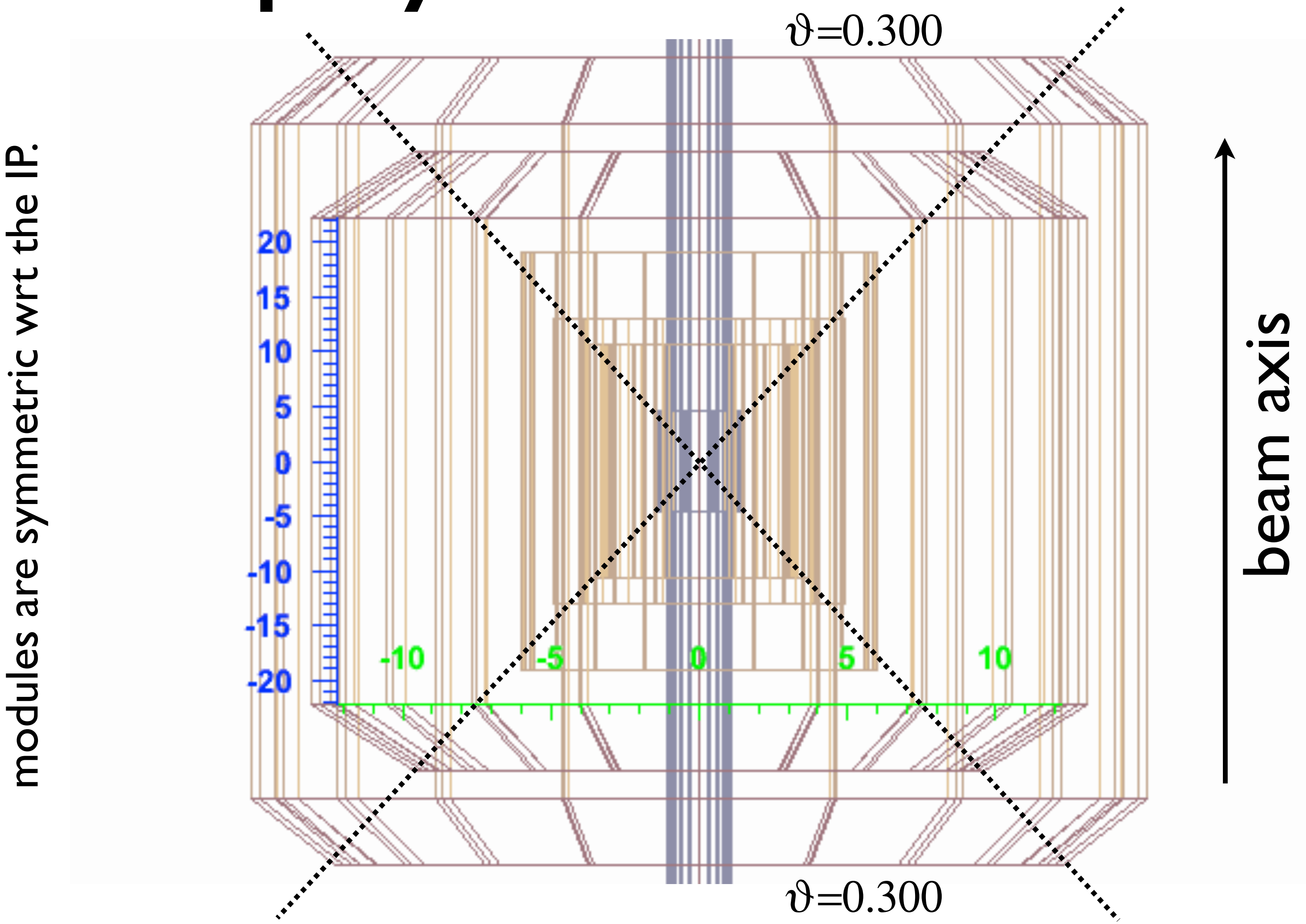
Plans for further studies

- Update of FastSim configuration:
  - modeling of material budget for L_0 solutions for striplets and pixels according to recent developments;
  - possible changes in detector geometry (e.g. radius of layers);
- Implement a more realistic model for striplets in FastSim, with strips tilted at 45 degrees wrt detector.
- Evaluate impact of bkg hits on hit resolution and pattern recognition using FastSim.
- Should we consider time-dependent measurements at DDbar threshold? With E_{cm}~ 4 GeV the average momentum of particles is reduced and material budget in SVT is more relevant.

Hit Merging and PatRec Confusion in FastSim

- Reference: Doug Roberts talk at Orsay 2009, "Hit Confusion".
- In FastSim there is the possibility of evaluating the impact of bkg on hit resolution and on pattern recognition quality.
  - Hit Merging depends on resolution of the detector;
  - Pattern Recognition quality depends on the resolution of the track;
- Work To Do: PatRec Confusion code is corrently broken (Dave Brown will fix it) and striplet model is not currently modeled correctly in FastSim (I will work on that). That requires changes in `PacDet,PacEnv,PacTrk` packages.

Display of SVT modules



angular coverage in CM ~ 95% (BaBar SVT ~89%)

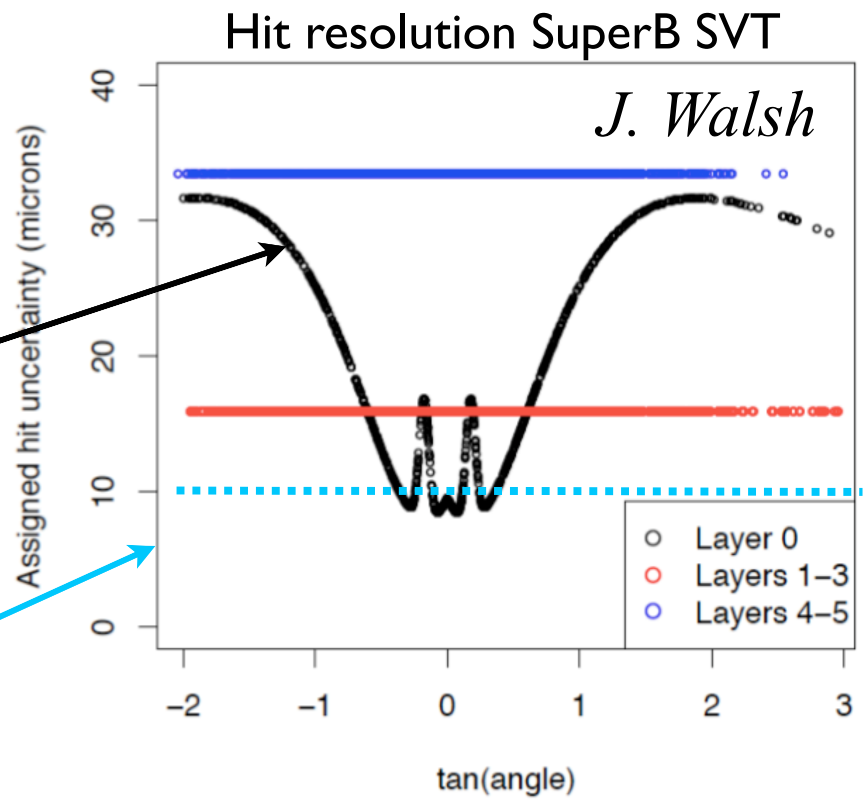
L_0 solutions: striplets vs Hybrid pixels

Hybrid Pixel

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

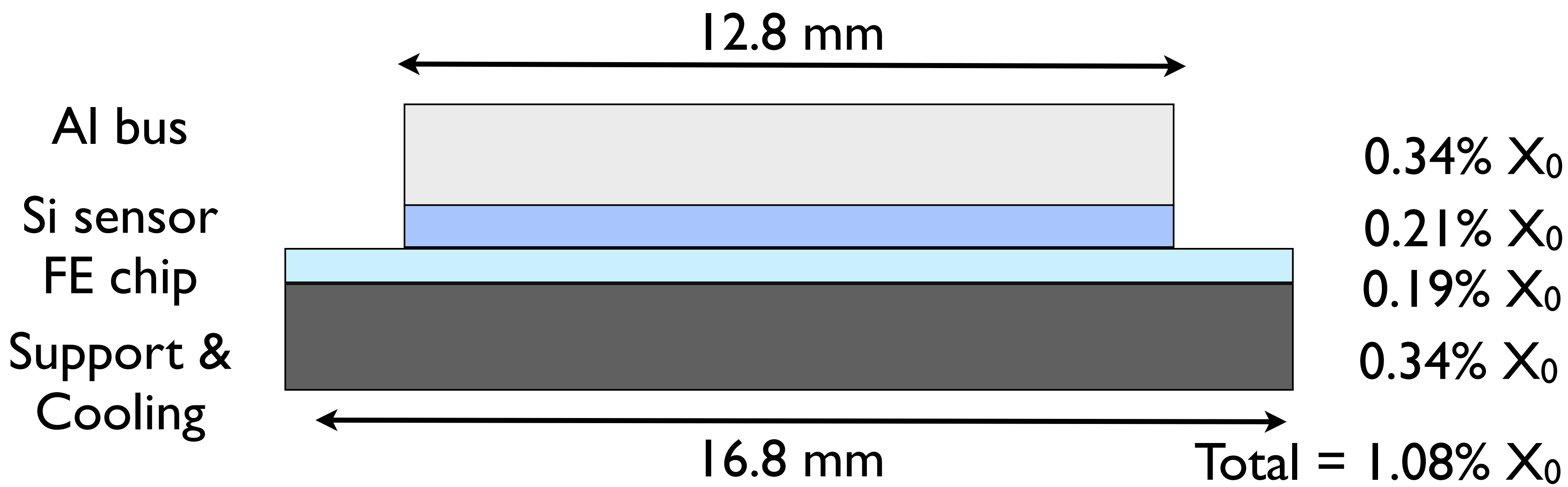
Striplets

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



Hybrid pixel solution

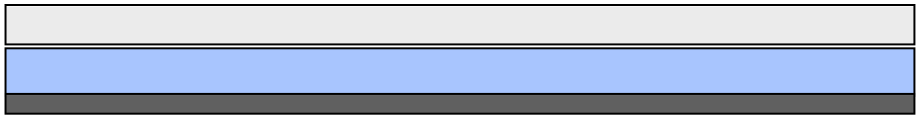
- Module cross section



Striplet solution

- Module cross section

Fan out — 0.14% X_0
Si sensor — 0.21% X_0
Support — 0.05% X_0

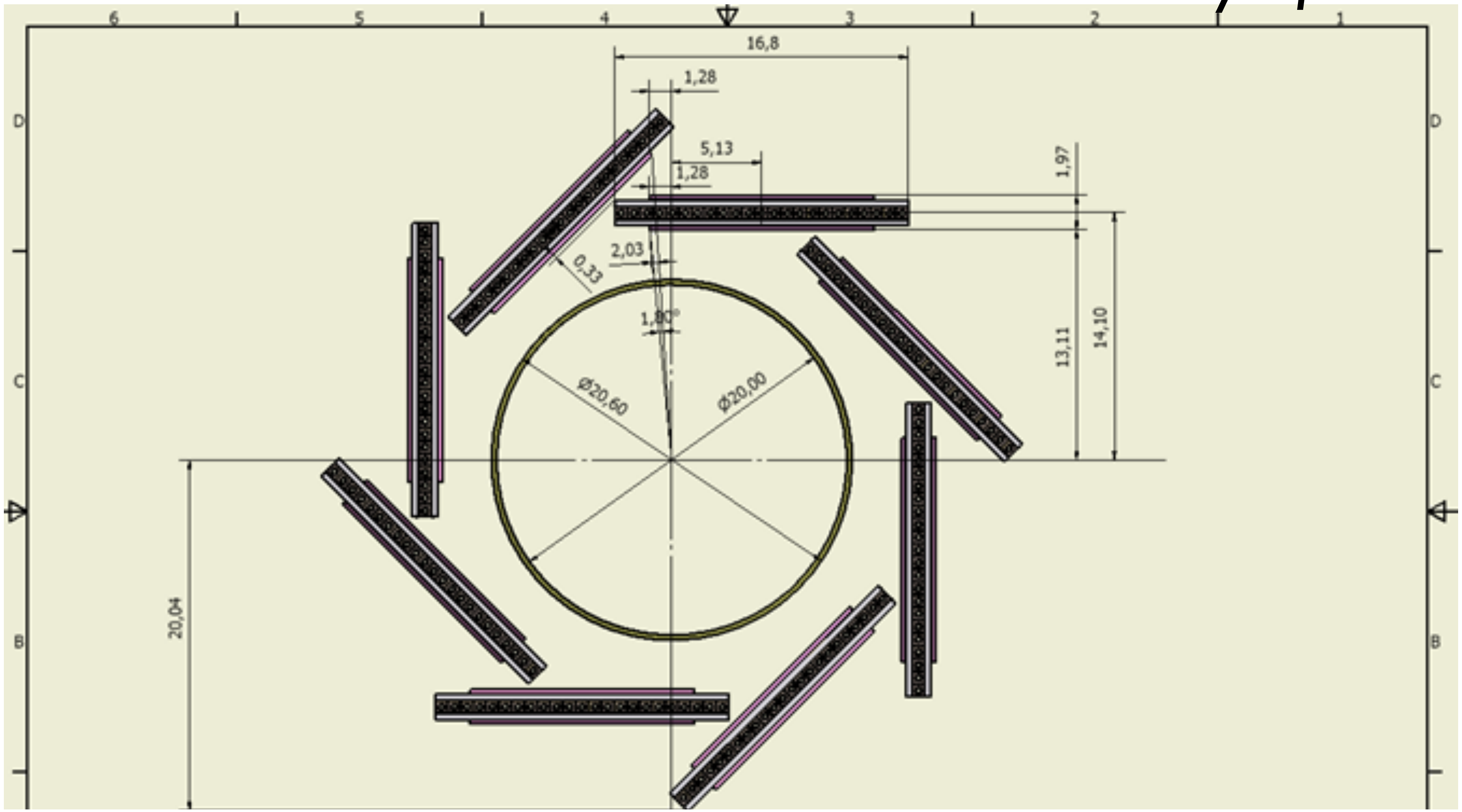


Si sensor overlap 3.4%

Total = 0.40% X_0

Pinwheel layout for L_0

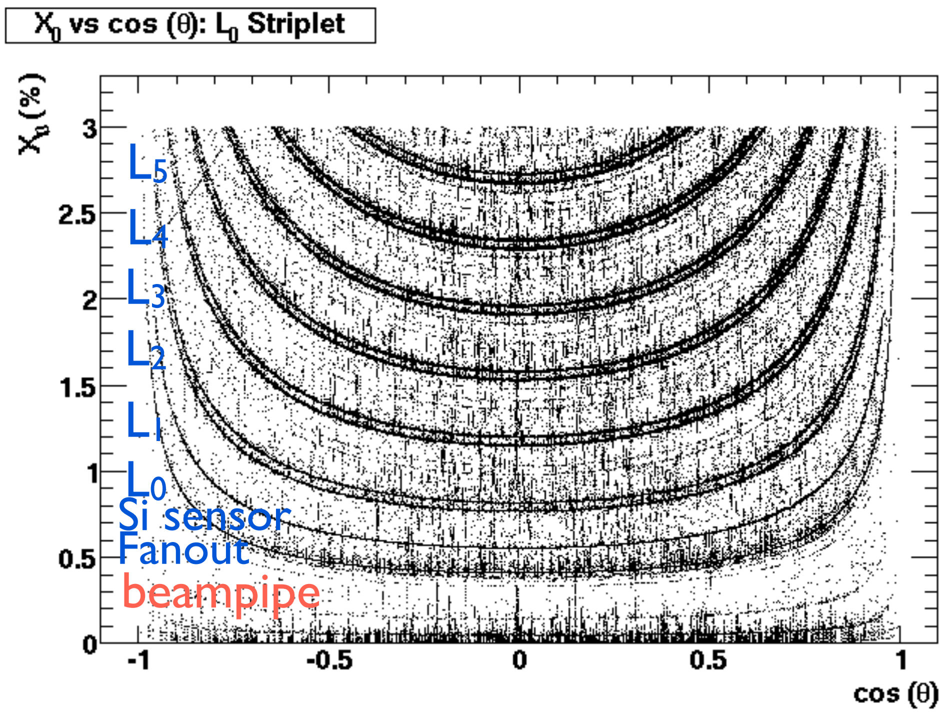
courtesy of F. Bosi

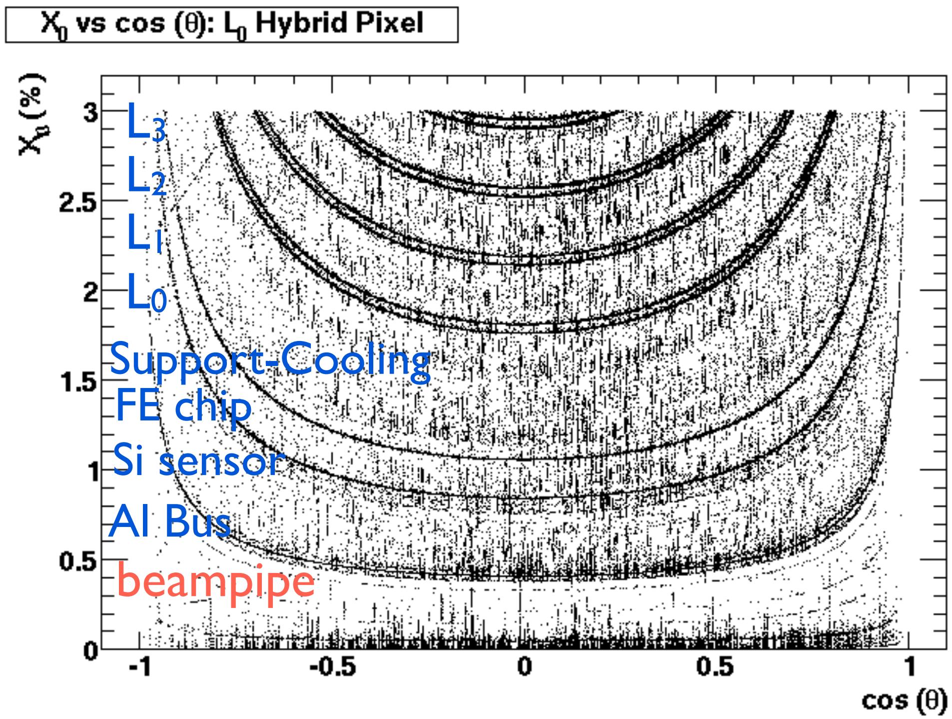


Design for MAPS solution

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.