Pixel performance studies

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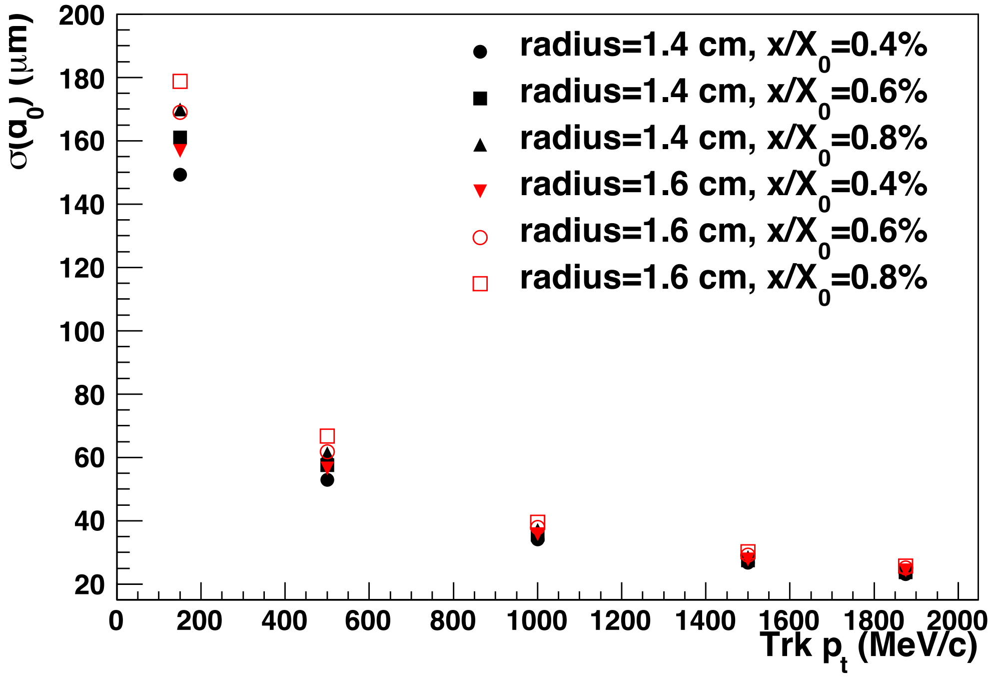
Outline

- Pixel performance *vs*:
  - material budget
  - radius
  - background

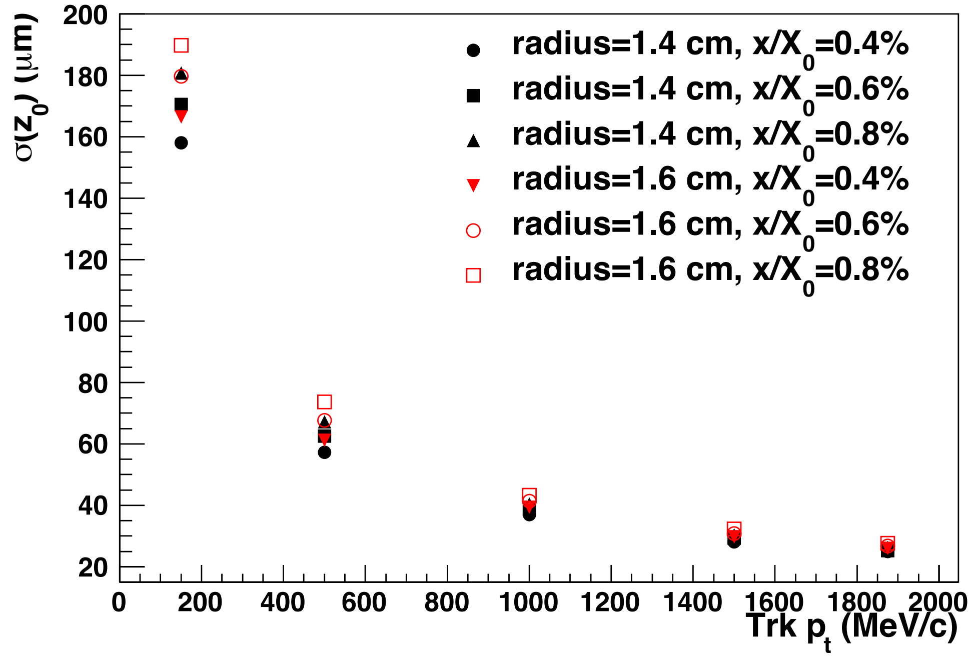
Pixel configuration

- Pixel radius = 1.4, 1.6 cm
- Material budget x/X_0 = 0.1 - 1.0 %
- Digital readout, 50x50 μm^2 pixel cell

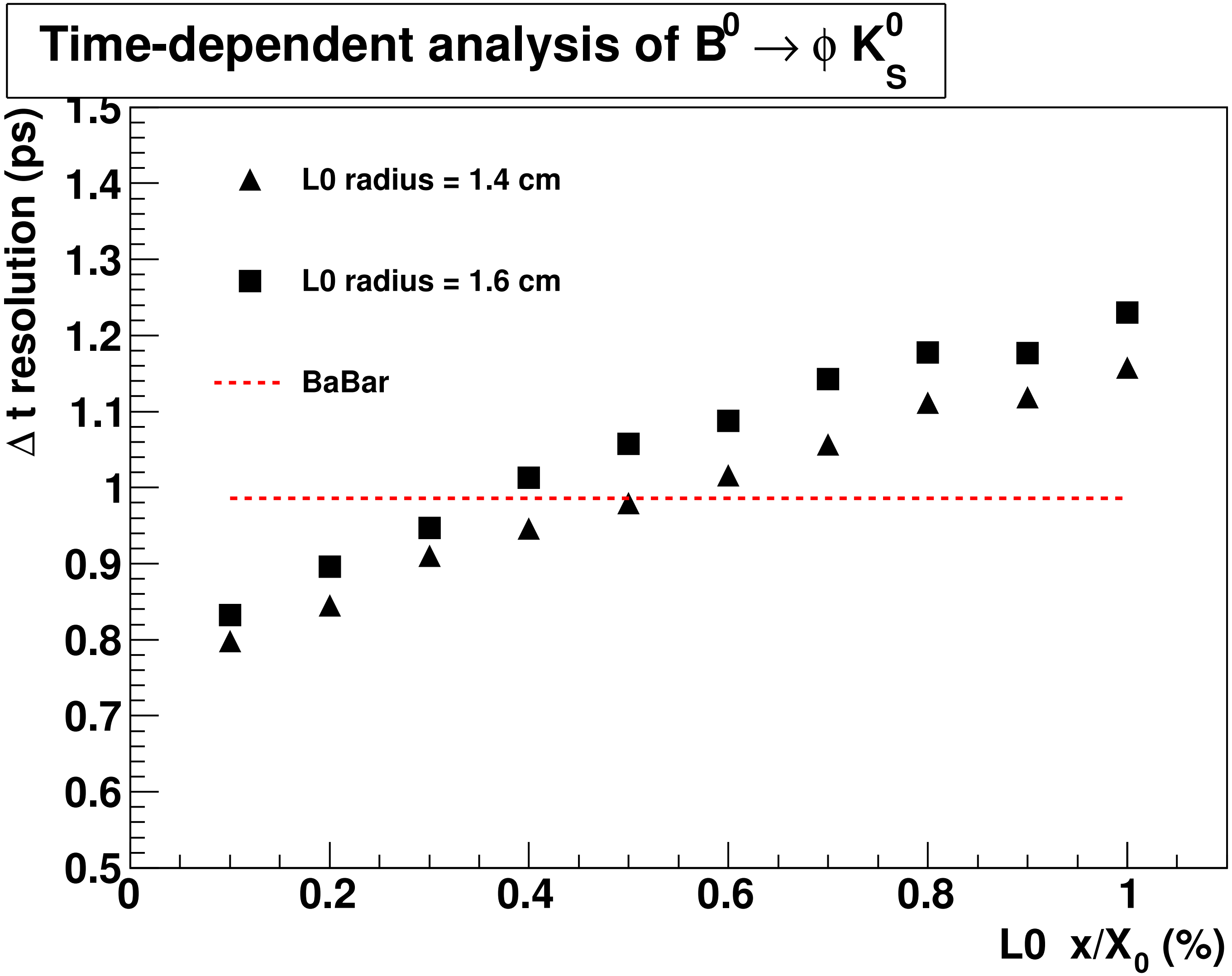
d_0 resolution



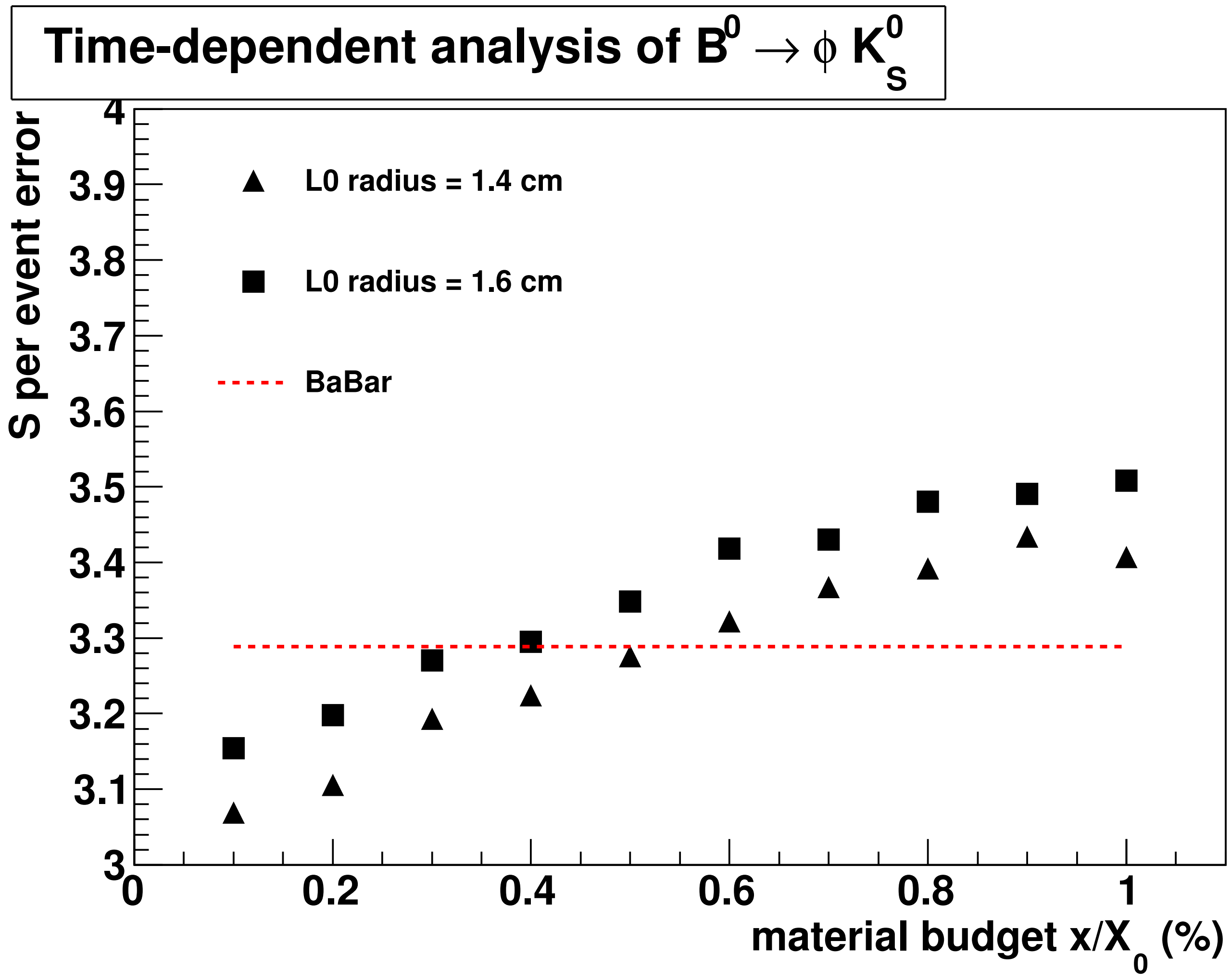
z_0 resolution



d_0 and z_0 resolution for single track (pion) events vs p_t



Δt resolution = mean of Δt error distribution



Maximal difference is about 6% wrt BaBar.

Adding background hits

- Use identical bkg rates, hit efficiencies and sensitive time windows as presented in Elba
- details are in the backup slides
- new QED pairs estimates from R. Cenci for L0 with correct geometry (radius ~1.6 cm) are 10-20% lower. Not included in this study.

May 2012 prod

Rate L0 ("phi") = 30.1*0.7*0.7 = 14.7 MHz/cm2
Rate L0 ("z") = 38.1*0.7*0.7 = 18.7 MHz/cm2

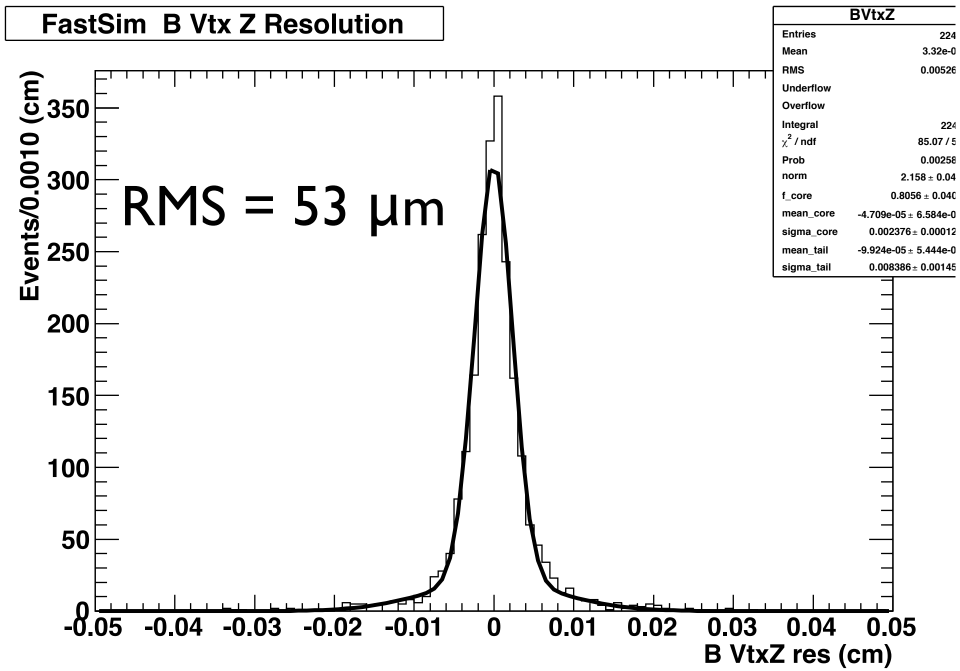
area norm. radius correction

Jun 2012 prod

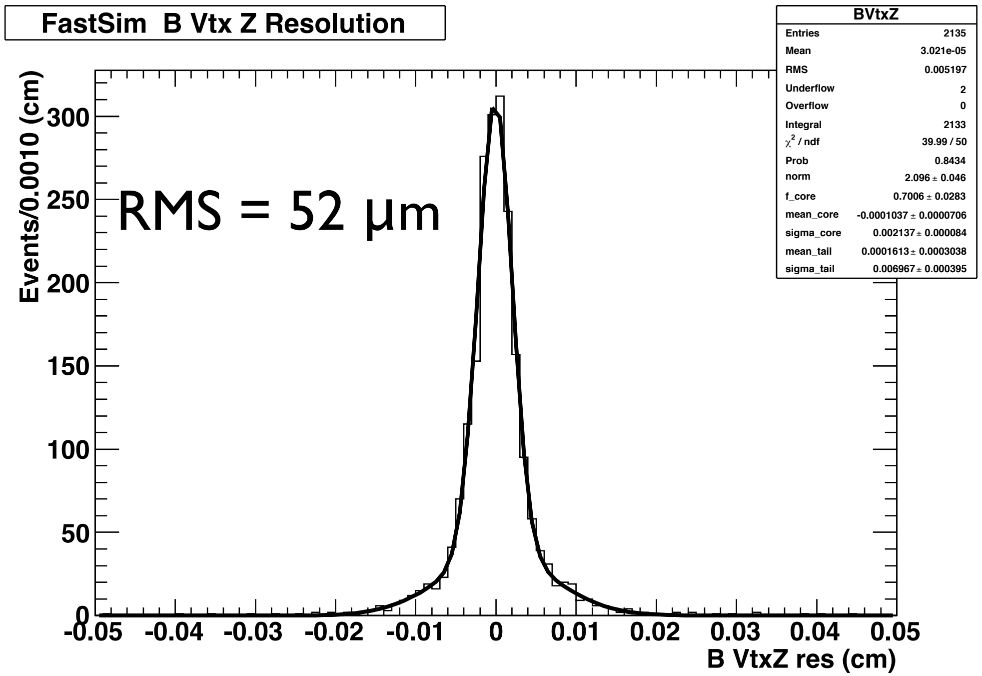
Rate L0 ("phi") = 18.7*0.725 = 13.5 MHz/cm2
Rate L0 ("z") = 20.7*0.725 = 15.0 MHz/cm2

area norm.

No bkg



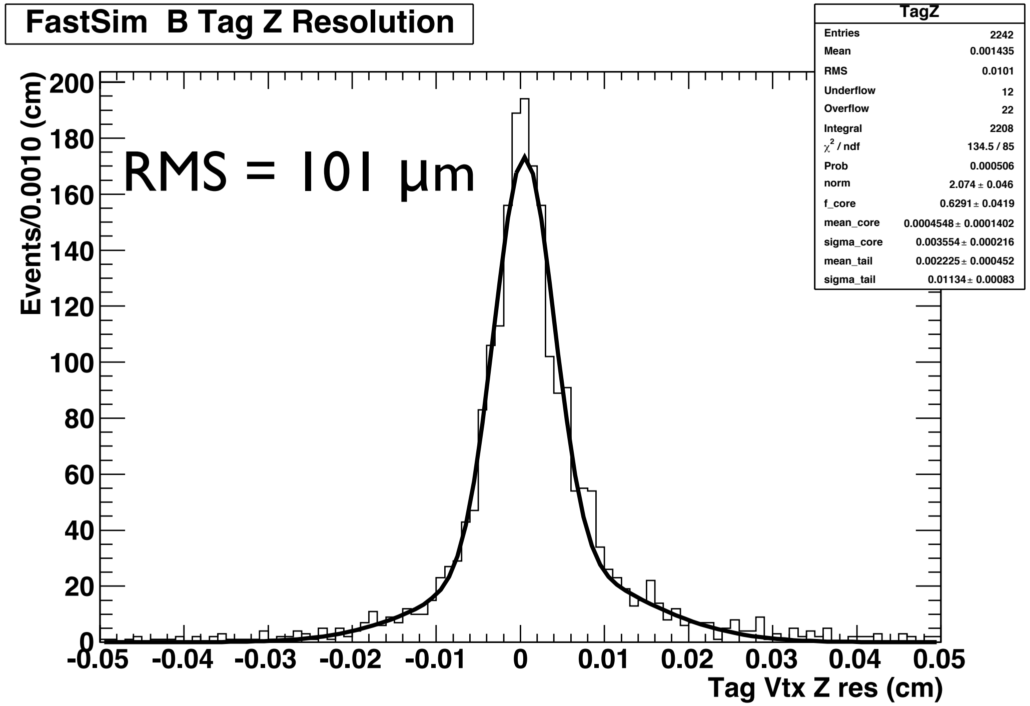
x5 nominal bkg



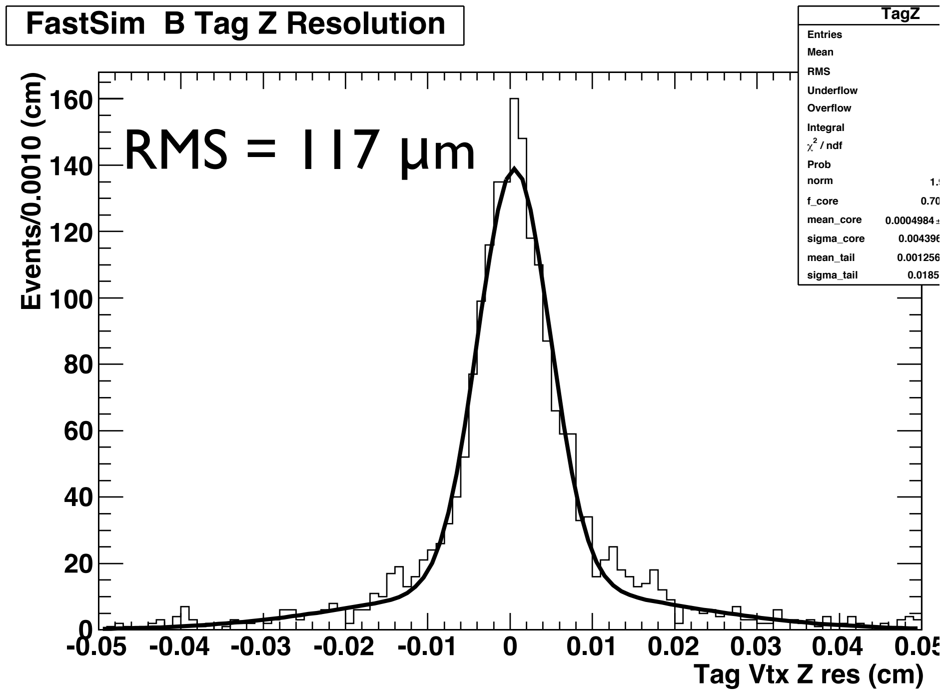
Example for pixel at r=1.6 cm with x/X_0=0.8%

B reco vertex z resolution

No bkg

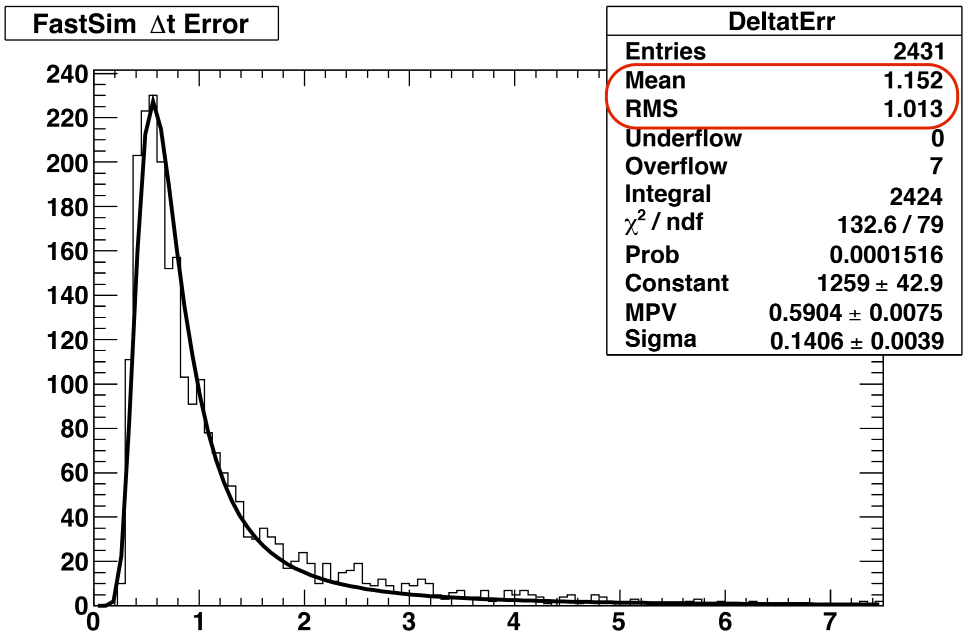


x5 nominal bkg

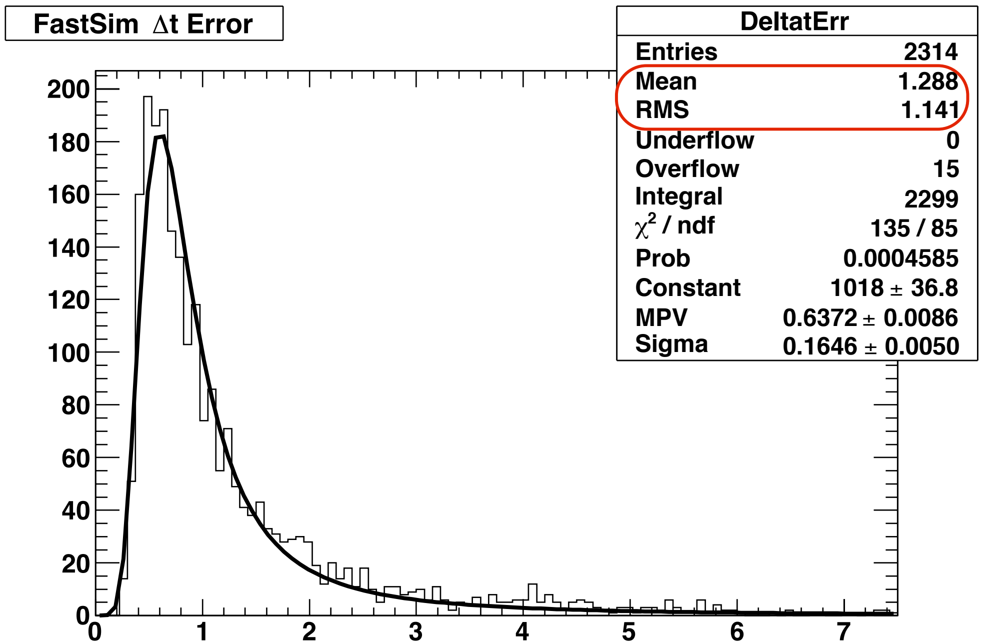


B tag vertex z resolution

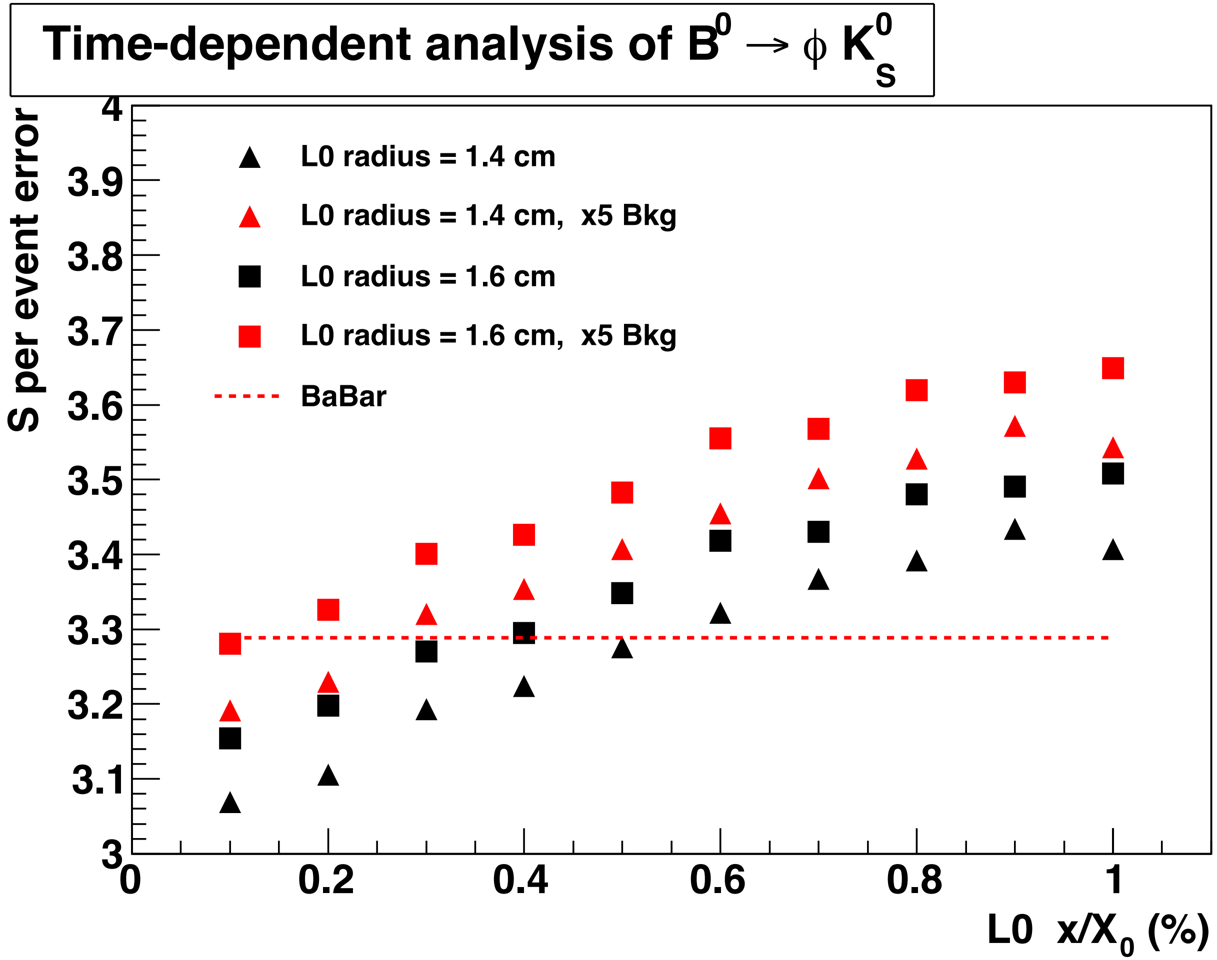
No bkg



x5 nominal bkg

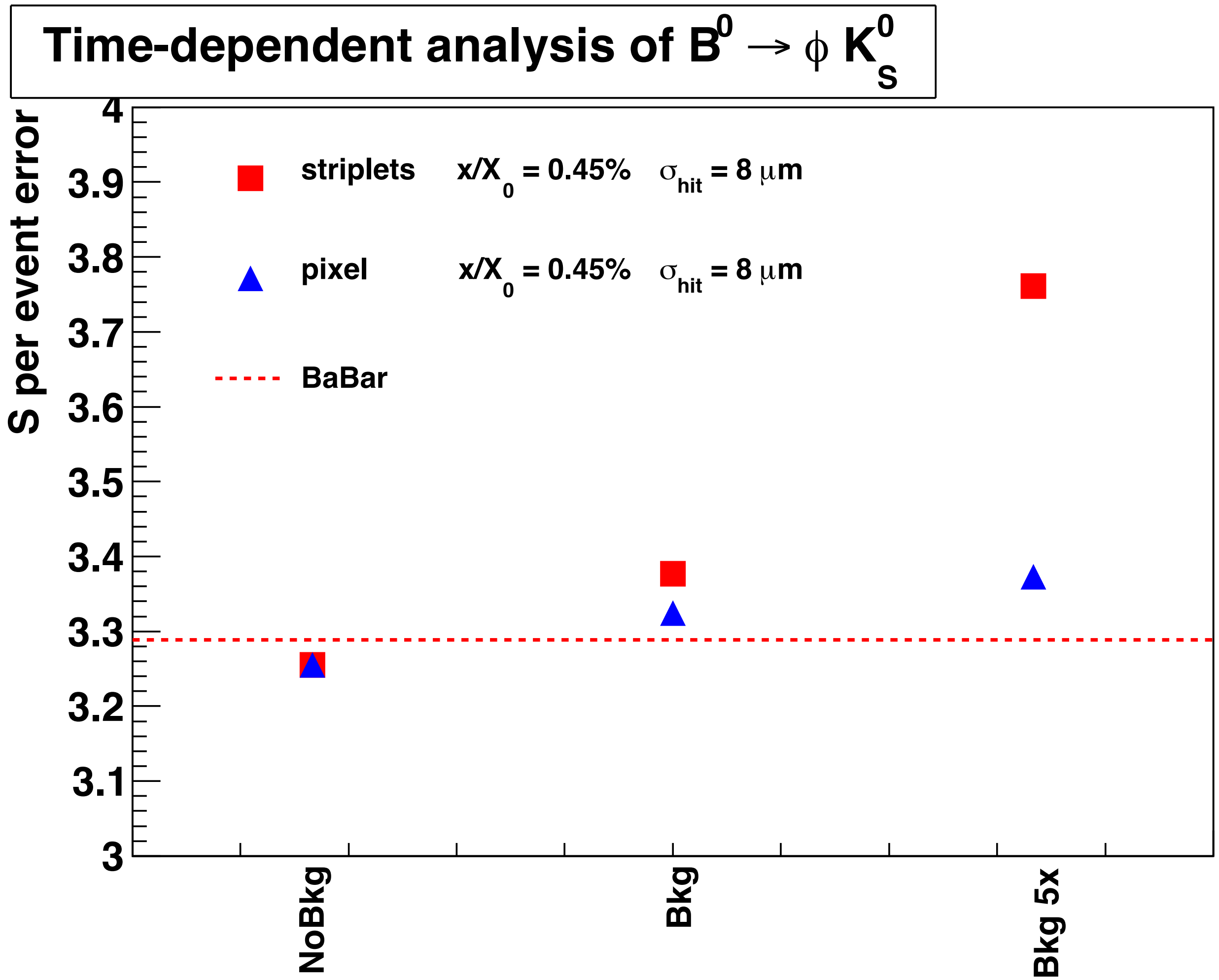


Δt error from the vertex-kinematic fit



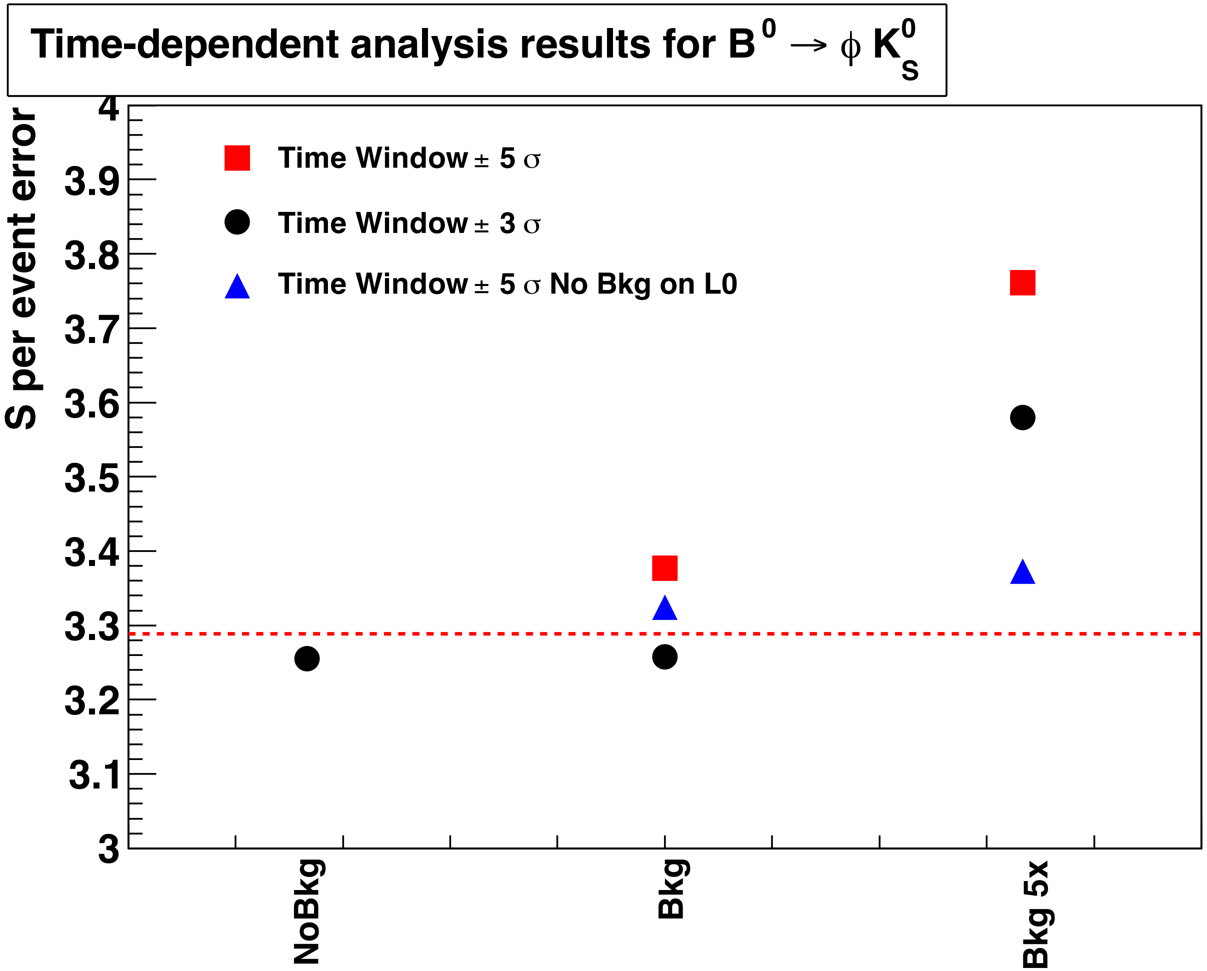
Effect of the bkg estimated for two points.

Average increase of 4% (3.6%, 4.4%) applied as a scale factor in the plot.



Striplets performance compared with pixel vs bkg

assuming identical material, radius and hit resolution



Tighter time window cuts or improved hit time resolution on L0 would be beneficial for striplets

- Performance with pixel L0 has been evaluated for a wide range of material budget and r= 1.4, 1.6 cm. Also with x5 nominal background

- In presence of x5 bkg pixel is more robust vs striplets due to lower occupancy. Performance depends on pixel material budget and radius

- Pixel solution with material budget similar to striplets (0.4% X_0) would allow comparable S per event error to BaBar also in presence of x5 nominal bkg.

Backup

Including all Bkg sources in FastSim

- Used higher statistics sample for determine bkg rates of QED Pairs generated in FastSim. Update table is below. Results are consistent with the previous ones.
- Scaling the offline time windows to obtain identical rates as in FullSim using the factor R=Rate(FullSim)/Rate(FastSim) evaluated on cluster rates. All bkg sources are effectively included in this way in FastSim.
- Use t0 resolutions for nominal peaking times.

Layer	Trk rate FastSim MHz/cm^2	Cluster FastSim MHz/cm^2	Track FullSim All Bkg MHz/cm^2	Cluster FullSim All Bkg MHz/cm^2	Ratio FullSim/FastSim R	RMS t0 σ(t0) (ns)	Effective window (μs) ±5σ(t0)×R
L0	1.23E+00	2.86E+00	1.625E+00	4.103E+00	1.43E+00	10	1.43E-01
L1	6.76E-02	1.91E-01	2.169E-01	5.397E-01	2.83E+00	15	4.24E-01
L2	3.20E-02	9.12E-02	1.623E-01	3.928E-01	4.31E+00	15	6.46E-01
L3	6.87E-03	1.70E-02	7.939E-02	2.080E-01	1.22E+01	25	3.06E+00
L4	4.61E-04	1.44E-03	2.237E-02	3.699E-02	2.57E+01	46	1.18E+01
L5	2.55E-04	8.36E-04	1.402E-02	2.234E-02	2.67E+01	80	2.14E+01

Sensitive time windows

- Bkg hits are considered if they are inside the offline sensitive time windows. Use nominal peaking times for this study. Some improvements are possible using shorter peaking times or reducing the sensitive time window (TW) from ±5σ to ±3σ of t0 resolution.

Layer	Peaking time (ns)	Frascati exercise (ns)	This study: ±5σ × R (ns)
L0	25	60	143
L1	100	100	424
L2	100	100	646
L3	200	150	3060
L4	500	400	11800
L5	1000	400	21400

From Lodovico Ratti presentation

Based on MC simulation results, the uncertainty in t_0 can be expressed as

$$\sigma_{t0} = \sqrt{\frac{T^2_{CK,TS}}{12} + 0.0625 \cdot T^2_{CK,TOT}}$$

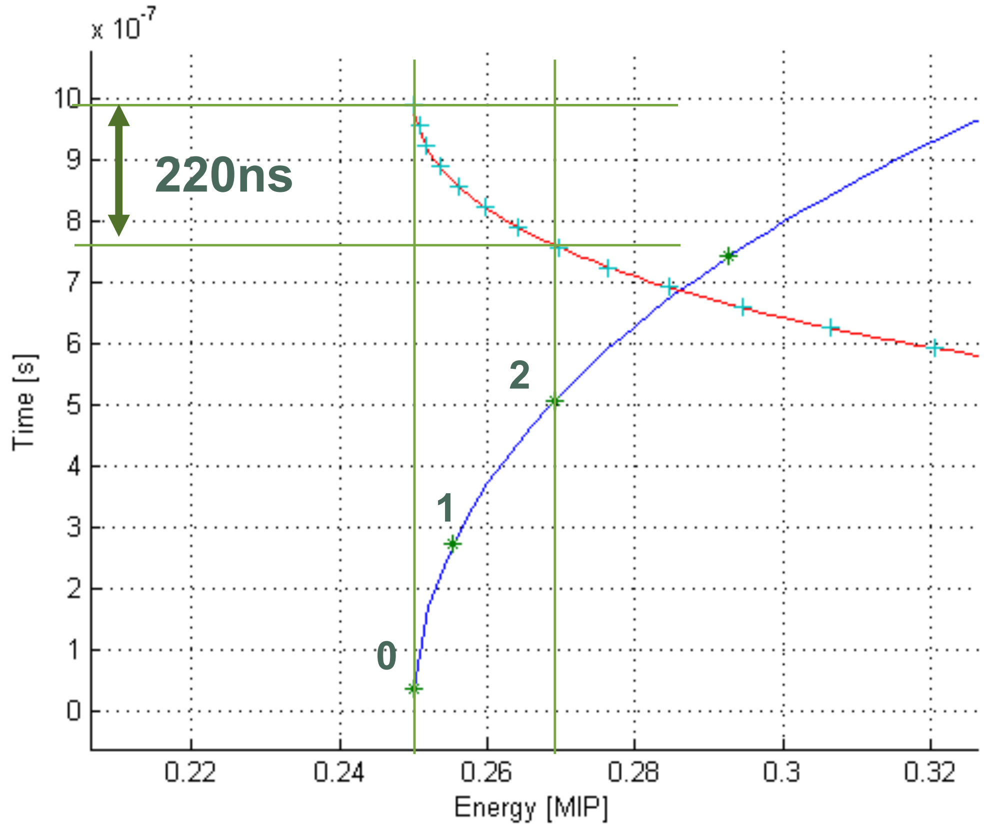
where the worst case value of σ_{walk}, ~0.25 $T_{CK,TOT}$ for TOT→0, is assumed

Layer	t_p [ns]	$t_p/T_{CK,TOT}$	$f_{CK,TS}$ [MHz]	σ_{walk} [ns]	σ_{t0} [ns]
0	25	4	30	1.6	9.8
1	100	4	30	6.2	11.4
2	100	4	30	6.2	11.4
3	200	4	30	12.5	15.8
4	500	4	30	31.2	32.6
5	1000	4	30	62.5	63.2

Actually σ_{walk} gets smaller for larger values of TOT, so better estimation of t_0 could be obtained

From Luca Bombelli presentation

Phase error of TOT clock when TOT should count “1”



Peaking Time = 1us

TOT = 4 bits

TOT clock = 4.25 MHz

Max error = 220ns

(including only Phase error of TOT clock)

From Luca Bombelli presentation

Timing Resolution with TOT

Peaking time [ns]	TOT bit	TOT clock [Mhz]	Max Time window [ns]	Time Error rms [ns]	Preliminary Jitter for 1 MIP [ns]	Preliminary Jitter for 0.3 MIP [ns]
375	4	11.3	114	33	10.3	34.6
	6	47.5	54	15		
500	4	8.5	141	41	12.7	43.3
	6	35.7	60	17		
750	4	5.66	196	56	17.6	60.3
	6	23.8	74	21		
1000	4	4.25	250	72	22.9	77.9
	6	17.8	87	25		

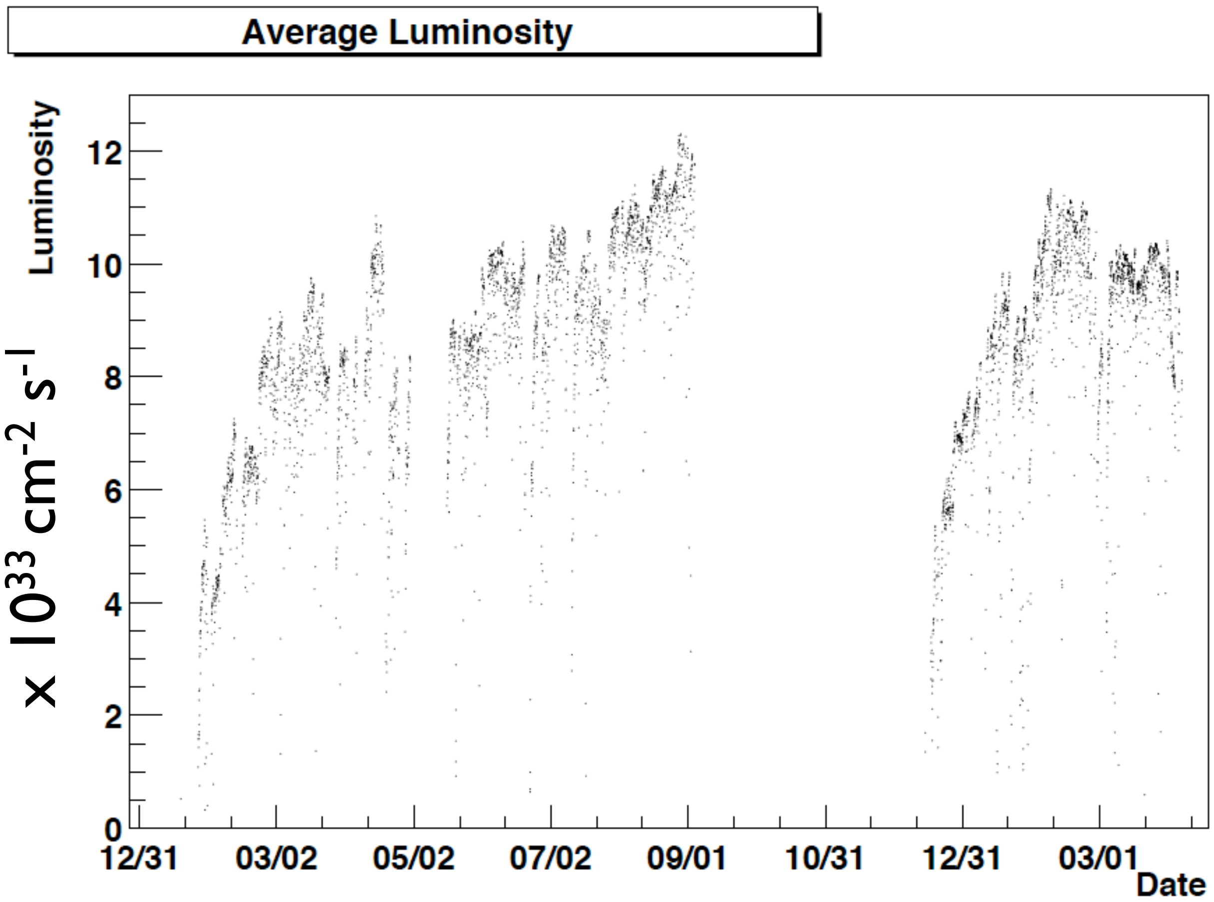
Efficiencies

- Use efficiencies at nominal peaking times for this study. Some improvements are possible using shorter peaking times.

Layer	Peaking time (ns)	Bkg (%) (r-ϕ/z)	Bkg x5 (%) (r-ϕ/z)
L0	25	99/99	96/96
L1	100	98/98	88/89
L2	100	98/98	89/89
L3	200	95/95	77/86
L4	500	98/98	89/93
L5	1000	98/98	86/91

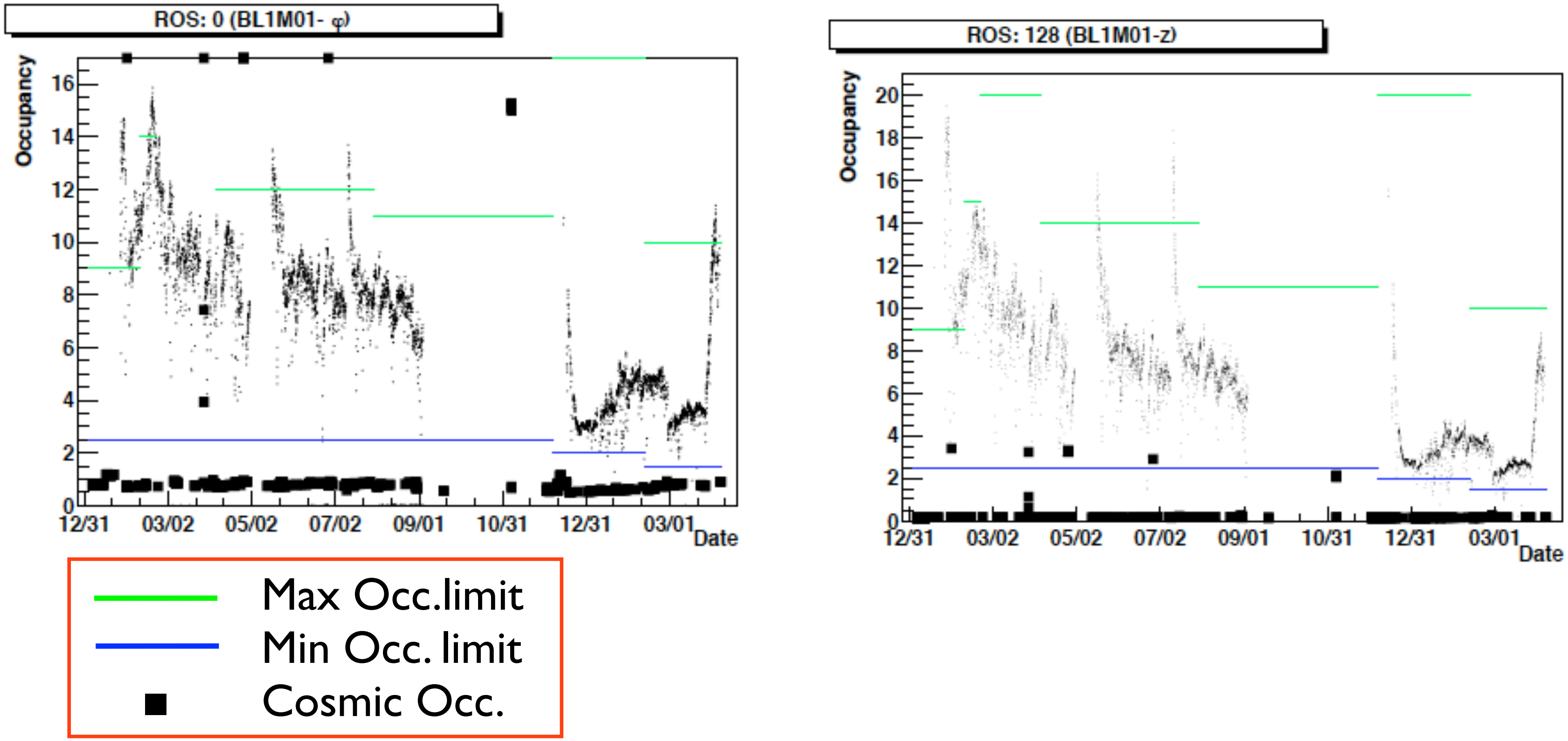
Considerations for track reconstruction in high bkg (see Isabelle talk)

BaBar luminosity 2007-2008



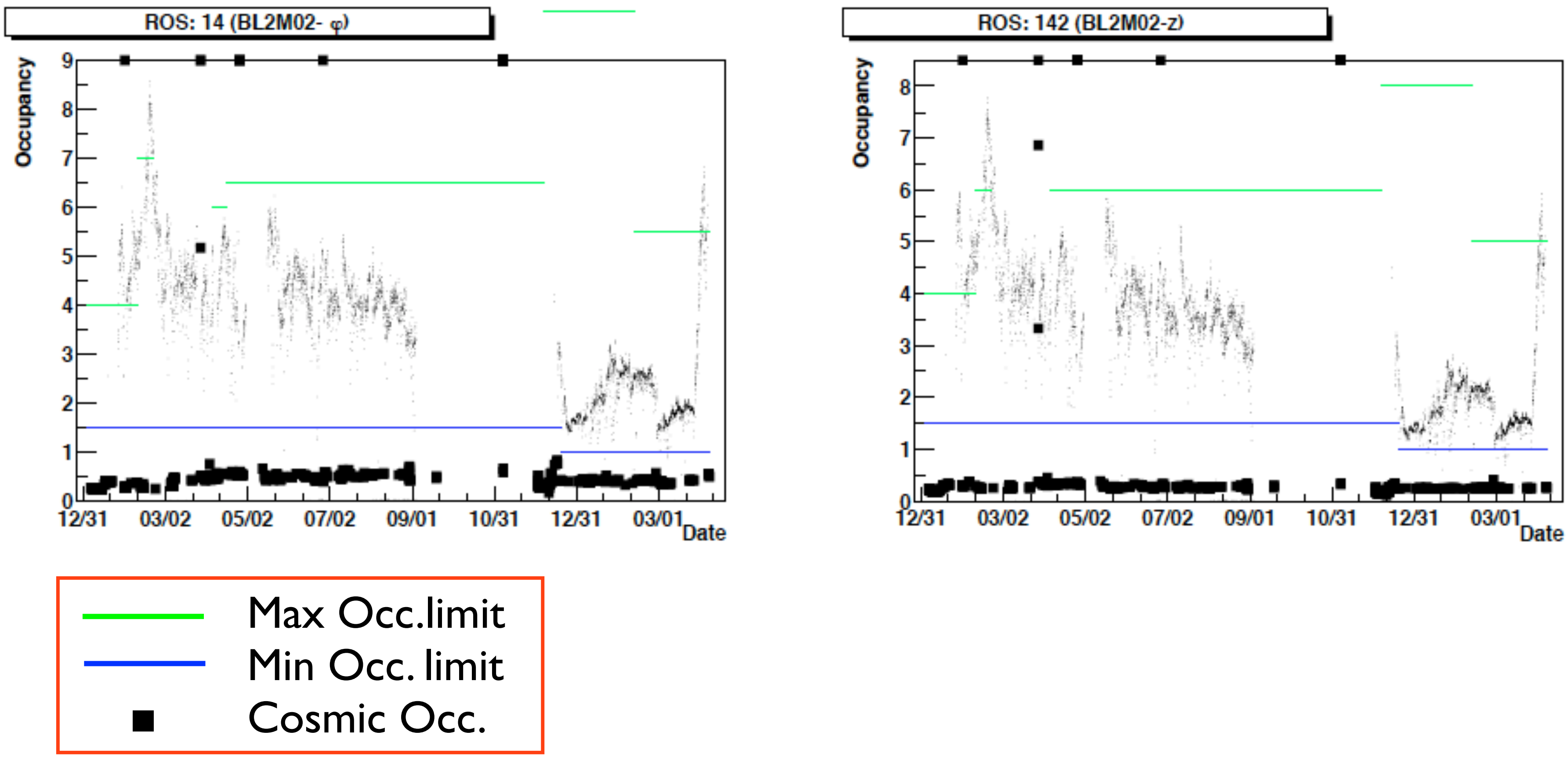
Highest luminosity in Sept 2007 and Feb 2008.
BaBar reached ~4 times the design luminosity

Occupancies in Layer1



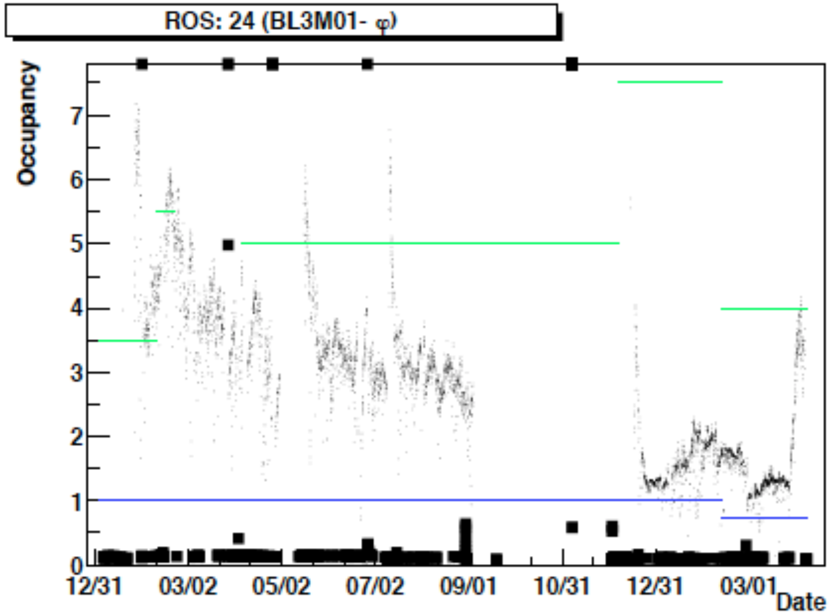
Online occupancies reached level greater than 10% in Layer1.

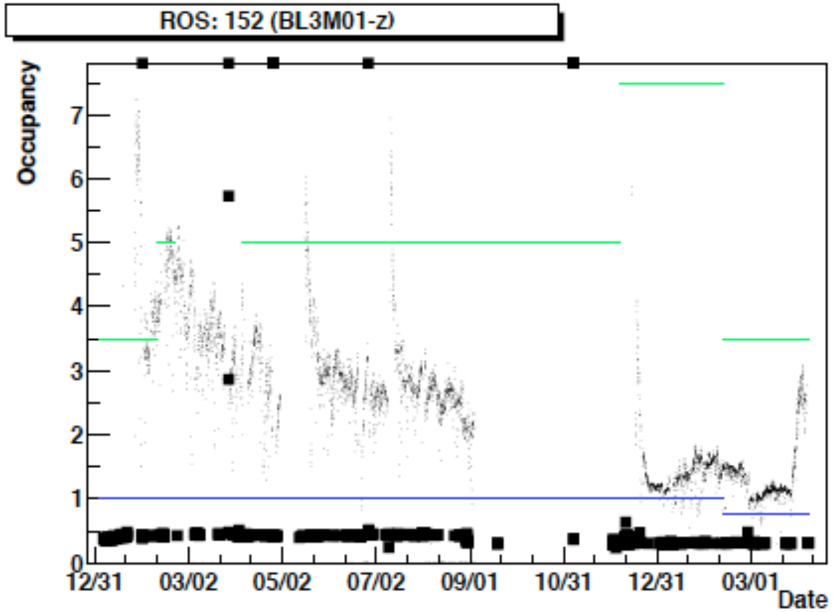
Occupancies in Layer2



Online occupancies reached level greater than 5% in Layer2.

Occupancies in Layer3

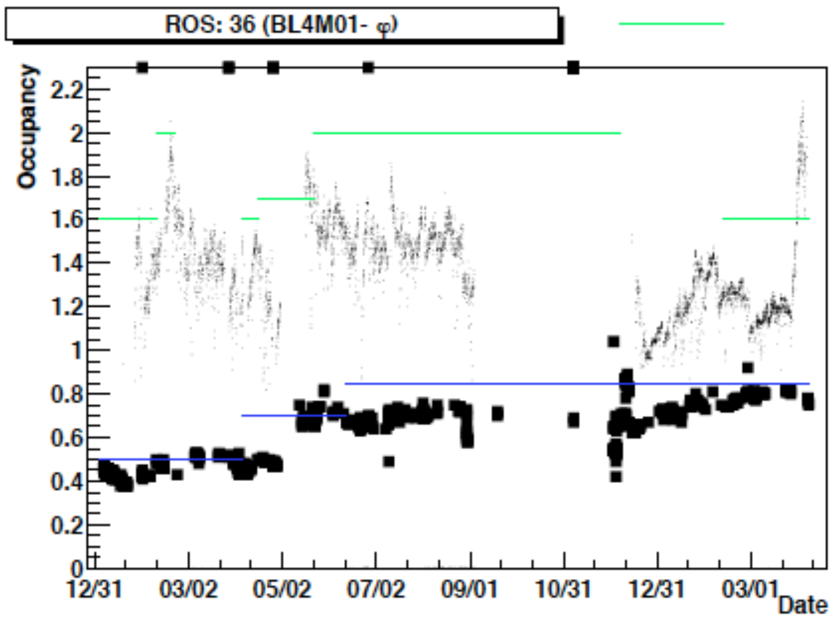


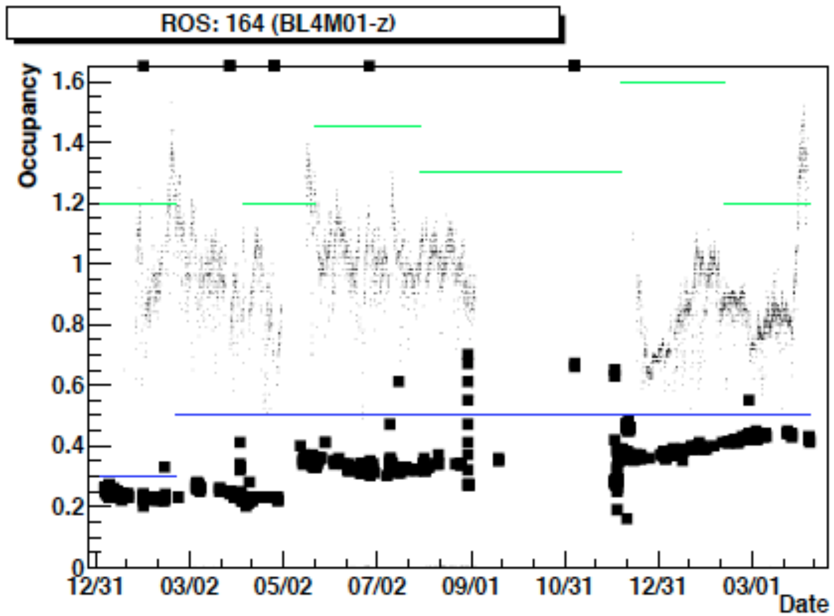


Max Occ.limit
Min Occ. limit
■ Cosmic Occ.

Online occupancies reached level greater than few % in Layer3.

Occupancies in Layer4

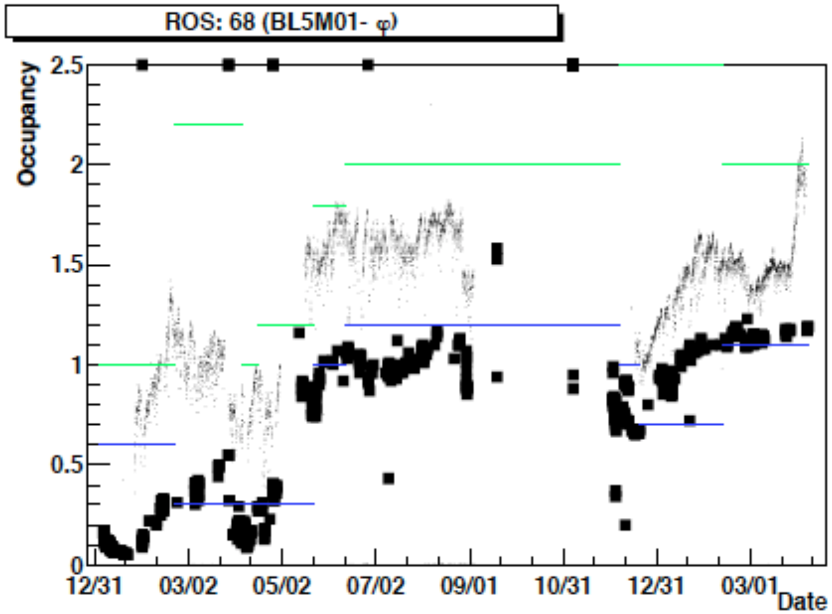


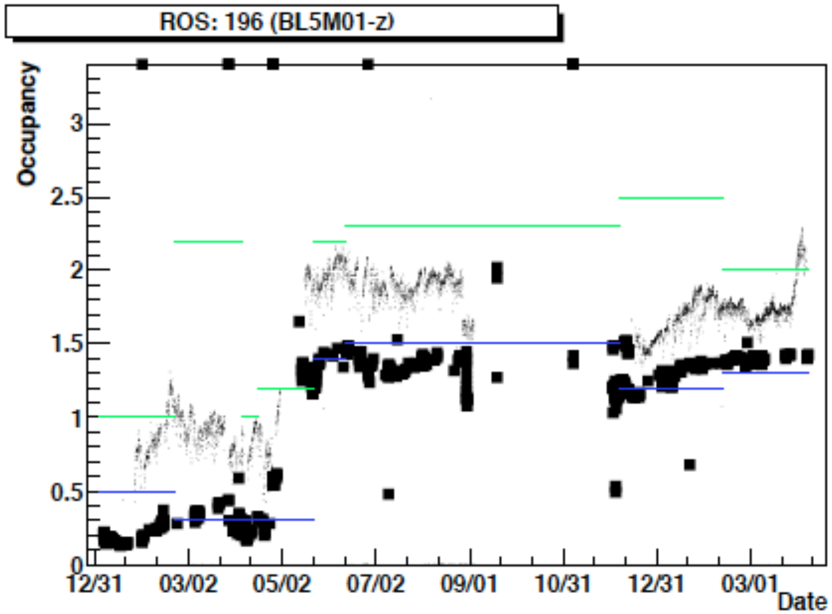


Max Occ.limit
Min Occ. limit
■ Cosmic Occ.

Online occupancies reached level of 1 % in Layer4.

Occupancies in Layer5





Online occupancies reached level of 1 % in Layer5.

Comparison of offline cluster occupancies

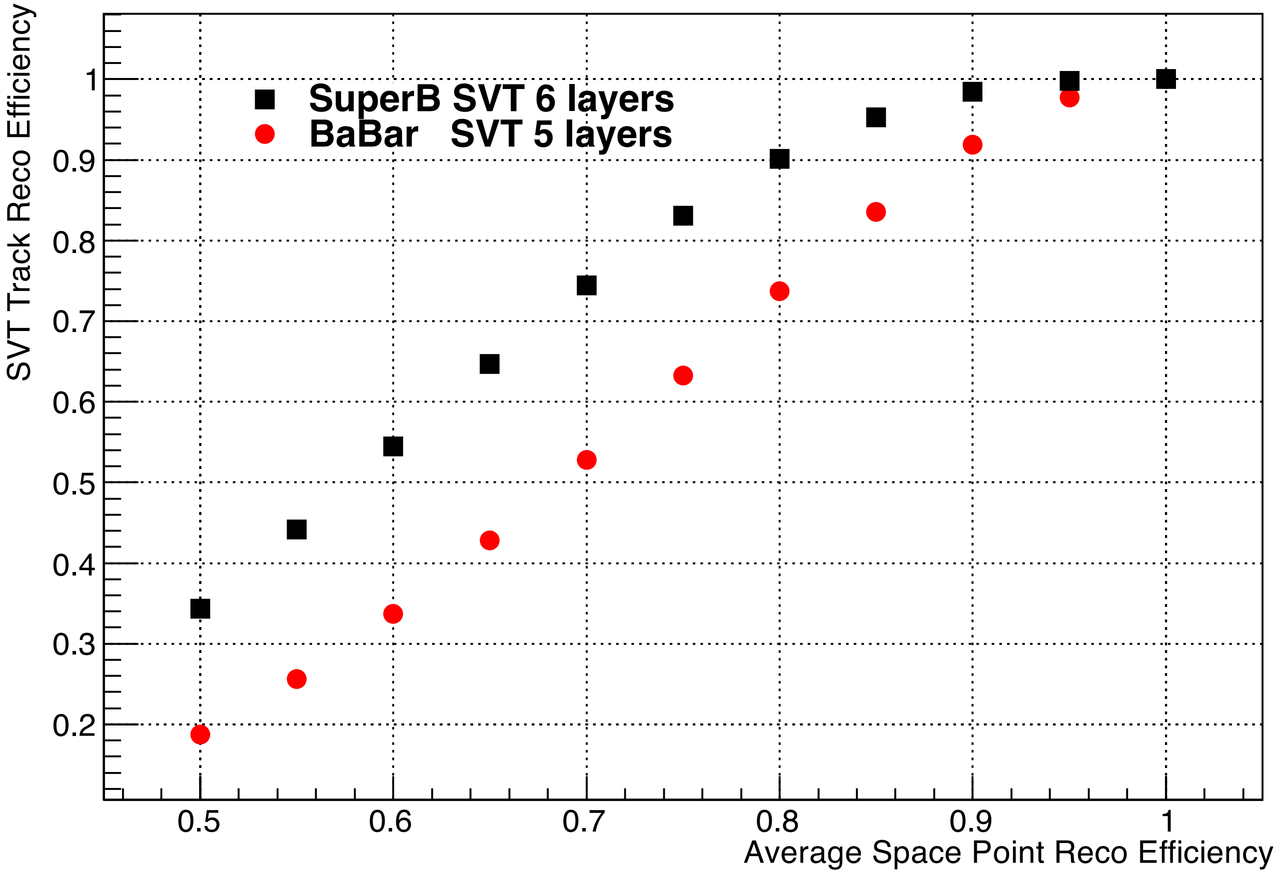
BaBar

	Average Offline Cluster Occ(%) Jan 2008 offline	Average Offline Cluster Occ(%) Mar 2008 offline
L1 phi	2.02	1.31
L1 z	1.57	0.98
L2 phi	1.61	1.07
L2 z	1.21	0.76
L3 phi	1.20	0.84
L3 z	0.55	0.38
L4 phi	0.51	0.33
L4 z	0.35	0.23
L5 phi	0.51	0.38
L5 z	0.43	0.32
Average Occ(%)	1.00	0.66

SuperB

	x5 Bkg, TW = +/- 5 sigma short peaking time + NOISE
L0 u	2.00
L0 v	1.99
L1 phi	2.25
L1 z	1.73
L2 phi	2.16
L2 z	1.46
L3 phi	4.94
L3 z	2.03
L4 phi	2.18
L4 z	1.56
L5 phi	1.64
L5 z	1.00
Average Occ (%)	2.08

- BaBar values are corresponding to the green line in occupancy plots. Max occupancy limit in Fast Monitoring plots which defines the range of acceptable occupancy values for that period of data taking.
- SuperB values are for 5 times nominal bkg, +/- 5 sigma time window, short peaking times for FEE and noise included in t_0 resolution
- Offline cluster occupancies at SuperB (with x5 Bkg) differ of a factor 2 or 3 wrt high luminosity data at BaBar



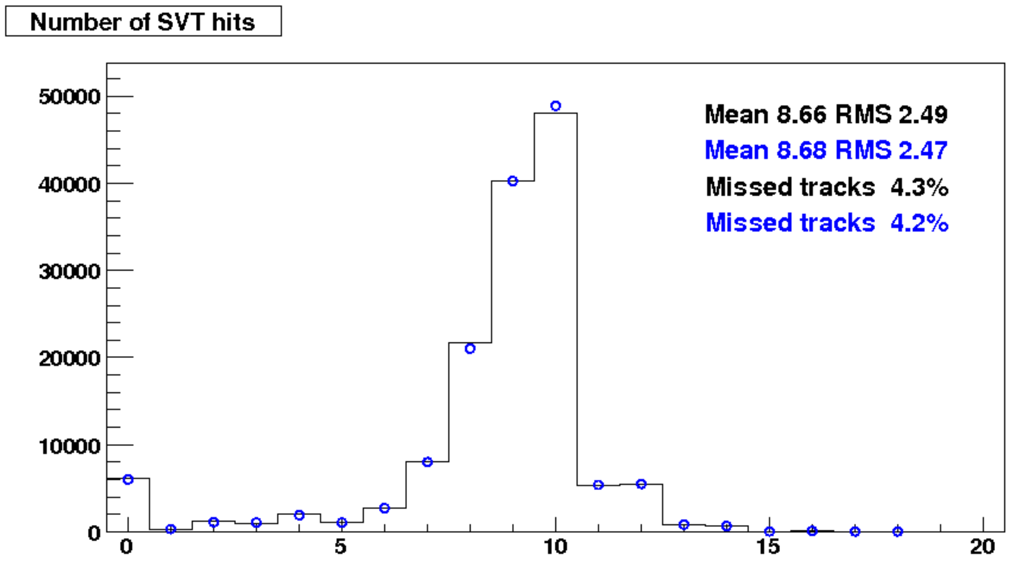
Track reco efficiency vs Space Point Reco Efficiency

Require at least 4 space points for standalone track reconstruction the in SVT

$$P = \sum_{k \geq 4}^{n} \binom{n}{k} p^k (1-p)^{n-k}$$

n=5 BaBar
n=6 SuperB

Distribution of number of SVT hits found on tracks reconstructed in the DCH.



Missed tracks:

ratio between the content of first bin and the sum of the entries.

To do: study the correlation between missed tracks and occupancy and extrapolate to the SuperB case.

Track reconstruction in heavy ion collisions with the CMS silicon tracker

NIM A 566 (2006) 123–126 (based on simulation studies)

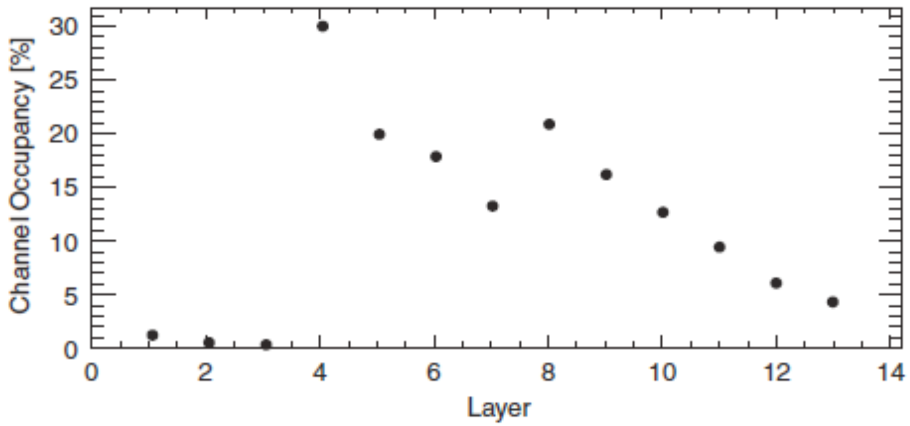


Fig. 1. Channel occupancy in the barrel region as a function of detector layer. Layers 1–3 correspond to the pixel detector, 4–13 to the Si-strip tracker.

Track seeding:

In heavy ion events, the seeding relies on three-hit combinations in the pixel detectors to achieve more precise initial estimates of the track parameters. Requiring three hits in three detector layers results in a 10% loss of overall reconstruction efficiency due to the geometric acceptance of the detector.

In very high bkg conditions it would be useful to have the inner layers instrumented with pixels. Track seeding is crucial in CMS pattern recognition for reconstruction of heavy ions collisions.