Estimation of the two-photon QED background in Belle II

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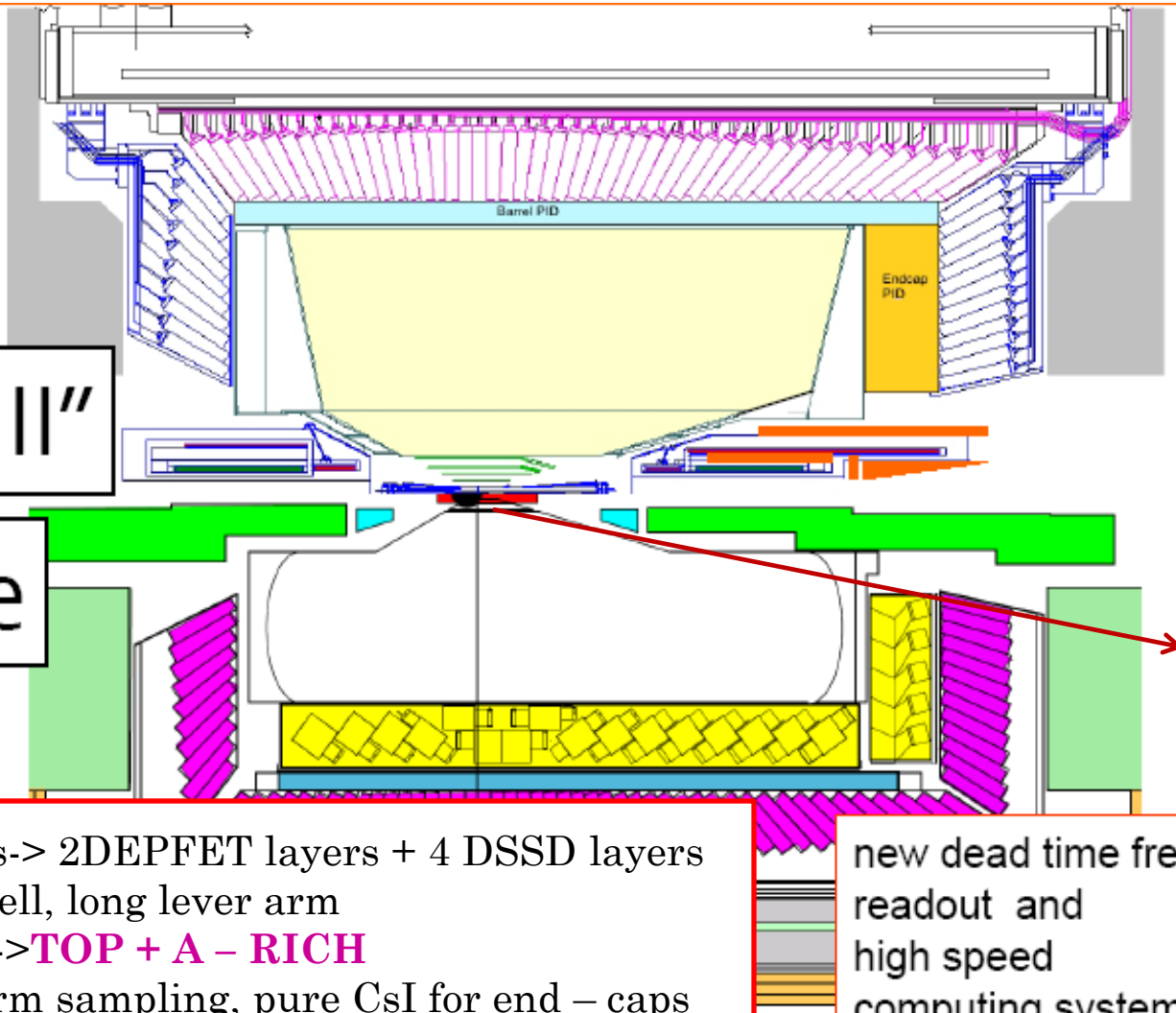
- Upgrade to the Belle II detector
- Expected background at Belle II
- QED experiments performed at KEK
- Comparison between data and MC
- Summary and Conclusion

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Belle Detector Upgrade



"Belle II"

Belle

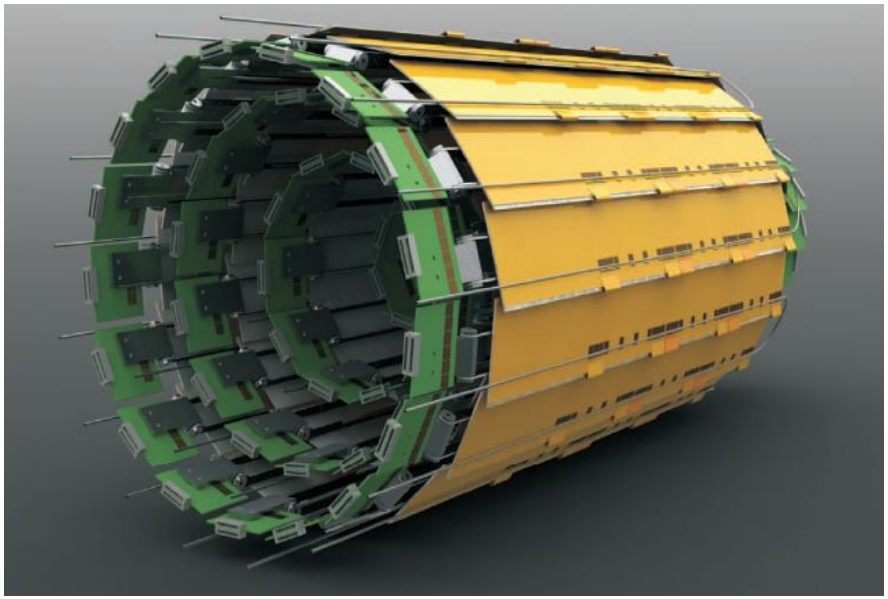
Belle:
4 layer
Silicon Strip
Detector

SVD: 6 layers-> 2DEPFET layers + 4 DSSD layers
CDC: small cell, long lever arm
ACC + TOF ->TOP + A – RICH
ECL: waveform sampling, pure CsI for end – caps
KLM: RPC -> Scintillator + SiPM (end – caps)

new dead time free readout and high speed computing systems

Si ~ Detectors

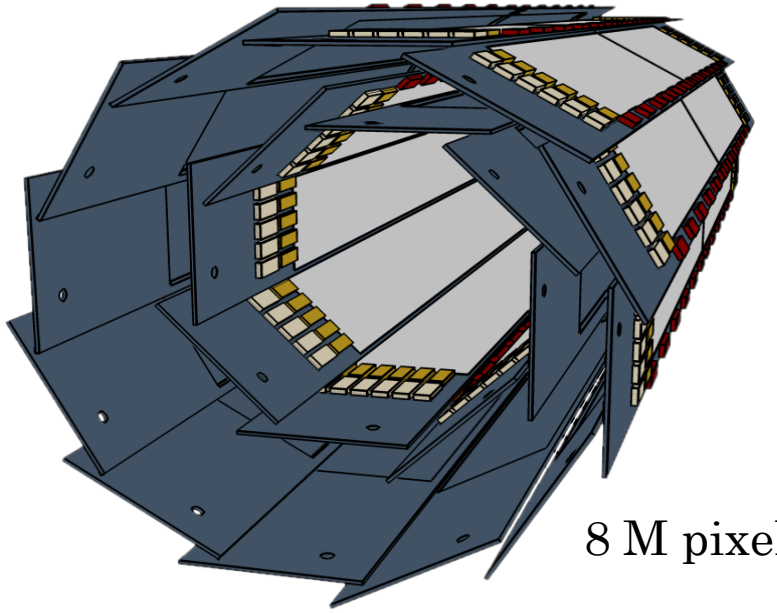
Strips vs. Pixels



Silicon Vertex Detector at Belle II

- **4 layers**
- **DSSDs (double sided strips)**
  - **z strips**
  - **phi strips**

Pixel Vertex Detector (PXD)



8 M pixels

2 layers

- **1.4 cm**
- **2.2 cm**

has to handle harsh background at Belle II

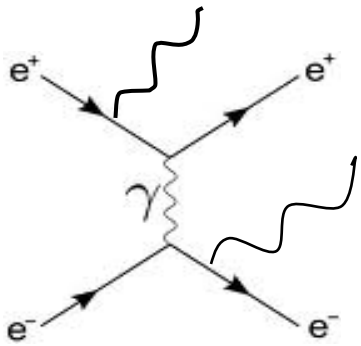
Expected Background at Belle II

- **Touschek effect** (intra-bunch scattering)
- **Beam-gas scattering** (bremsstarhlung and Coulomb scattering)
- **Synchrotron Radiation**

Machine induced background

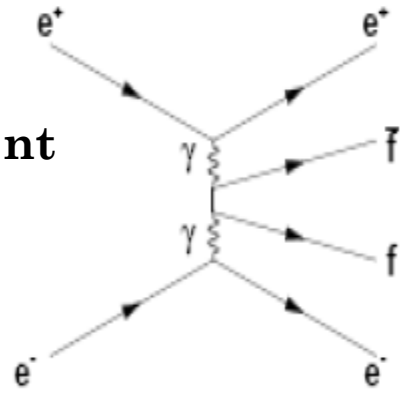
Increase x**20**

- **Radiative Bhabha scattering**



$\sigma \sim 50nb$

- **Two-photon process event**



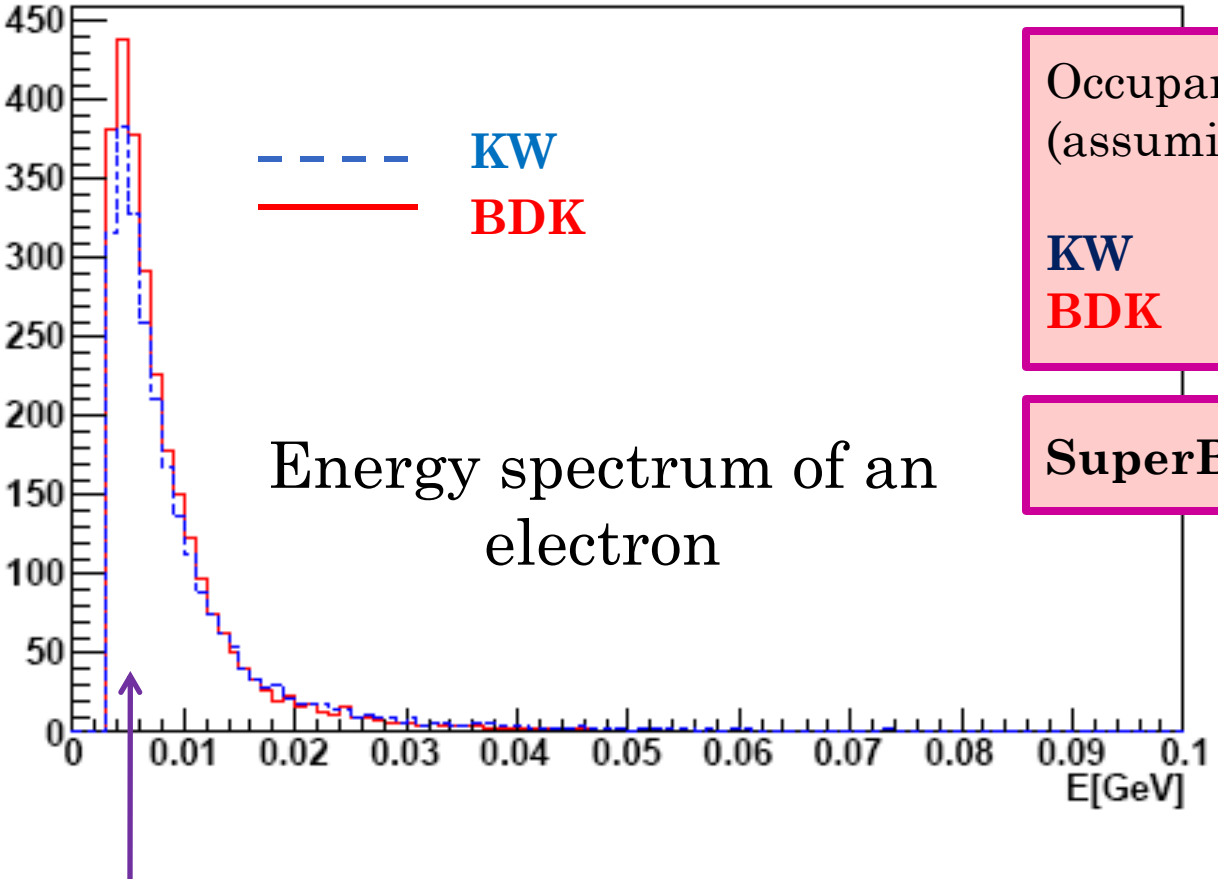
Luminosity-related background

Increase x**40** due to luminosity

$\sigma \sim O(10^7 nb)$

$R \sim 10 MHz / cm^2$

Simulation of the two-photon QED process for Belle II



Occupancy in 1st PXD layer (assuming 3 pixels/ $e^{\pm}$ track):

KW (**0.25%**)
BDK (**0.26%**)

SuperB (**1.3%**)

high rate at very low momentum
(~ 5 – 20MeV)

Try to clarify discrepancy by experiment

What do we expect?

SuperKEKB Simulation: ~ 2500 tracks per PXD frame
(~ 13 000 tracks, SuperB Simulation)

- L ~ 1000 /nbs
- Integration time = 20 μs **(PXD)**
- Radius = 1.4 cm **(PXD)**

Factor 2000 less

Scale to **KEKB** conditions:

- L ~ 10 /nbs ($10^{34} cm^{-2} s^{-1}$)
- Integration time = 2 μs **(SVD)**
- Radius = 2 cm **(SVD)**

Belle

1.2 tracks/SVD frame

Can we measure this small effect?

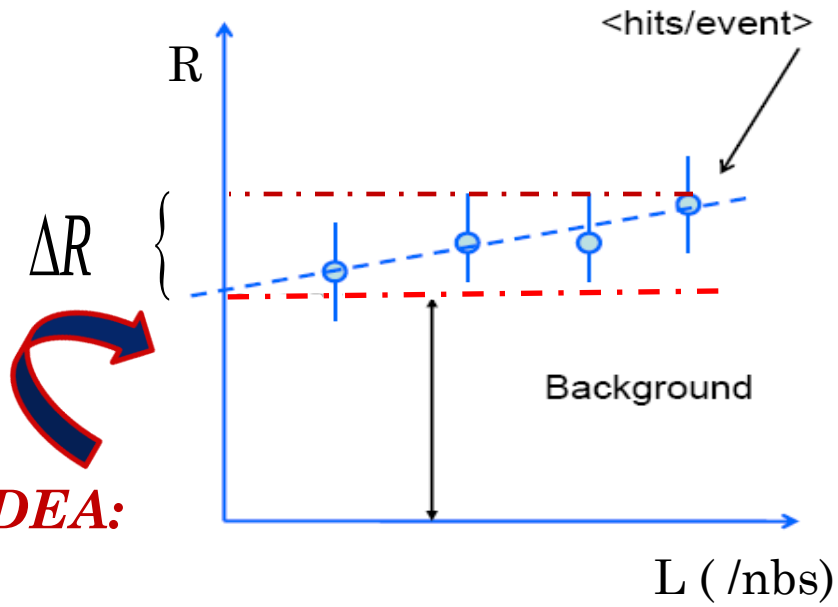
SuperB: 6.7 tracks/frame on average

QED Background Runs in Belle

Real data to solve the MC puzzle

- A few MeV cannot be triggered at Belle

Random Triggers (unbiased background)



IDEA:

- vary luminosity
- look at change in # hits in SVD
- extrapolate to L = 0 to estimate
  $\gamma\gamma$ QED background

Background events generated by 3 sources:

- B – physics (few)
- Machine background
- QED

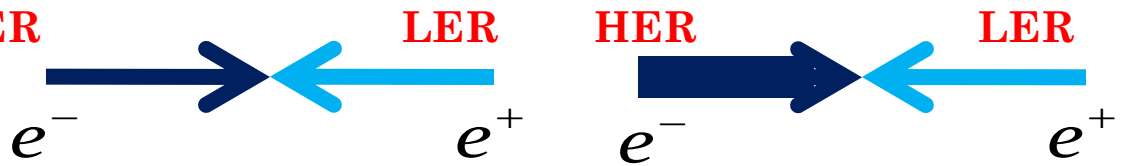
depends only on luminosity and not on the particular beam setting

Performed QED experiments

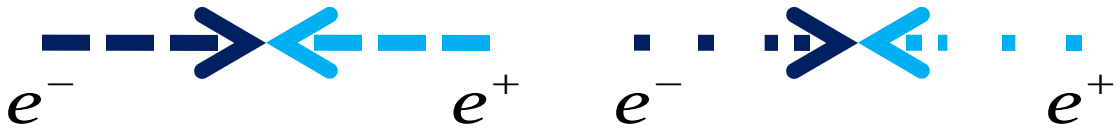
Random Trigger Runs and Data Sample :

Exp. A (separate the beams vertically)

Exp. B (increase vertical beam size in HER)

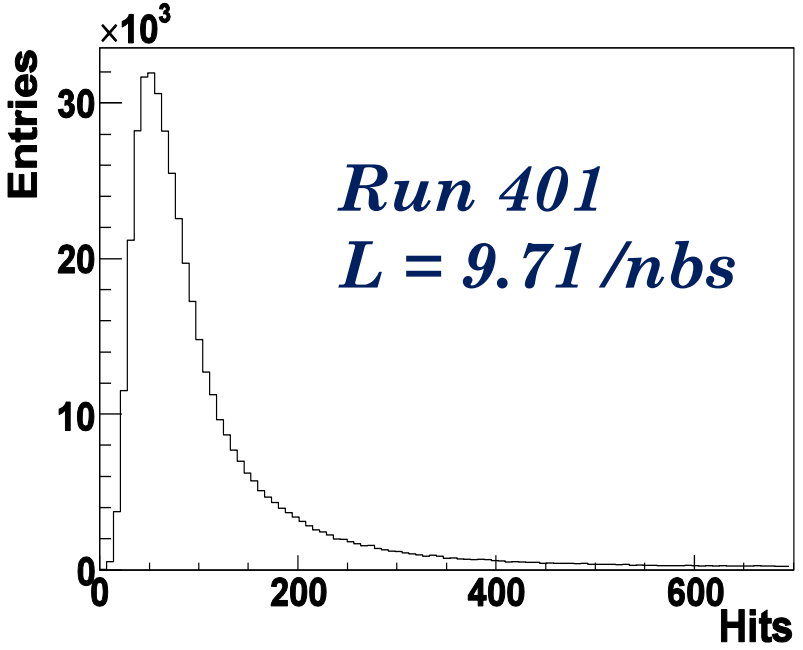


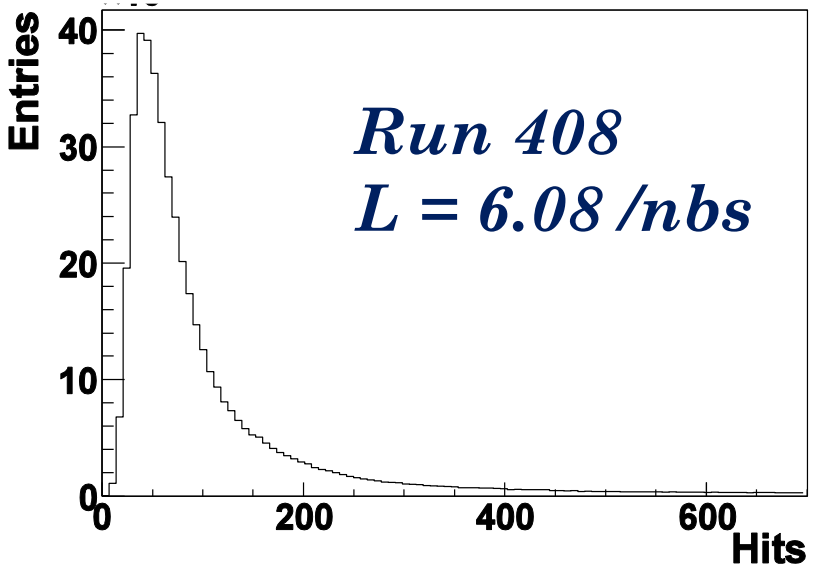
Exp. C (change beam currents by stopping injection)



Experiments performed in May 2010, KEKB closed end of June 2010

QED Experiment: Hit Multiplicity in SVD





SVD hit multiplicity in the 1st SVD layer

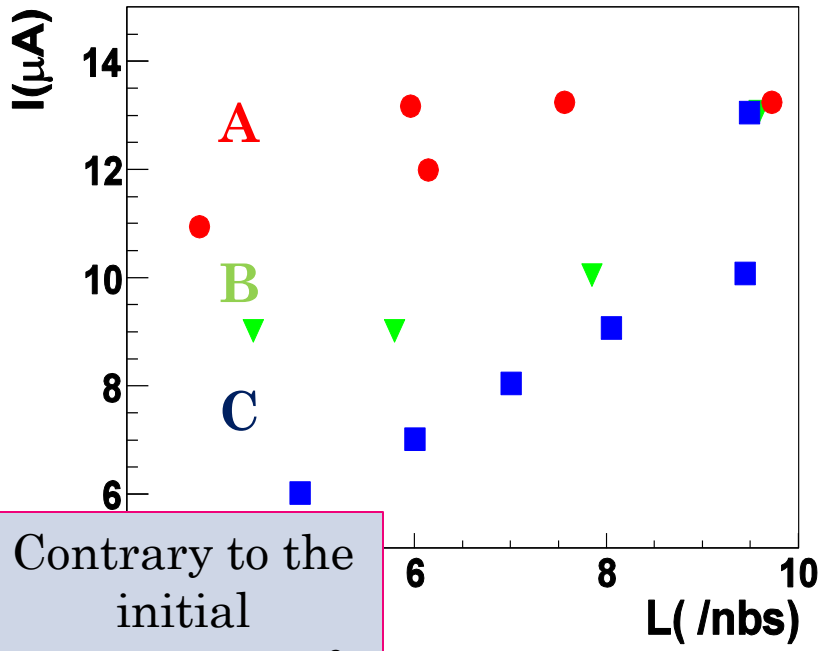
$$R = < N_{hits} > = 108$$

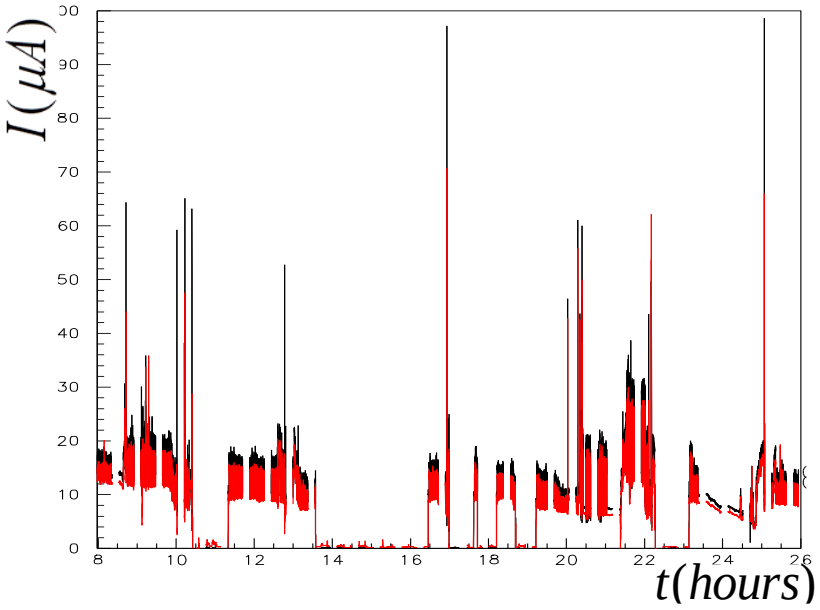
Hit Rate decreases

$$R = < N_{hits} > = 99$$

we really see an effect !

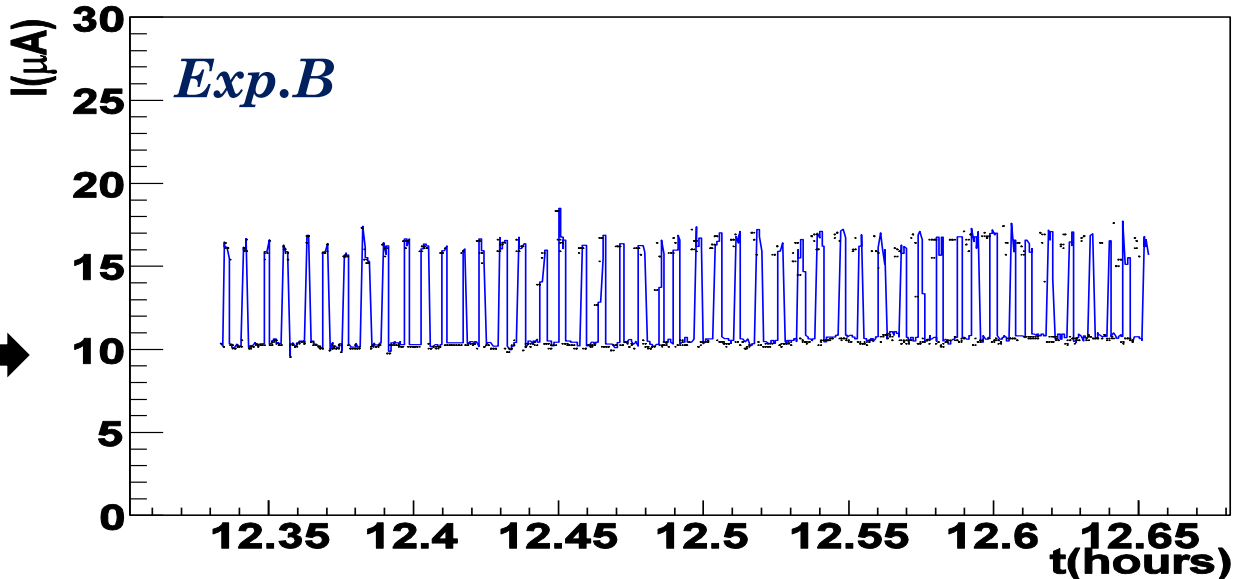
Varying Luminosity



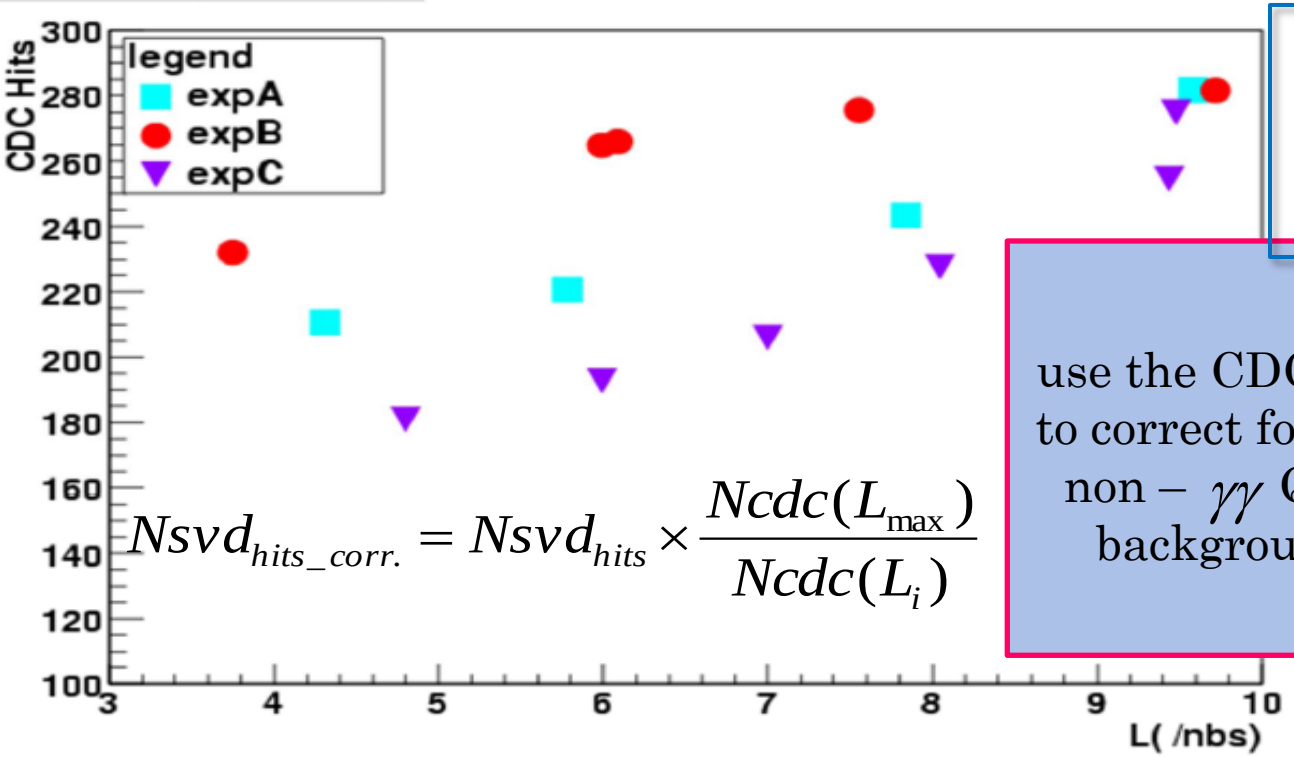


Contrary to the initial assumption of no QED present in the CDC

CDC current quite unstable



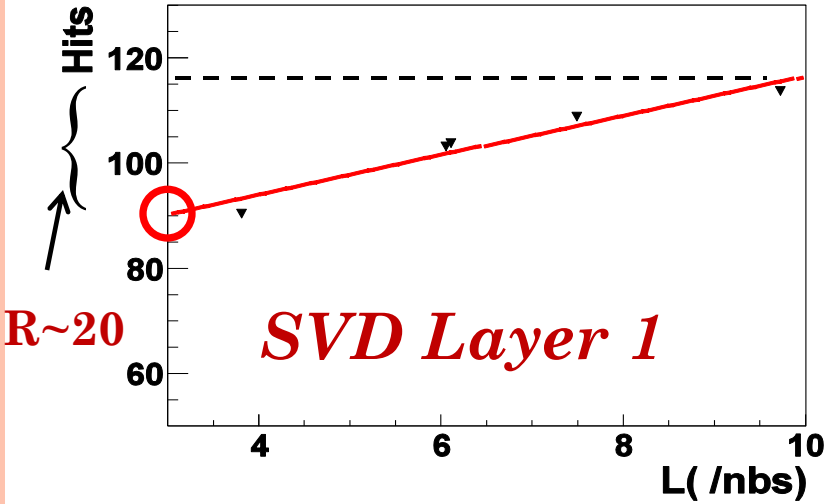
Varying Luminosity

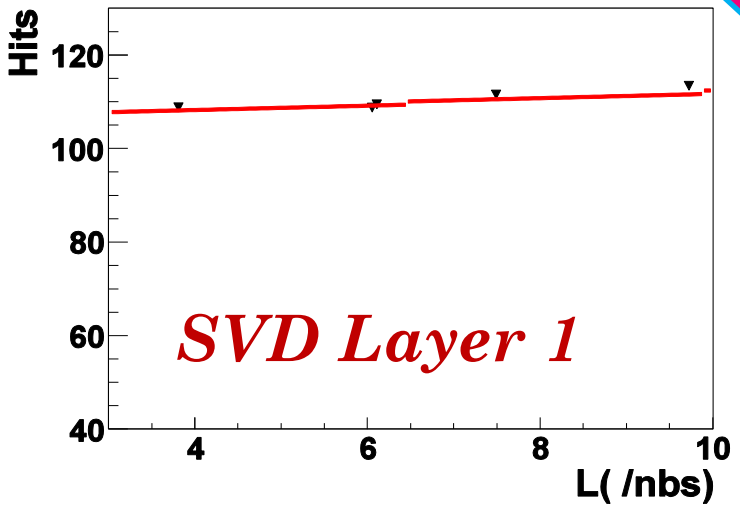


$$Nsvd_{hits\_corr.} = Nsvd_{hits} \times \frac{Ncdc(L_{max})}{Ncdc(L_i)}$$

Big Surprise: very different behavior

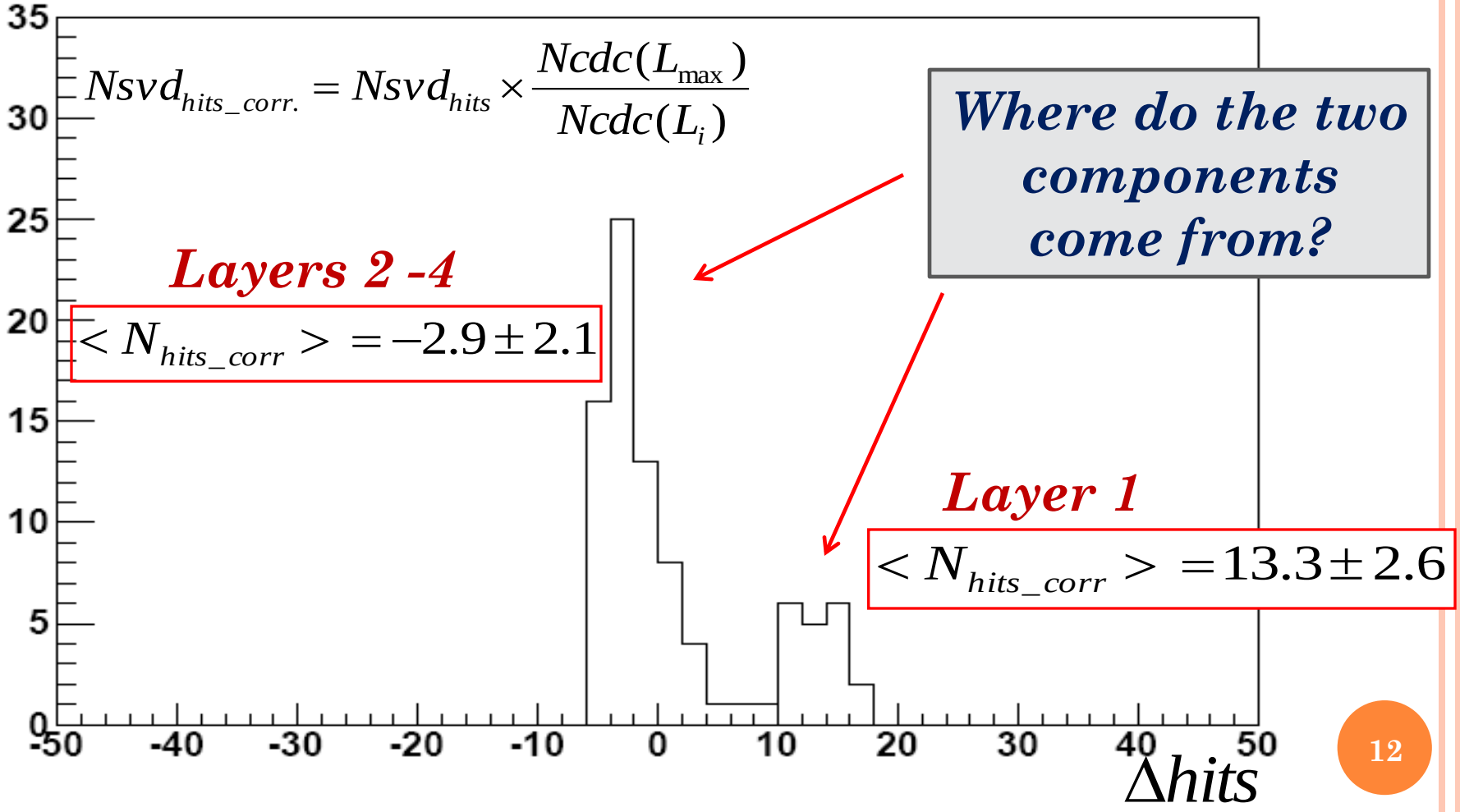
use the CDC hits to correct for the non – $\gamma\gamma$ QED background





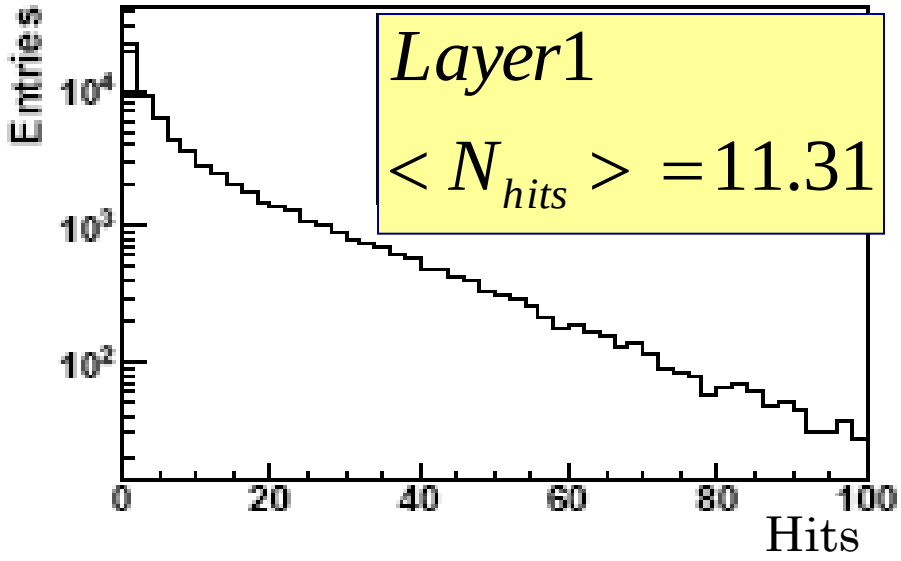
Observed Excess Of Hits For All Measurements

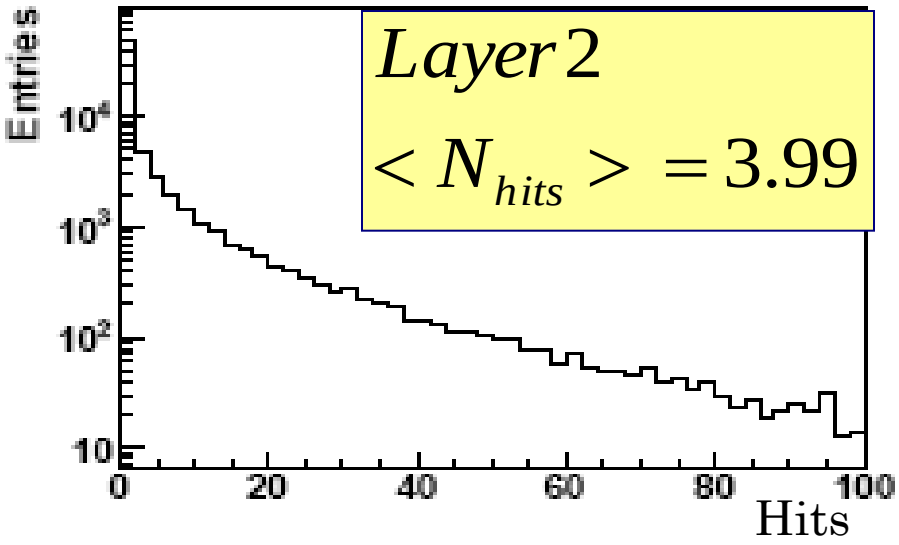
- *All Layers and All Experiments included*



Full Detector Simulation

- *to determine how many hits a track produces in each SVD layer*
  - SVD hit multiplicity – z strips (similar for φ strips)

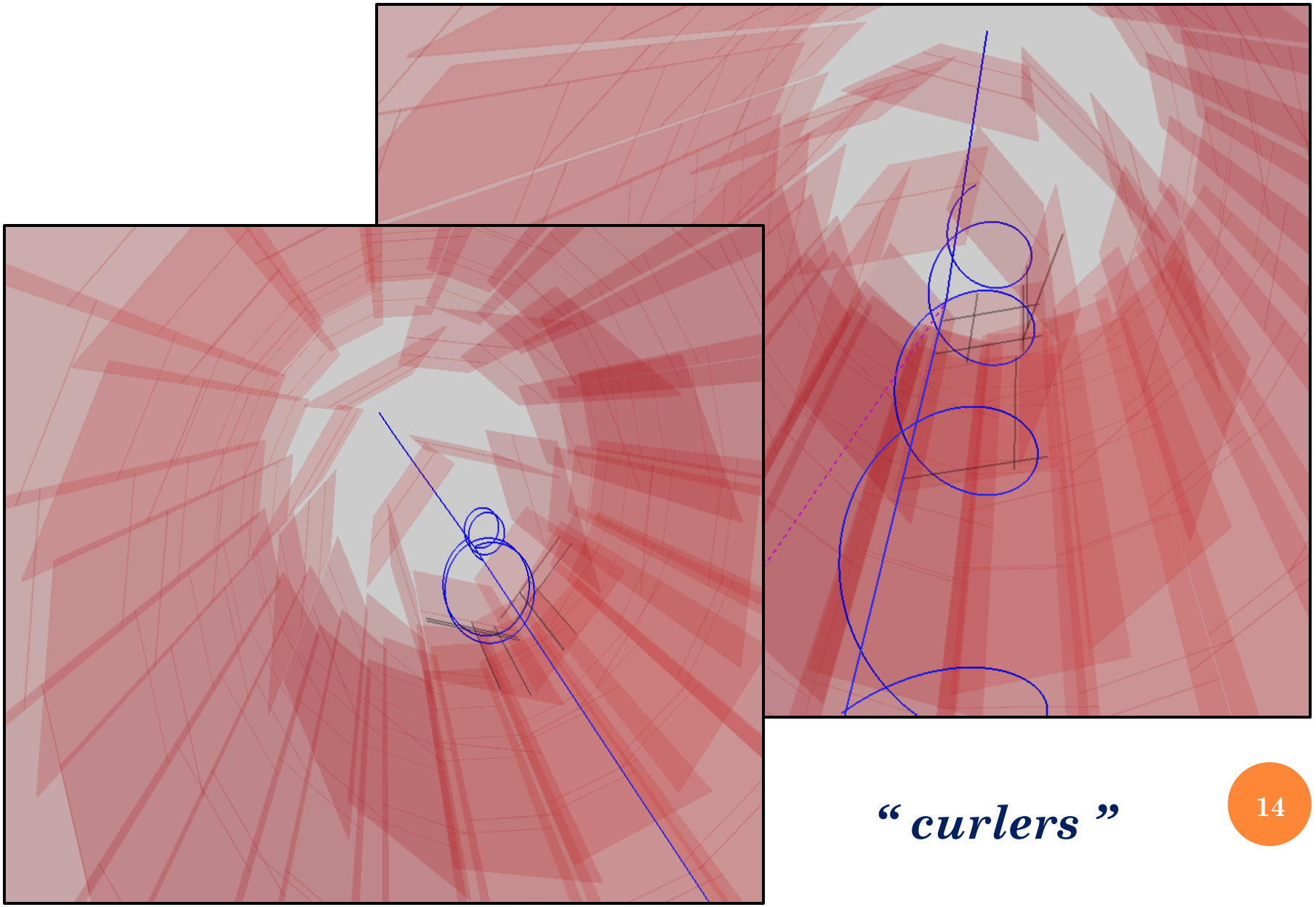




SVD Layer	$< N_{hits} >$
1	11.31
2	3.99
3	1.84
4	1.32

Counts decrease as the radius increases

Event Display



“curlers”

Comparison Between Data And Monte Carlo

	MC vs. Data	Data		KW	SuperB (BDK)
		Average	QED		
BELLE	***Hits (1st SVD layer)***	~ 100	13.3 ± 2.6	11.31	62.2
	Hits (2nd – 4th SVD layer)	~ 45	-2.9 ± 2.1	2.38	13.1
BELLE II	***Occupancy (1st PXD layer)***			**0.7%**	**4.0%**

PXD occupancy limit: 2-3%

Safe

Deadly

SuperB
Track Rate: $R_T = 1.8 MHz/cm^2$

Belle II
Track Rate: $R_T = 1.6 MHz/cm^2$

Summary and Conclusion

- Estimate of occupancy for Belle II PXD is extremely important
- MC estimates of QED background differ substantially
- Clarify by experiment with Belle before KEKB shutdown
- Full MC simulation using KW gives consistent picture with measurements
- Our prediction and SuperB's calculation now in agreement
- Expected occupancy from $\gamma\gamma$ QED measurements for layer 1 is 0.7 % $\longrightarrow$ safe operation

Thank you for your attention

Expected number of tracks and hits per SVD frame

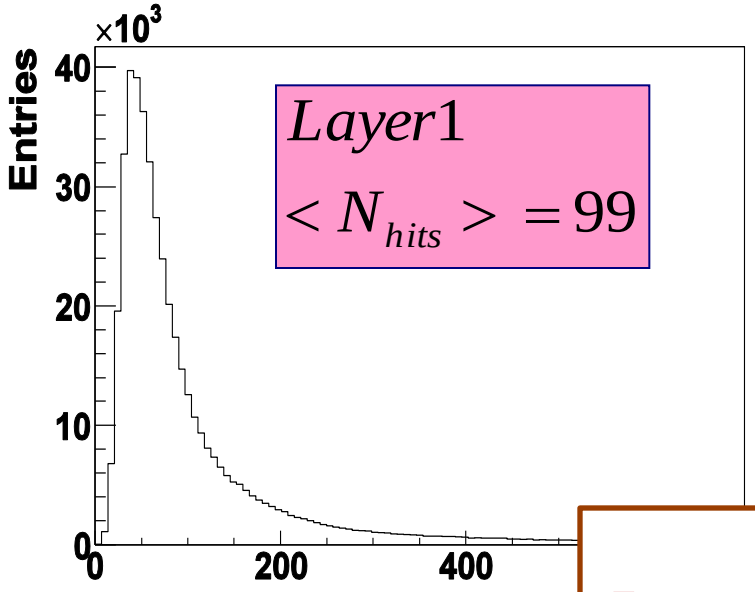
Expected number of	Tracks		Hits	
Experiment	**Belle II**	SuperB	**Belle II**	SuperB
PXD	2500	13800	7500	41400
SVD	1.2	6.7	3.7	20.3

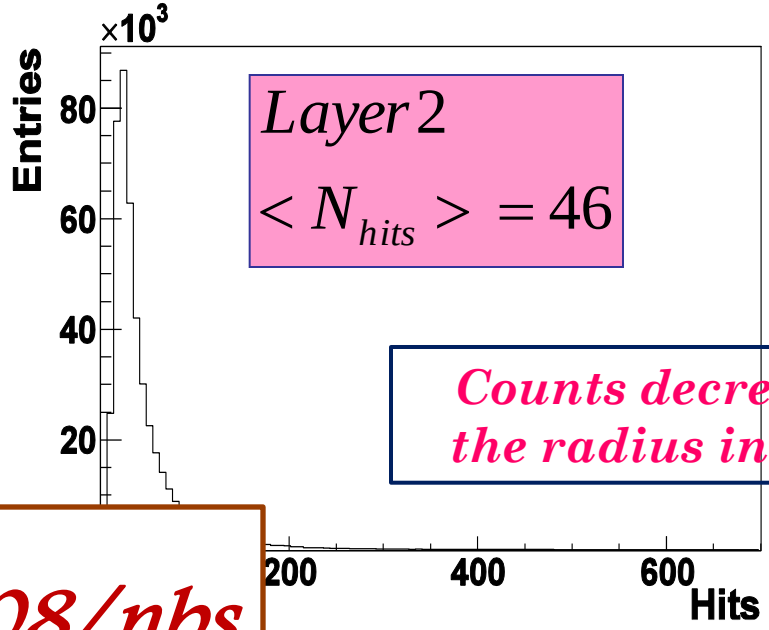
$$N_{tracks} = Rate \times t_{PXD} \times r_{corr} \times Area = 10^{7} \times (2 \times 10^{-5}) \times \frac{(1.3)^2}{(1.4)^2} \times 80 = 13800$$

SuperB: Rate for the two-photon process

Experiment B – Run 408

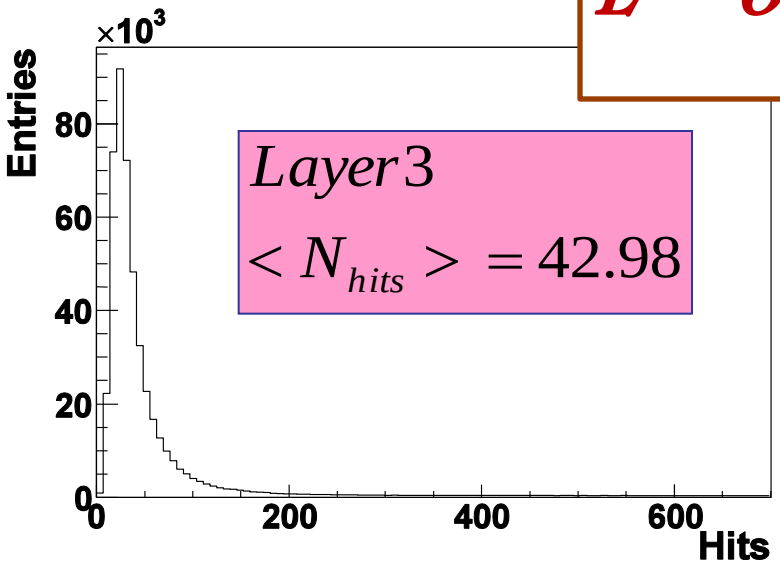
- SVD hit multiplicity – z strips (similar for φ strips)

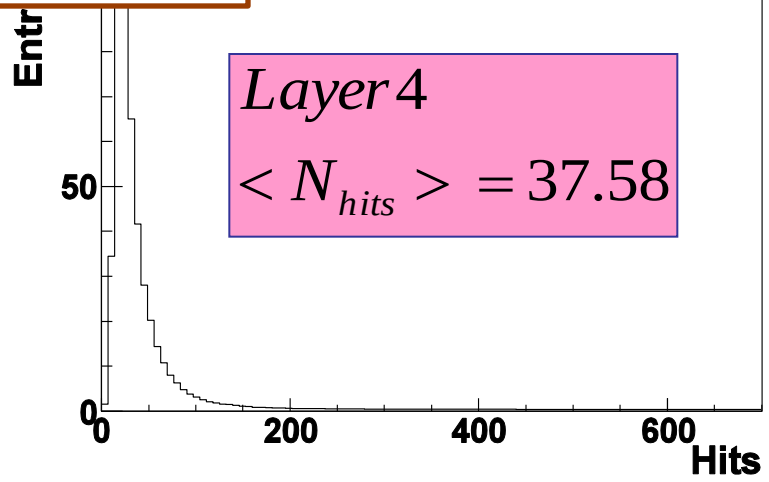




Counts decrease as the radius increase

L = 6.08/nbs





SuperB's rate for the two-photon process

SuperB
Track Rate: $R_T = 1.8 MHz/cm^2$

Belle II
Track Rate: $R_T = \frac{N_{tracks}}{Area \times t_{PXD}} = \frac{2600}{80 \times 20 \times 10^{-6}} = 1.6 MHz/cm^2$

SuperB and Belle II now in agreement