Update on QED Pairs Bkg studies in FastSim

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Outline

- QED Pairs Bkg in FastSim
- Impact on track parameter resolutions
- Impact on time-dependent measurements
- Summary

Validation tests

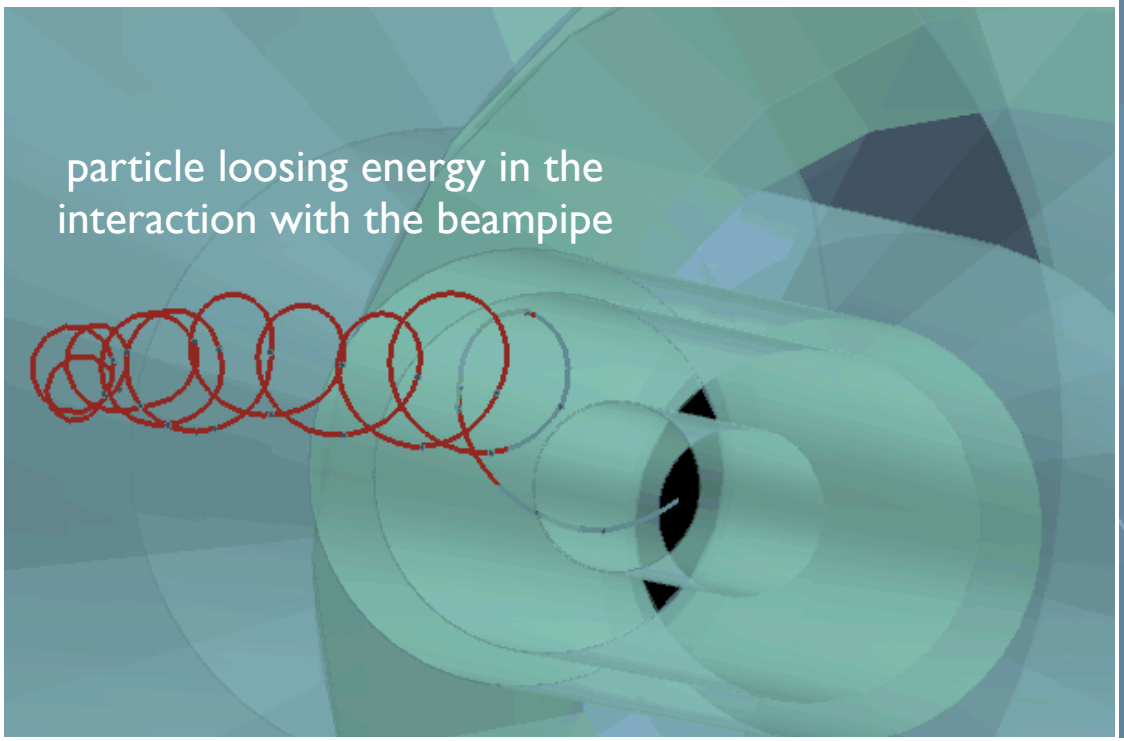
- Generate single track electron events:
  - scan in p_t and $\cos(\theta)$ for validating the number of intercepts with sensitive layers; ✓
  - use simplified geometry with silicon (and vacuum based) sensors only for debugging with and without beam pipe; ✓
  - setup/debugging of simulation parameters:
    - configuration files: PacDetector/IP_SuperB_shielded.xml does not work for this studies. Use instead PacDetector/IP_SuperB.xml at present without shielding. ✓
    - voxels definition in PacDetector/IP_SuperB.xml was not correct for this studies and had to be fixed. Voxel definition in configuration files is still under investigation.
    - change of very basic FastSim parameters that regulates simulation of particle interaction with material (min momentum for Bremms, shower and simulation). ✓

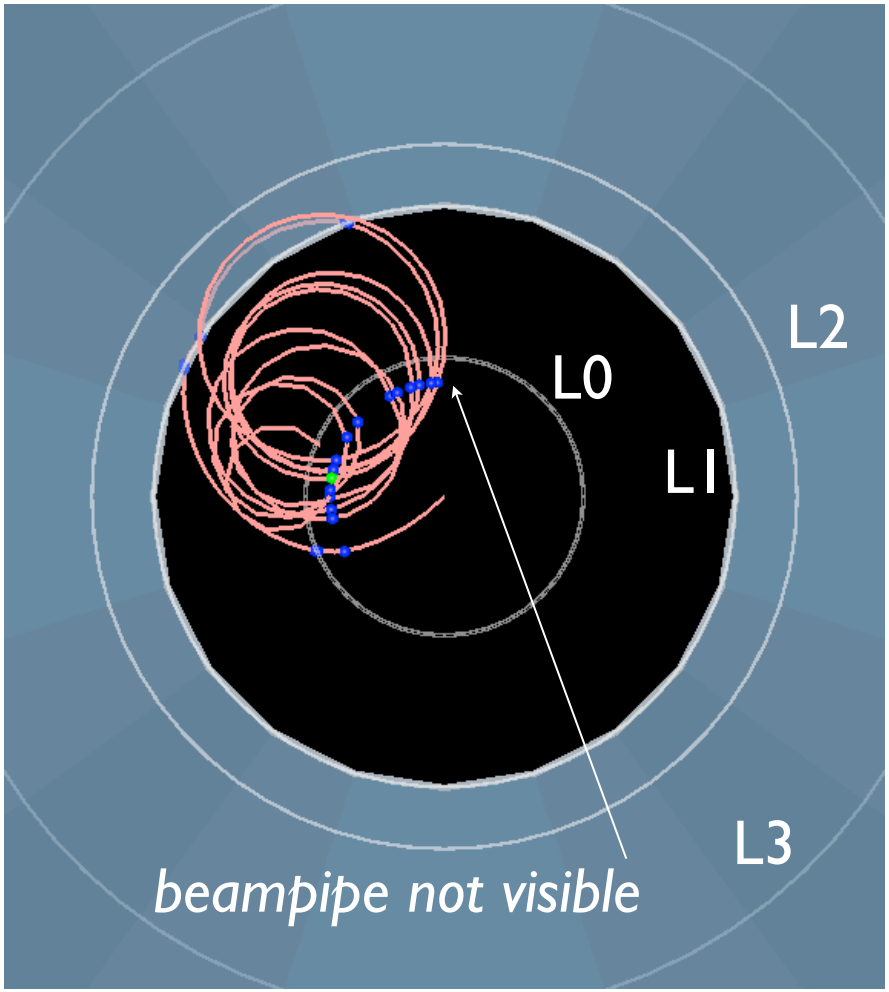
Single Track Events

Electron

p_t = 10 MeV/c

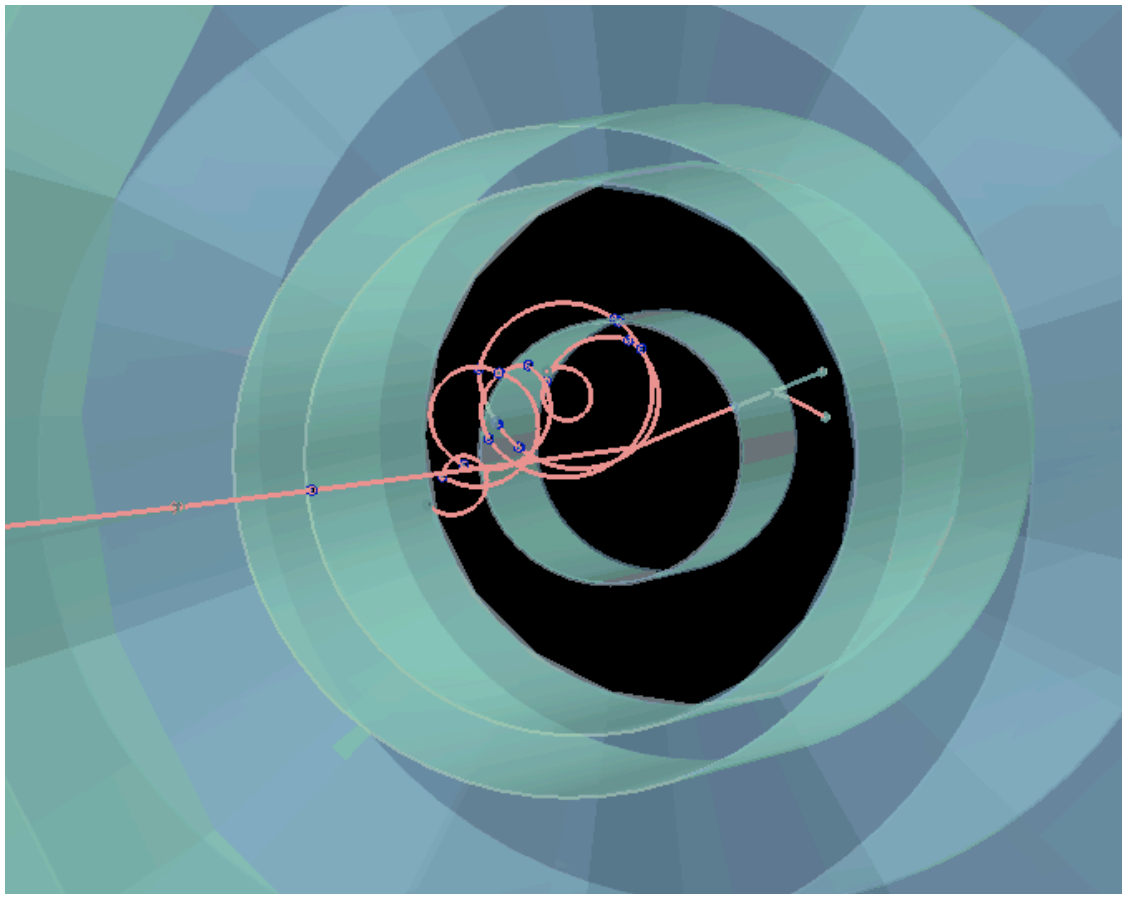
θ=45°

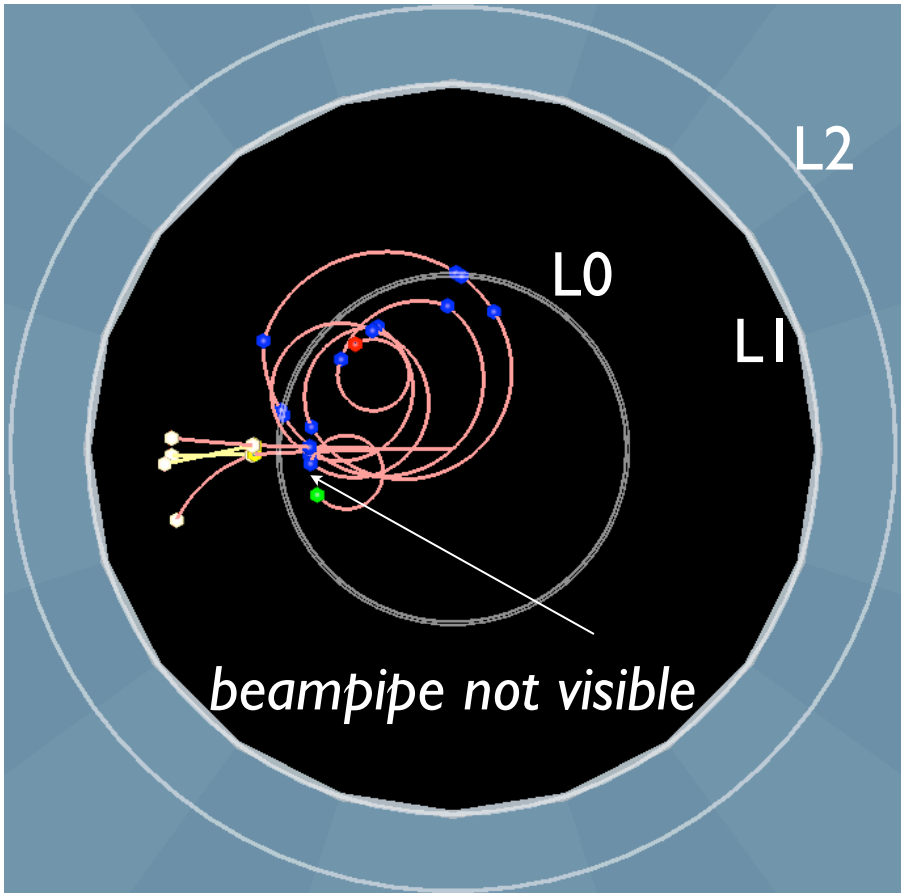




QED Pairs Event

A track has multiple intersections with L0





Pairs Bkg Rates in FastSim

Beampipe radius = 1.3 cm
L0 radius = 1.6 cm

Diag36	NEvt Gen	Pairs rate	N Evt at Layer	<# intercept>/ evt	<# trk>/evt	<#intercept> /trk	Radius	HM Length	Trk rate/ cm^2	Cluster rate/ cm^2
L0	100000	7.30E+09	1372	2.77	1.19	2.32	1.6	5.172	1.15E+00	2.67E+00
L1	100000	7.30E+09	374	3.126	1.152	2.71	3.32	10.73	7.03E-02	1.91E-01
L2	100000	7.30E+09	263	3.076	1.156	2.66	4.02	13	3.38E-02	8.99E-02
L3	100000	7.30E+09	121	2.785	1.132	2.46	5.92	19.14	7.02E-03	1.73E-02
L4	100000	7.30E+09	22	4.273	1.091	3.92	12.22	22.28	5.12E-04	2.01E-03
L5	100000	7.30E+09	16	5.062	1.062	4.77	14.22	30.91	2.25E-04	1.07E-03

Beampipe radius = 1.0 cm
L0 radius = 1.6 cm

Small change (<10%) according to FastSim in rates at L0 when changing beampipe radius from 1.3 to 1.0 cm and L0 radius = 1.6 cm

Diag36	NEvt Gen	Pairs rate	N Evt at Layer	<# intercept>/ evt	<# trk>/evt	<#intercept> /trk	Radius	HM Length	Trk rate/ cm^2	Cluster rate/ cm^2
L0	100000	7.30E+09	1495	2.73	1.18	2.32	1.6	5.172	1.23E+00	2.86E+00
L1	100000	7.30E+09	382	3.065	1.136	2.70	3.32	10.73	7.08E-02	1.91E-01
L2	100000	7.30E+09	268	2.996	1.146	2.61	4.02	13	3.41E-02	8.93E-02
L3	100000	7.30E+09	124	2.911	1.129	2.58	5.92	19.14	7.18E-03	1.85E-02
L4	100000	7.30E+09	24	2.75	1.083	2.54	12.22	22.28	5.55E-04	1.41E-03
L5	100000	7.30E+09	18	3.556	1.056	3.37	14.22	30.91	2.51E-04	8.46E-04

...with Layer0 at 1.4 cm

Beampipe radius = 1.3 cm
L0 radius = 1.4 cm

Diag36	NEvt Gen	Pairs rate	N Evt at Layer	<# intercept>/ evt	<# trk>/evt	<#intercept> /trk	Radius	HM Length	Trk rate/ cm^2	Cluster rate/ cm^2
L0	100000	7.30E+09	1627	2.855	1.215	2.35	1.4	4.55	1.80E+00	4.24E+00
L1	100000	7.30E+09	369	2.846	1.163	2.45	3.32	10.73	7.00E-02	1.71E-01
L2	100000	7.30E+09	258	2.988	1.155	2.59	4.02	13	3.31E-02	8.57E-02
L3	100000	7.30E+09	123	2.821	1.171	2.41	5.92	19.14	7.38E-03	1.78E-02
L4	100000	7.30E+09	24	3.750	1.042	3.60	12.22	22.28	5.34E-04	1.92E-03
L5	100000	7.30E+09	17	3.294	1.118	2.95	14.22	30.91	2.51E-04	7.40E-04

Beampipe radius = 1.0 cm
L0 radius = 1.4 cm

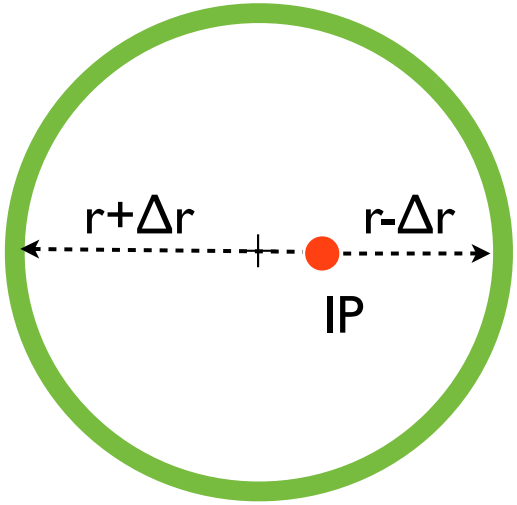
Small change (10%) according to FastSim in rates at L0 when changing beampipe radius from 1.3 to 1.0 cm and L0 radius = 1.4 cm

Diag36	NEvt Gen	Pairs rate	N Evt at Layer	<# intercept>/ evt	<# trk>/evt	<#intercept> /trk	Radius	HM Length	Trk rate MHz/cm^2	Cluster MHz/cm^2
L0	100000	7.30E+09	1869	2.772	1.194	2.32	1.4	4.55	2.04E+00	4.72E+00
L1	100000	7.30E+09	389	2.889	1.159	2.49	3.32	10.73	7.35E-02	1.83E-01
L2	100000	7.30E+09	273	2.81	1.139	2.47	4.02	13	3.46E-02	8.53E-02
L3	100000	7.30E+09	128	3.469	1.133	3.06	5.92	19.14	7.44E-03	2.28E-02
L4	100000	7.30E+09	24	4.167	1.042	4.00	12.22	22.28	5.34E-04	2.13E-03
L5	100000	7.30E+09	19	3.105	1.105	2.81	14.22	30.91	2.77E-04	7.80E-04

...with IP not in nominal position

Beampipe radius = 1.0 cm
L0 radius = 1.4 cm
IP in (0.2, 0, 0)

Diag36	NEvt Gen	Pairs rate	N Evt at Layer	<# intercept>/ evt	<# trk>/evt	<#intercept> /trk	Radius	HM Length	Trk rate/ cm^2	Cluster rate/ cm^2
L0	100000	7.30E+09	2006	2.85	1.19	2.39	1.4	4.55	2.18E+00	5.22E+00
L1	100000	7.30E+09	386	3.018	1.14	2.65	3.32	10.73	7.18E-02	1.90E-01
L2	100000	7.30E+09	262	3.328	1.149	2.90	4.02	13	3.35E-02	9.69E-02
L3	100000	7.30E+09	121	3.017	1.124	2.68	5.92	19.14	6.97E-03	1.87E-02
L4	100000	7.30E+09	23	3.739	1.043	3.58	12.22	22.28	5.12E-04	1.83E-03
L5	100000	7.30E+09	17	4.647	1.059	4.39	14.22	30.91	2.38E-04	1.04E-03



Moderate variation (+20%) according to FastSim in rates at L0 when moving the IP about 2 mm far in the XY plane from the nominal position. This is consistent with the naive expectation of null increase in case of linear approximation in a small interval Δr around r of the bkg rate vs r.
Local maximum increase of bkg rate at L0 can be estimated by reducing the radius from 1.6 cm to 1.4 cm (+60%).

- *According to FastSim studies*:
  - +10% variation in cluster rates at L0 when changing the beampipe radius from 1.3 to 1.0 cm;
  - reduction of a factor 0.6 in cluster and track rates when changing the L0 radius from 1.4 to 1.6 cm;
  - +20% average variation (60% max) in cluster rates at L0 when moving the IP 2 mm far in the XY plane from the nominal position;

Comparison with FullSim

FastSim
Beampipe radius = 1.0 cm
L0 radius = 1.4 cm

Diag36	N Evt at Layer	Trk rate MHz/cm^2	Error MHz/cm^2	Cluster MHz/cm^2	Error MHz/cm^2
L0	1869	2.04E+00	4.66E-02	4.72E+00	1.08E-01
L1	389	7.35E-02	3.72E-03	1.83E-01	9.27E-03
L2	273	3.46E-02	2.09E-03	8.53E-02	5.15E-03
L3	128	7.44E-03	6.57E-04	2.28E-02	2.01E-03
L4	24	5.34E-04	1.09E-04	2.13E-03	4.36E-04
L5	19	2.77E-04	6.37E-05	7.80E-04	1.79E-04

Few events in L4, L5 large statistical uncertainties.

FullSim Rate from
Riccardo Cenci
L0 radius = 1.4 cm
L0 with cylindrical shape

	Track MHz/cm^2	Cluster MHz/cm^2
L0	2.24E+00	5.90E+00
L1	1.02E-01	2.29E-01
L2	6.10E-02	1.24E-01
L3	2.65E-02	4.91E-02
L4	8.32E-03	1.11E-03
L5	5.00E-03	6.50E-03

Good agreement in L0 and reasonable in L1-L2
Sizable discrepancy in L3,L4,L5 under investigation

Impact of Pairs Bkg on track parameters resolution

- generate single track pion events:
  - $p_t \in [0.05, 2.0]$ GeV/c
- over impose pairs bkg events;
- hit merging and pat rec confusion algorithms add bkg hits to the track;
- fit for track parameters:

$$P \equiv \left(d_0, \ \varphi_0, \ \omega, \ z_0, \ \tan\lambda \right)$$

$$\vec{F}(P:l) = \begin{cases} \left(\frac{\sin(\varphi_0+\omega l)}{\omega} - (1/\omega + d_0)\sin\varphi_0 \right) \hat{x} \\ \left(-\frac{\cos(\varphi_0+\omega l)}{\omega} + (1/\omega + d_0)\cos\varphi_0 \right) \hat{y} \\ (z_0 + l\tan\lambda)\,\hat{z} \end{cases}$$

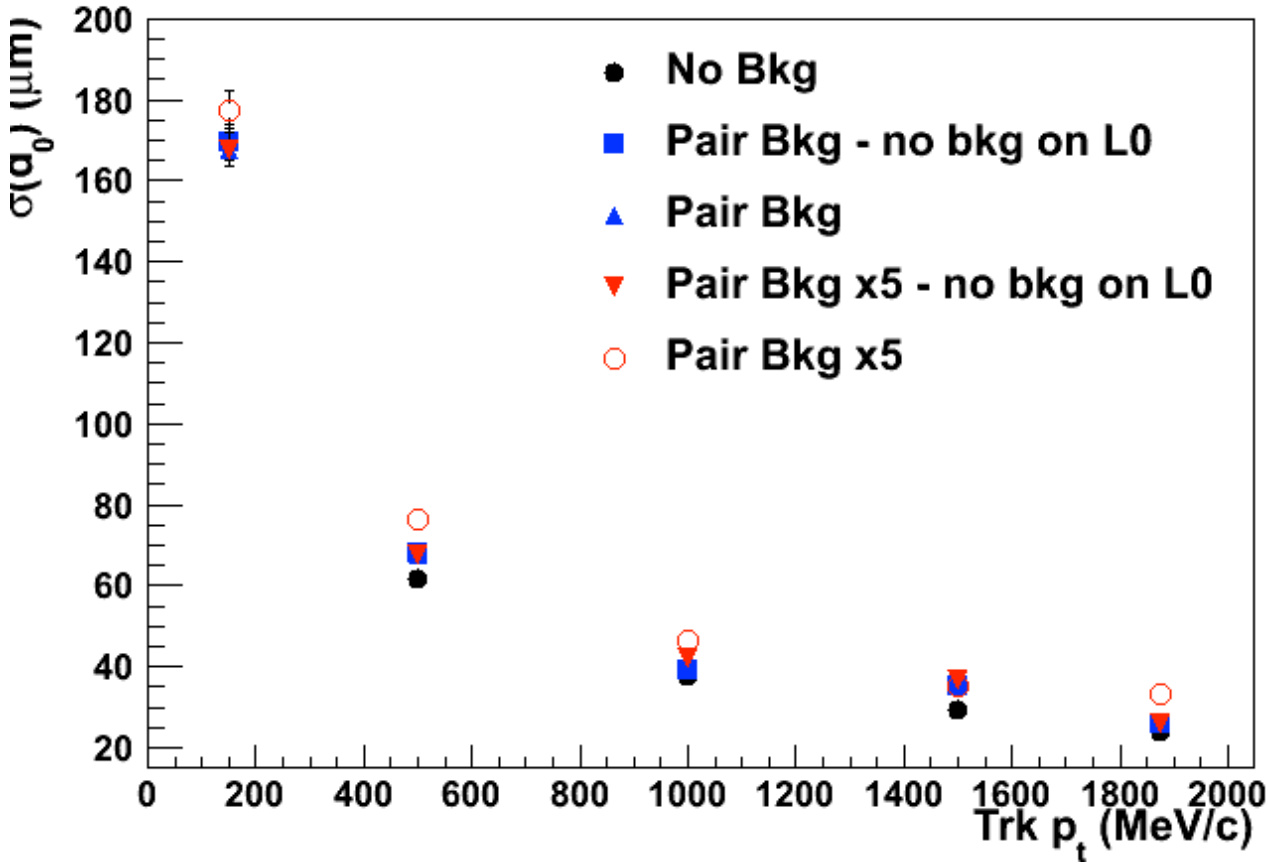
Validation test for Pairs Bkg mixing

- Generate single neutrino events and over impose QED pairs bkg in FastSim using the bkg frames and the technology to import them:
  - confirmation of track rate showed previously: ✓
    - 1.20 MHz/cm^2 at L0 radius 1.6 cm and beampipe radius 1.3 cm (L0 area 100 cm^2)
  - vary the time sensitive window for the different SVT layers and monitor the corresponding change in number of hits; ✓
  - tune the parameters for hit merging and pat rec confusion: ✓
    - removed cuts on number of hits associated to the track and minimum p_t value.

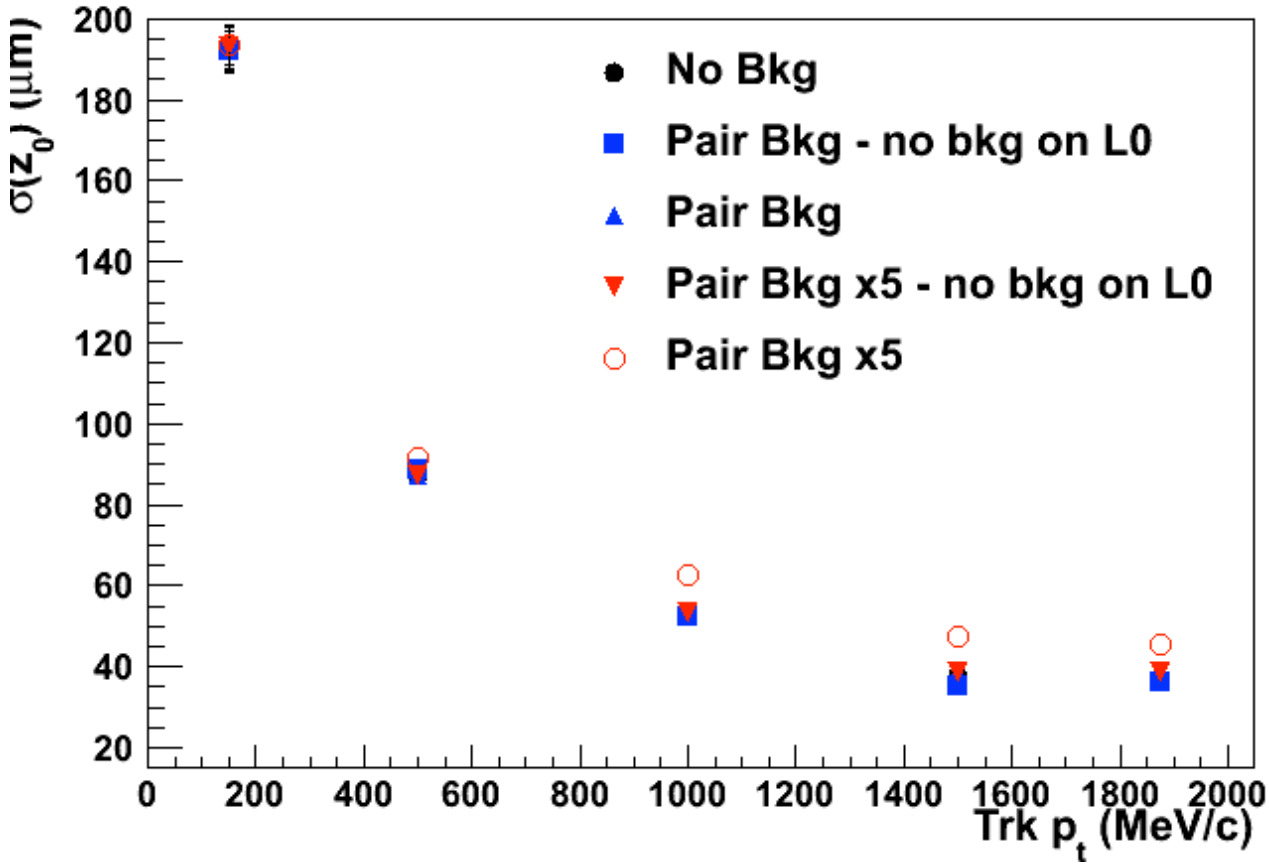
Sensitive time windows

- Bkg hits are considered if they are inside the offline sensitive time windows. For the following study use:
  - L0 60 ns
  - L1-L2 100 ns
  - L3 150 ns
  - L4-L5 400 ns

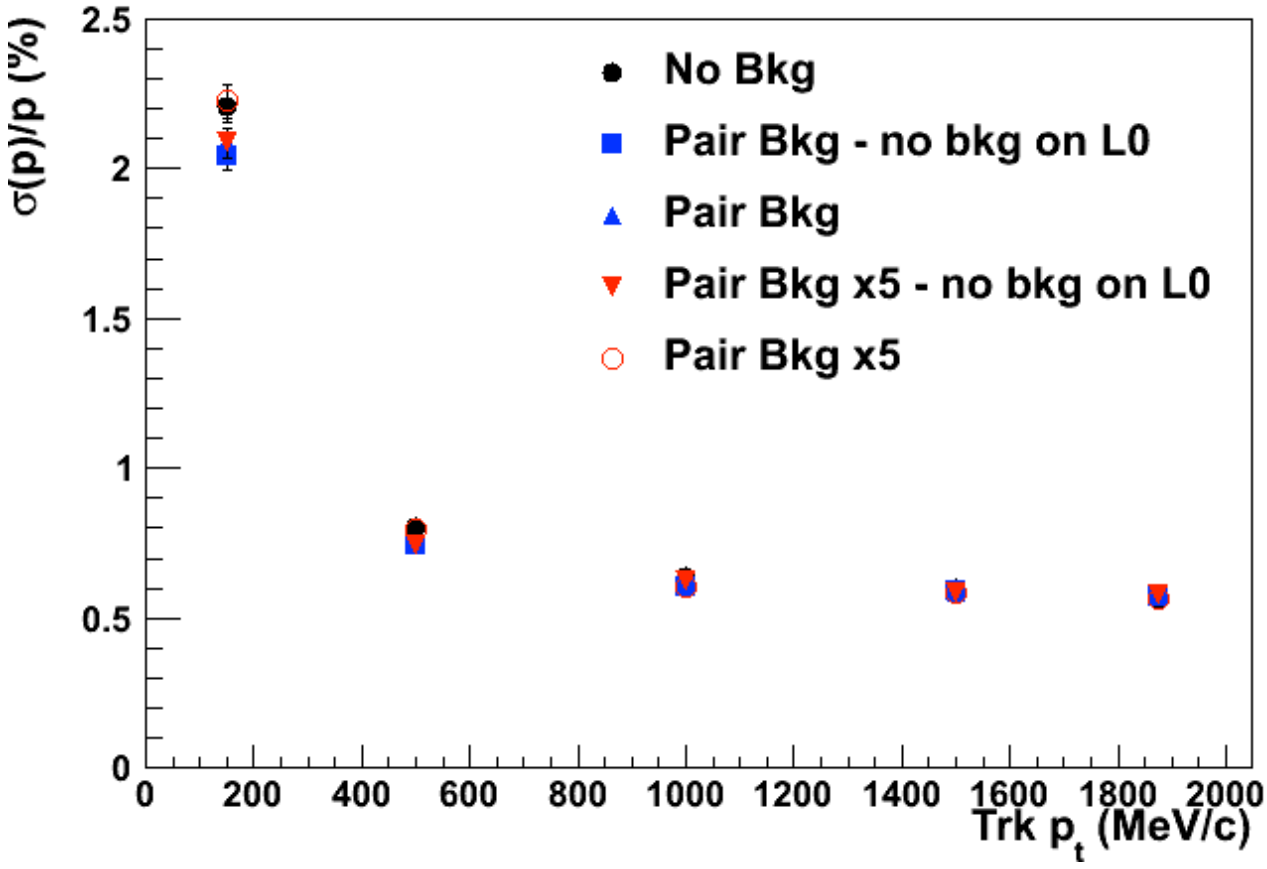
d_0 resolution



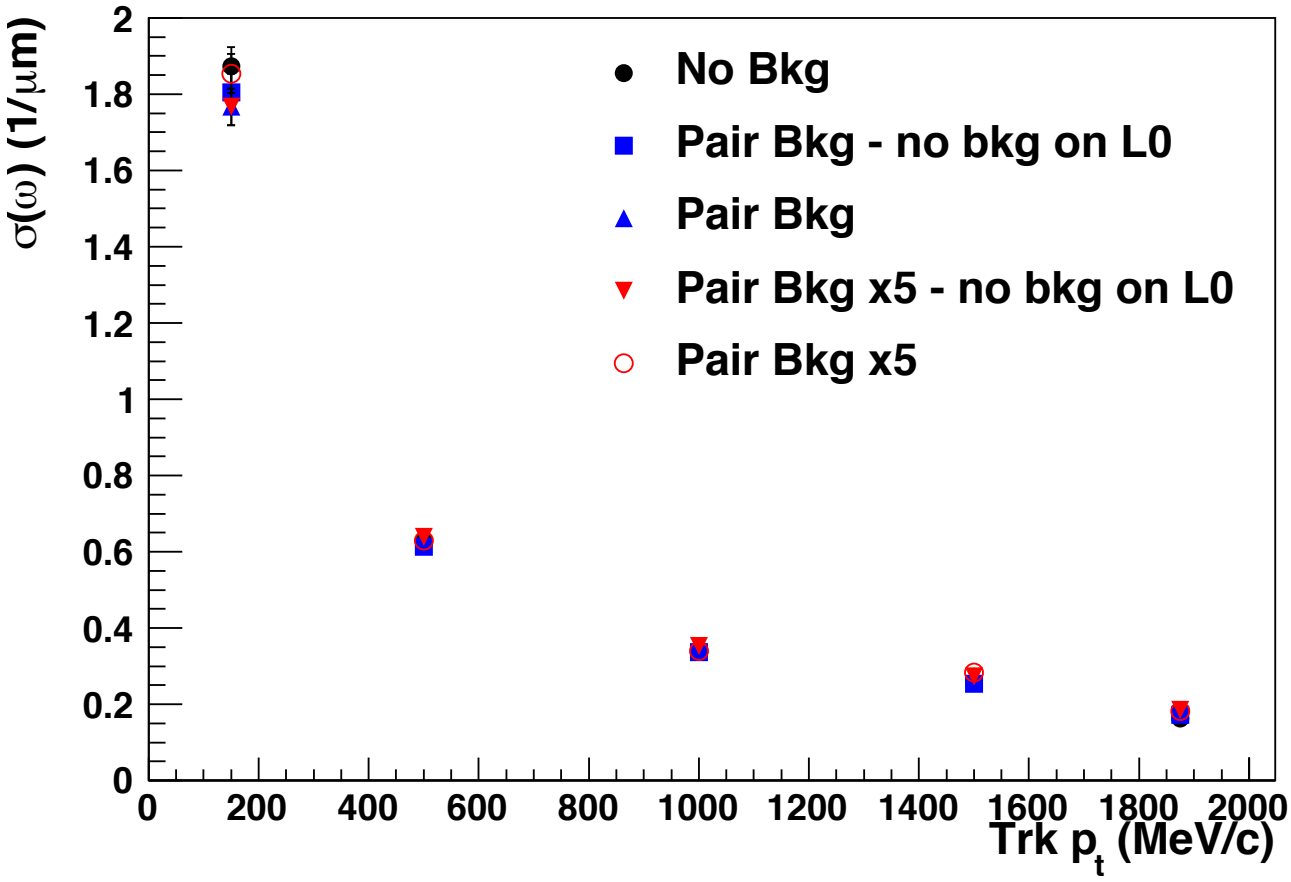
z_0 resolution



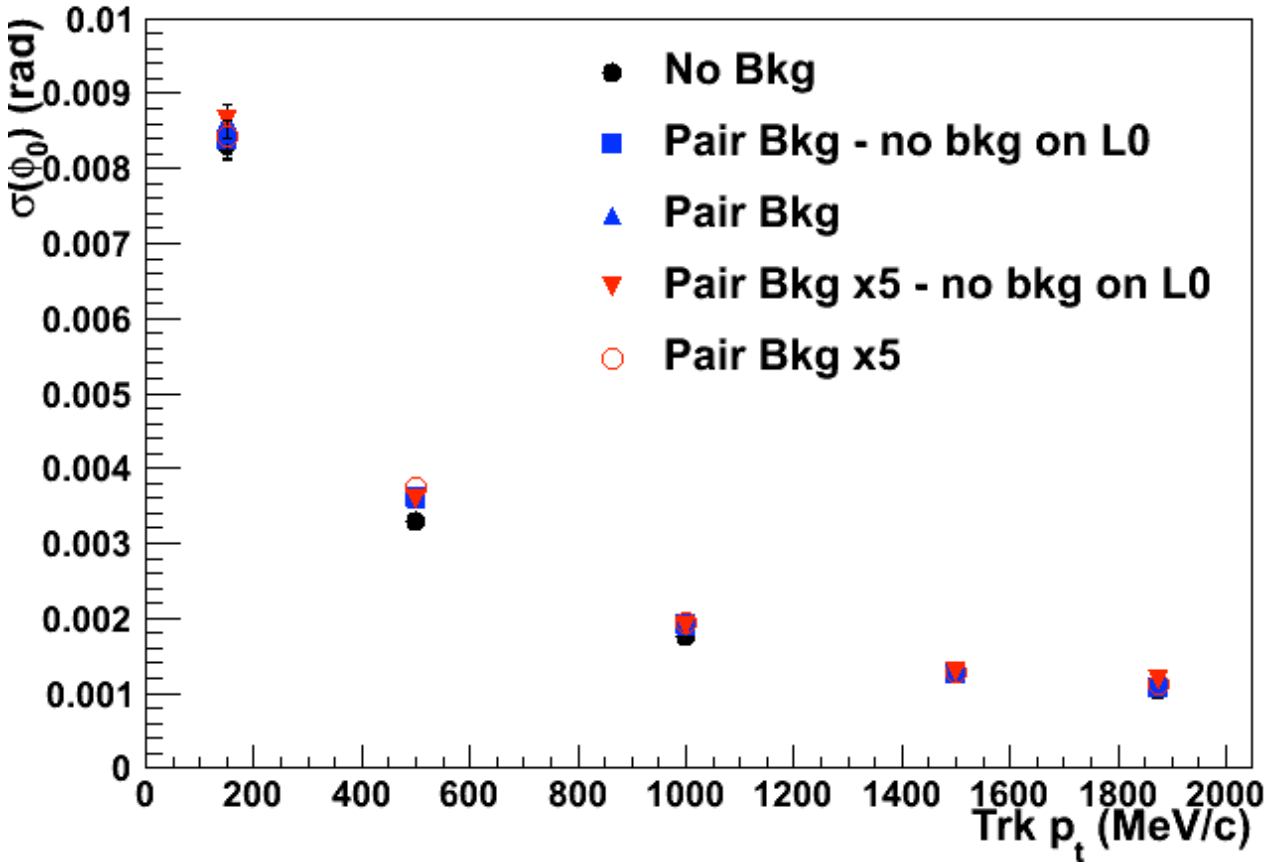
p_t resolution



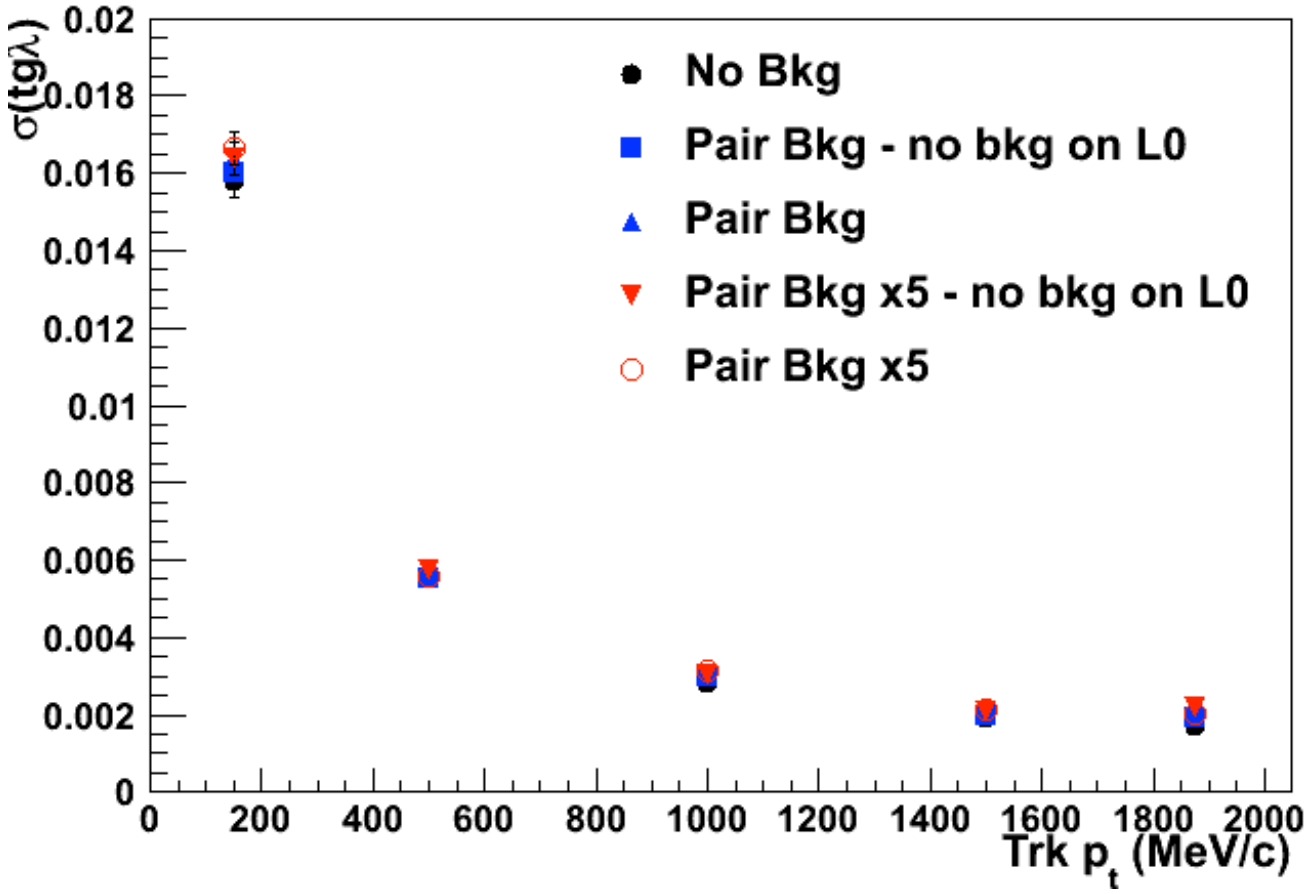
ω resolution



Φ_0 resolution



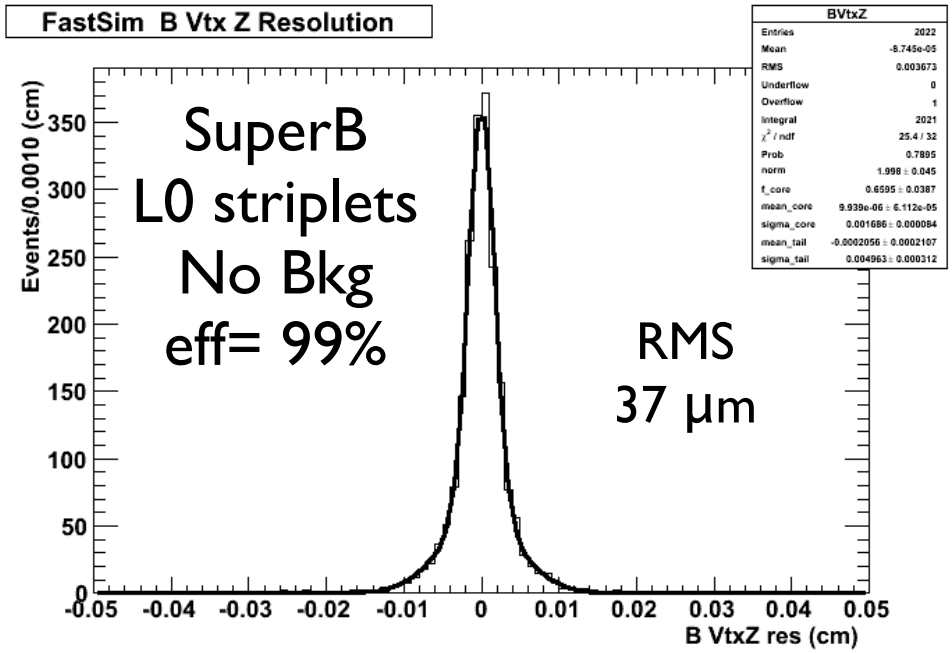
tan(λ) resolution

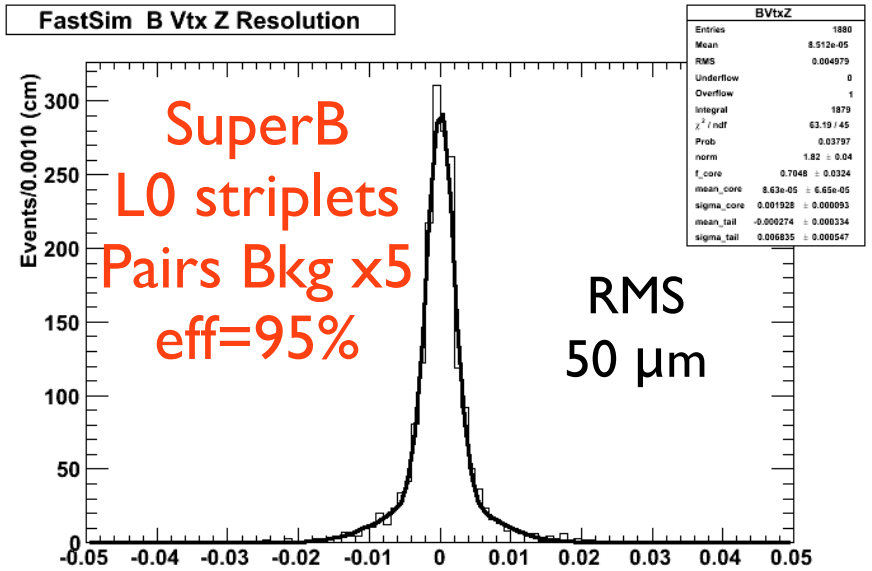


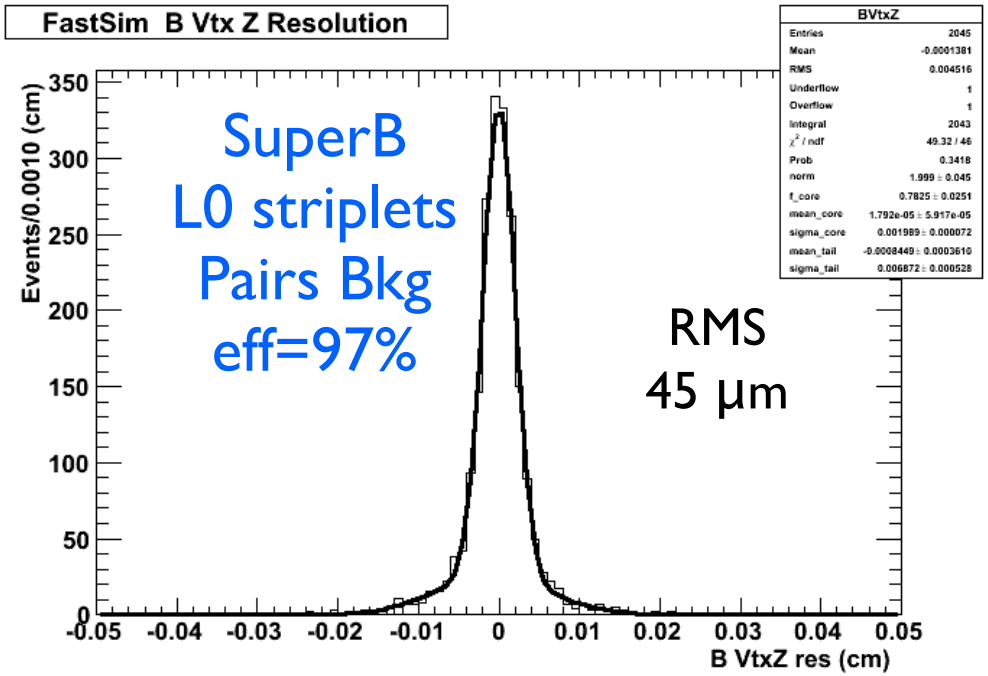
Impact on time-dependent measurements

- Generate 5k $B \rightarrow \phi K_s$ signal events with over imposed QED pairs bkg;
- Do not reject low momentum electrons using dE/dx. Use GoodTracksTight selection for determination of Tag vertex position. Use GoodTracksLoose for $\phi \rightarrow K^+K^-$ tracks and ChargedTracks for $K_s \rightarrow \pi^+\pi^-$.
- Bkg mixing and efficiency variations are included. For hit efficiency use guess values for this study:
  - hit efficiency for all layers : 99% no bkg, 97% pairs bkg, 95% pair bkg x5.
- Need to redo the study using numbers from FEE efficiency simulations. *See presentations of Luca Bombelli and Lodovico Ratti.*

Decay vertex resolution

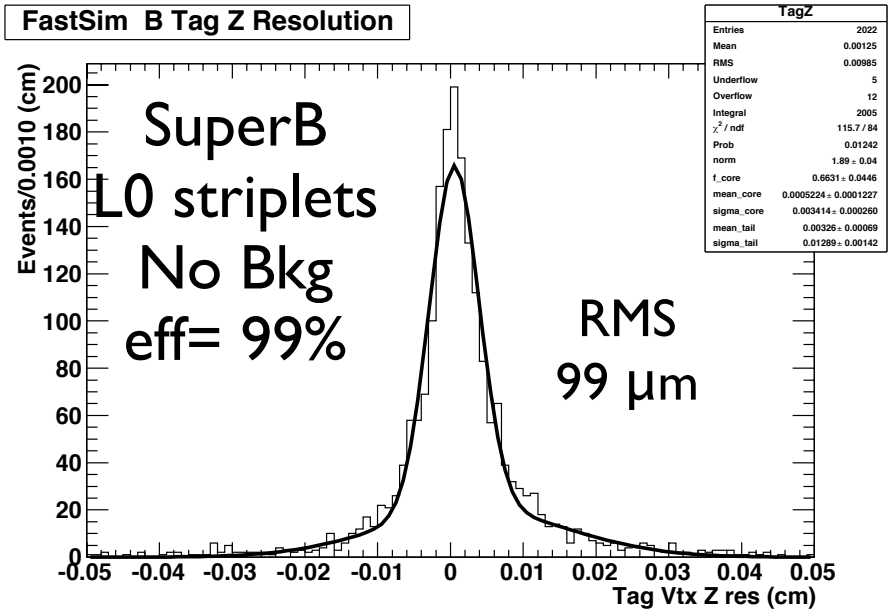


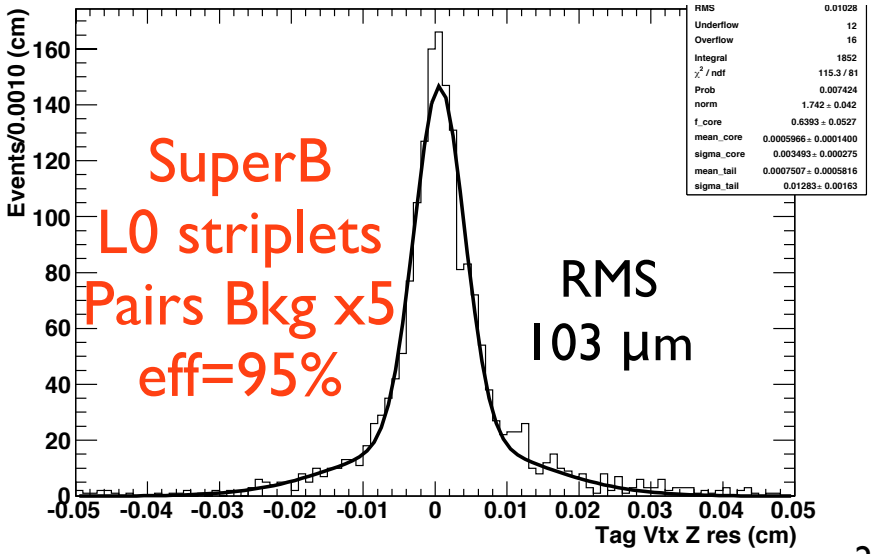


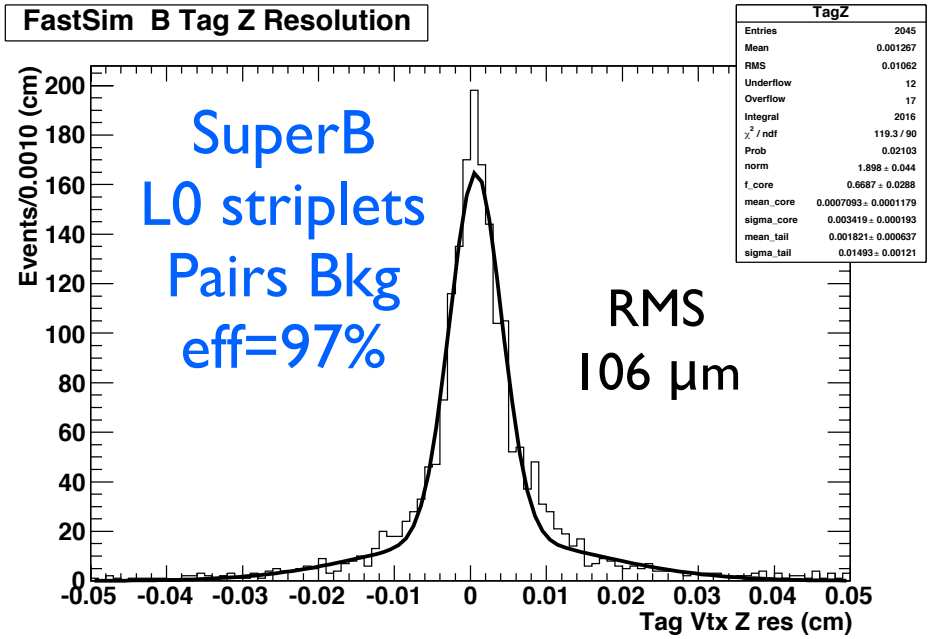


- Not removing low momentum electrons using SVT dE/dx information in this study.
- Use GoodTracksLoose for $\phi \rightarrow K^+K^-$ and ChargedTracks for $K_s \rightarrow \pi^+\pi^-$.
- *Probably some margin of improvement using an optimized selection in presence of bkg.*

Tag side vertex resolution

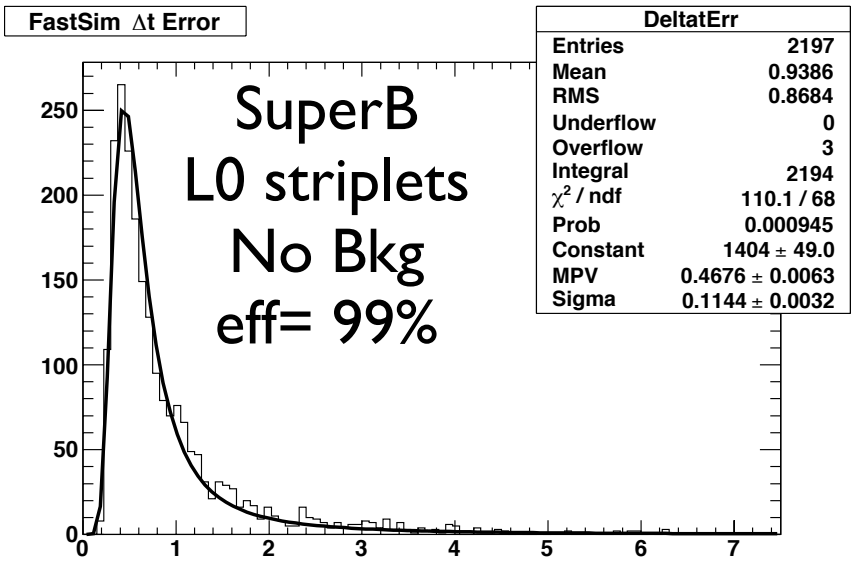


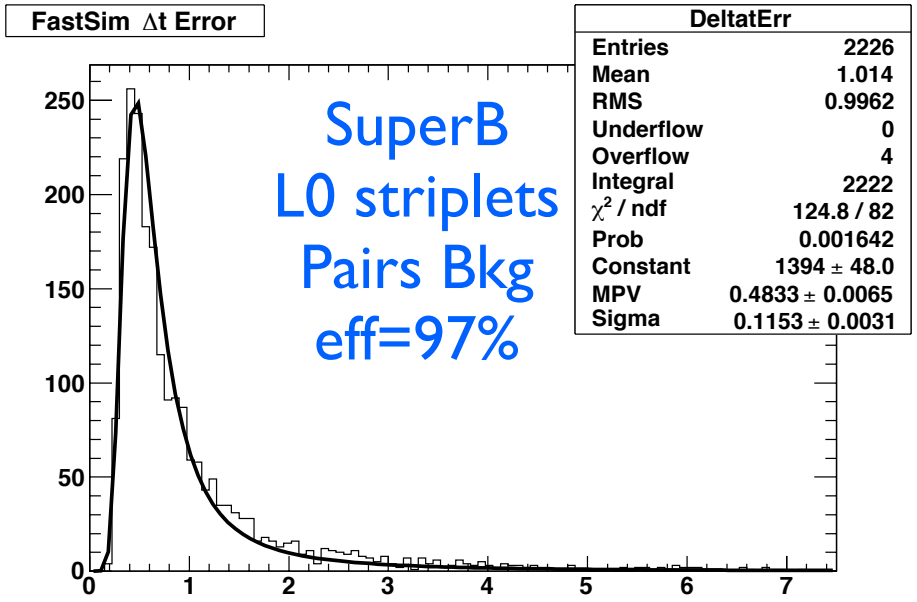


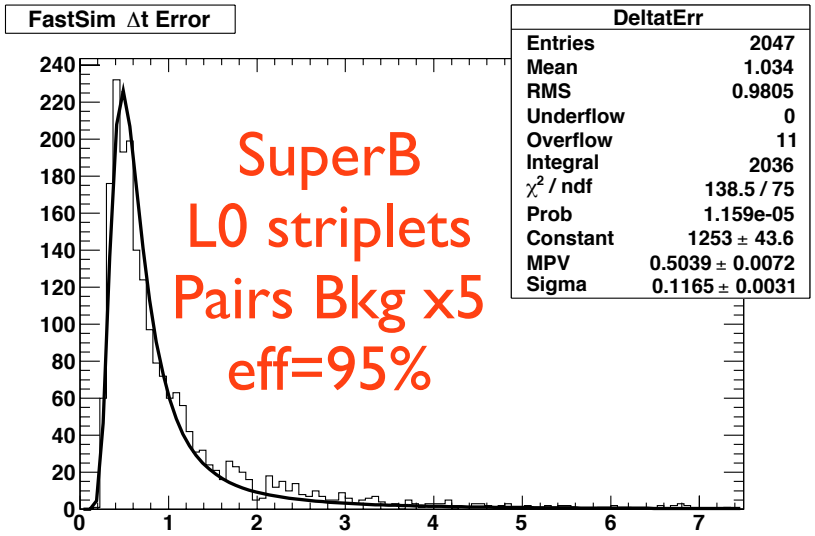


- Not removing low momentum electrons using SVT dE/dx information in the SVT.
- Use GoodTracksTight selection for determination of B Tag vertex position.

Δt error distribution

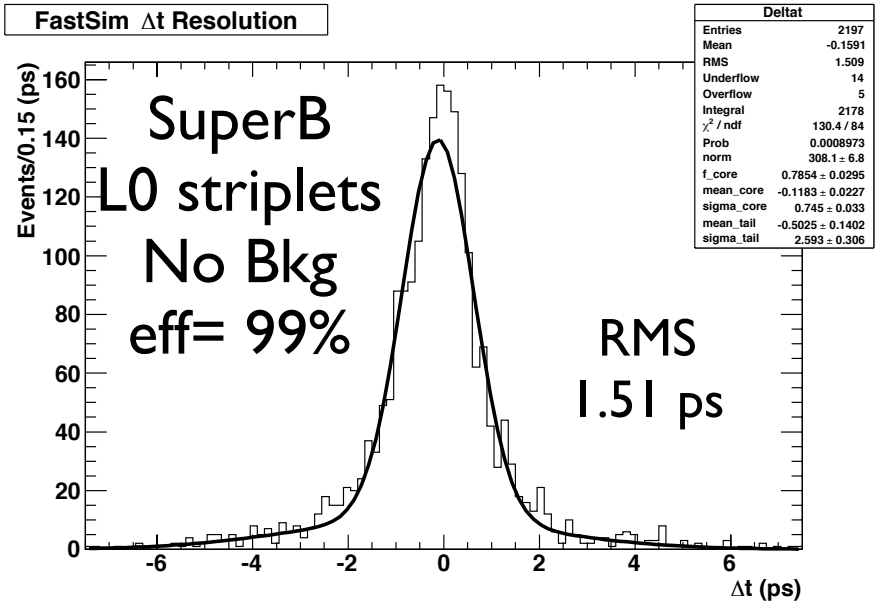


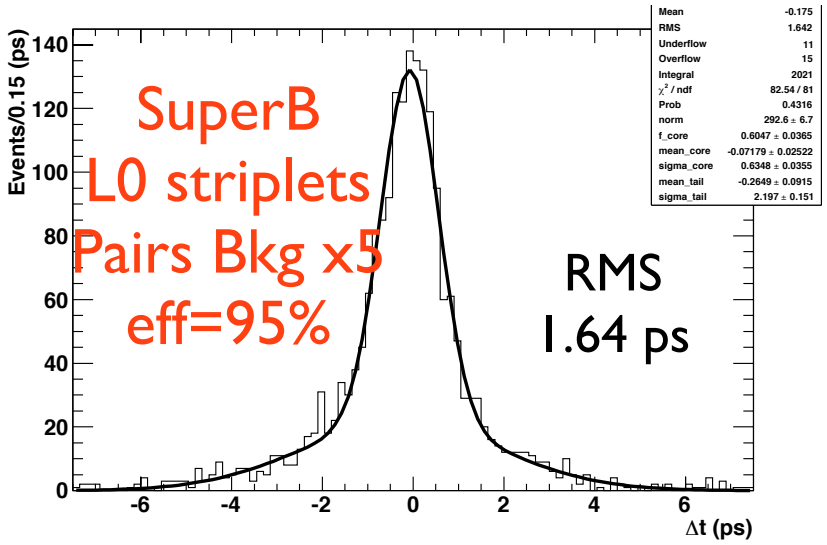


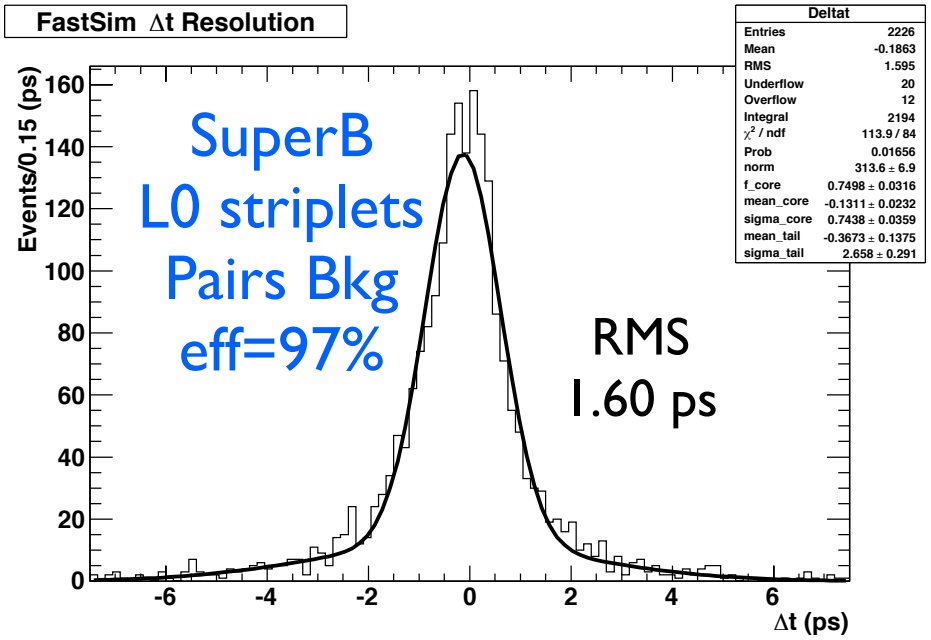


- 8%, 10% change in mean Δt error value wrt no bkg.

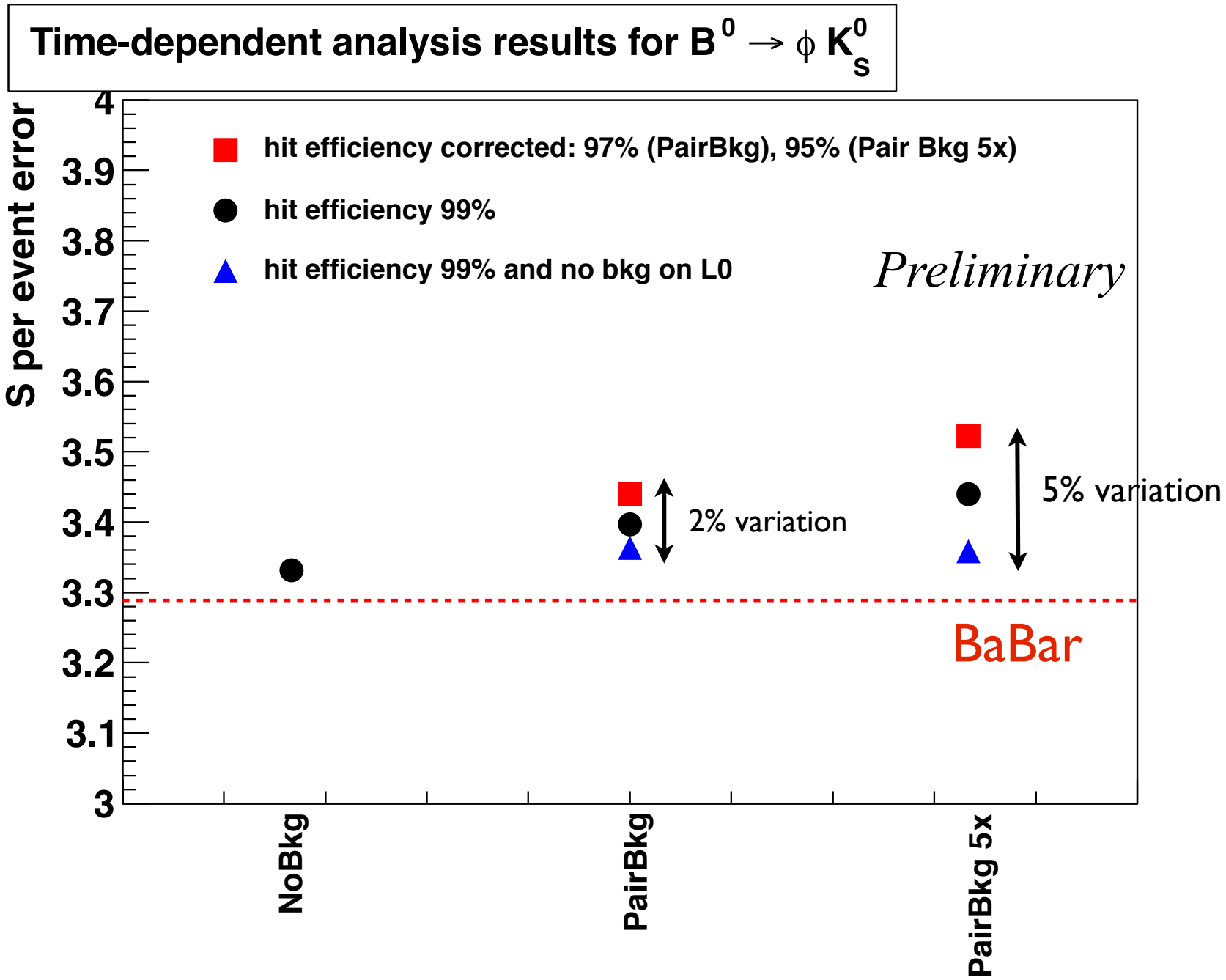
Δt resolution







- 6%, 9% change in RMS of Δt residual wrt no bkg.


Time-dependent analysis results for B0 → φ K0S
S per event error
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
hit efficiency corrected: 97% (PairBkg), 95% (Pair Bkg 5x)
hit efficiency 99%
hit efficiency 99% and no bkg on L0
Preliminary
2% variation
5% variation
BaBar
NoBkg
PairBkg
PairBkg 5x

Summary

- Generated Pairs Bkg events using FastSim. Comparison with FullSim reasonably good in inner layers: the most relevant for vertexing performances. Discrepancies in the outer layers under investigation.
- Impact of Pairs Bkg on SVT performances evaluated, as an exercise, using present FastSim bkg rates:
  - small but sizable worsening in d0 and z0 resolution (~10-15% effect with x5 bkg);
  - small effect on S per event error (5% worsening with x5 bkg).
- Final results require additional bkg sources (Touschek bkg relevant for outer layers) and tuning of Pairs bkg rates according to FullSim. Need also updated hit efficiency values in presence of bkg. Expected relatively small variations of the performances.

Backup

Typical QED Pair event