QED Background at Belle Experiment

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- Belle detector upgrade: Belle II
- Expected background at Belle II
- QED experiments performed at KEK
- Comparison between data and MC
- Summary and Conclusion

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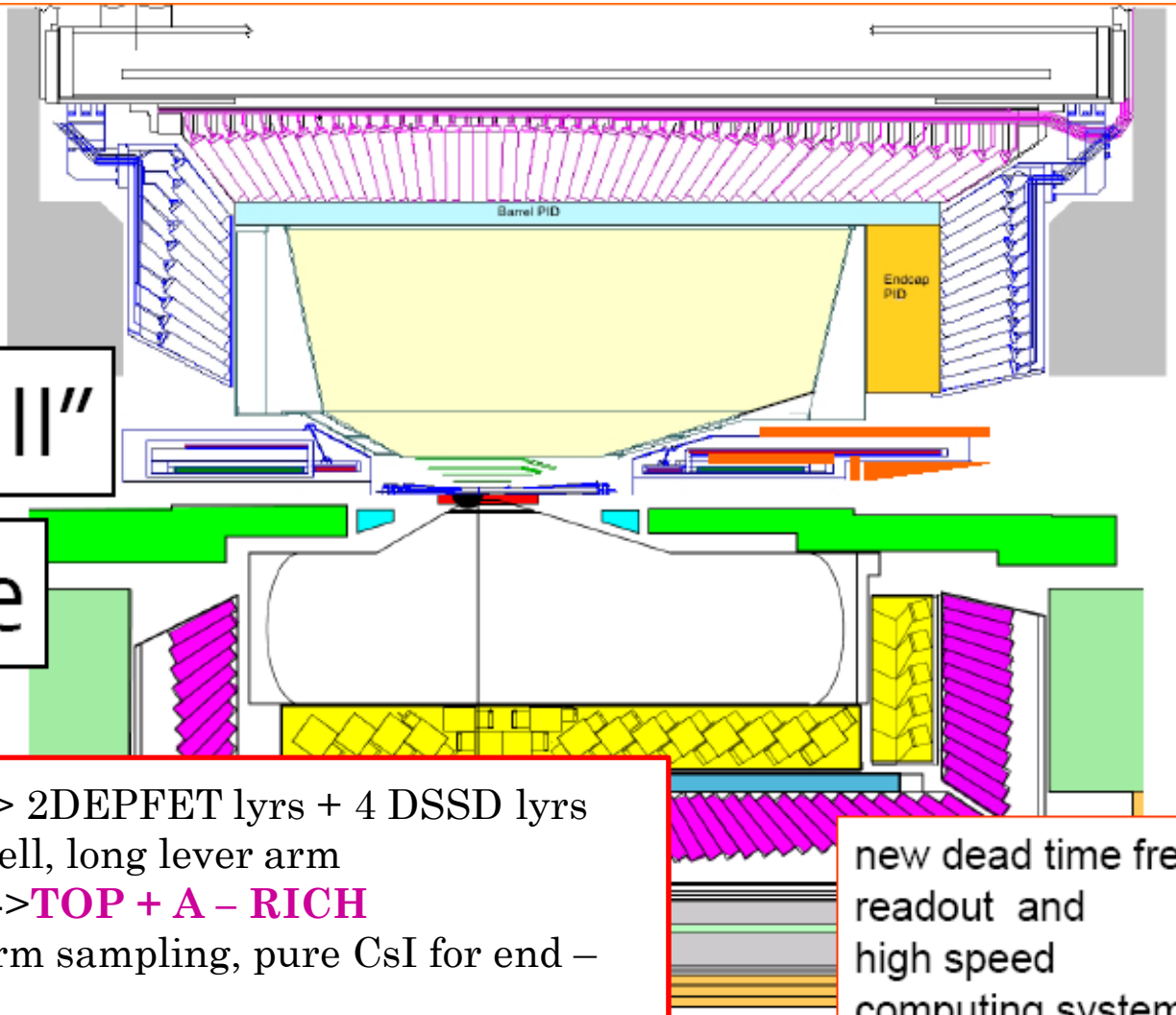
Belle Detector Upgrade



"Belle II"

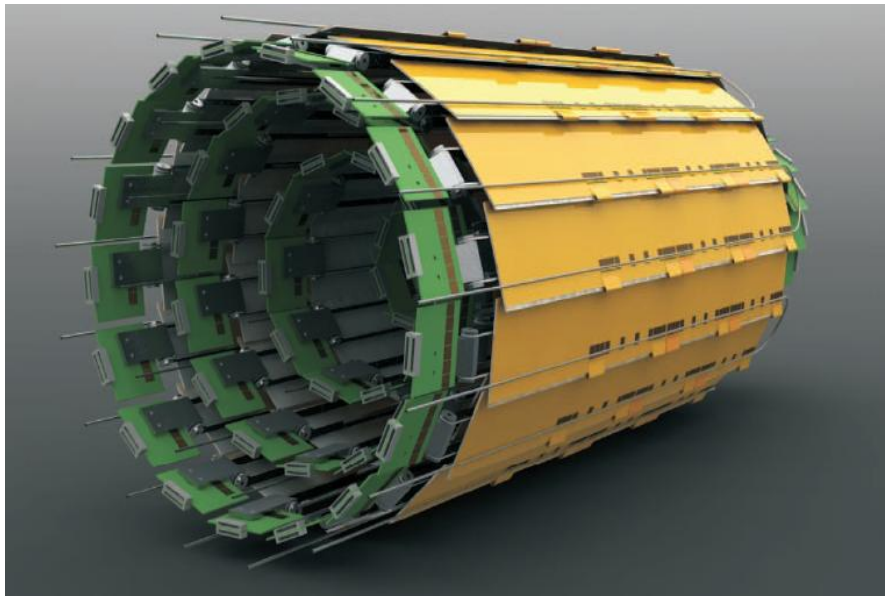
Belle

SVD: 6 lyrs -> 2DEPFET lyrs + 4 DSSD lyrs
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

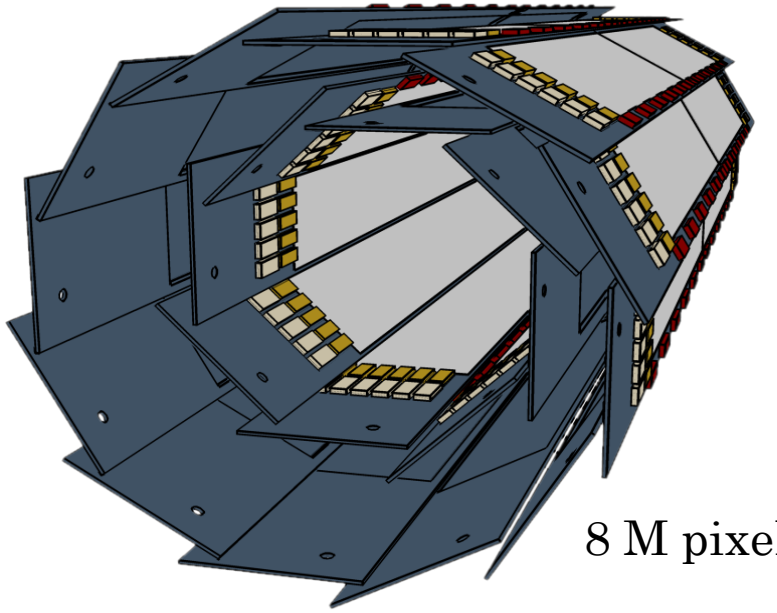


Silicon Vertex Detector at Belle II

- **4 layers**
- **DSSDs**
  - **z strips**
  - **phi strips**

4 cm

Pixel Vertex Detector (PXD)



8 M pixels

2 layers

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

has to handle harsh background at Belle II

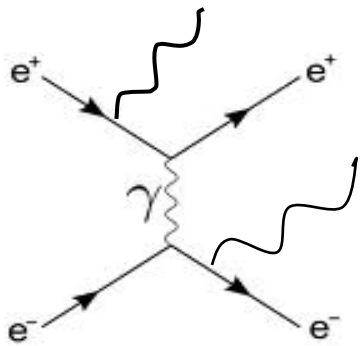
Expected Background at Belle II

Machine background ← *expected increase by a factor **20***

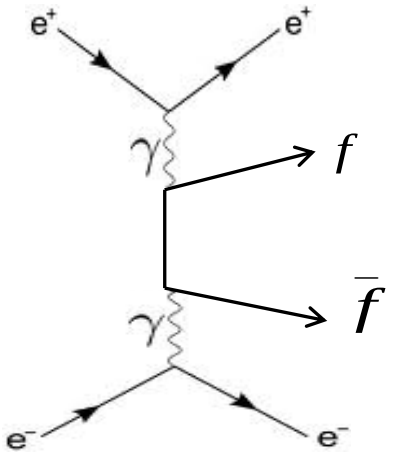
- Beam – gas scattering (bremstrahlung and Coulomb scattering)
- Touschek effect (intra – bunch scattering) ← *this is expected to be the main background*
- Synchrotron Radiation

Luminosity – related background ← *increase by a factor of **40** (due to luminosity)*

- Radiative Bhabha scattering $\gamma\gamma$ reactions

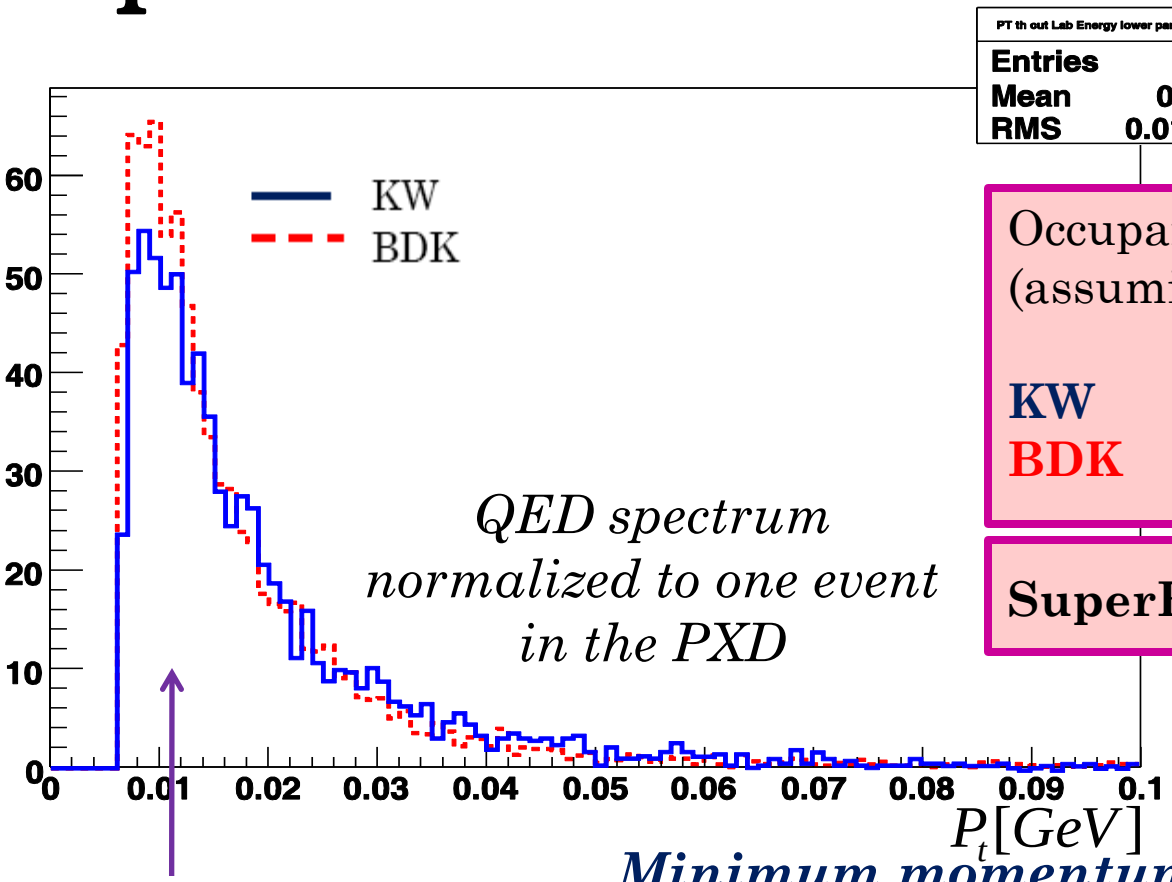


$\sigma \sim 50nb$



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

2 photon Simulation for Belle II



QED spectrum normalized to one event in the PXD

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

KW (**0.1%**)
BDK (**0.07%**)

SuperB (**1.3%**)

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

Minimum momentum needed to reach the tracking detectors

CDC : > 100MeV
SVD : > 40MeV
PXD : e^- with energy > 5.8MeV

Question: Who is right?

What do we expect?

SuperKEKB Simulation: ~ 800 tracks per PXD frame
(~ 13 000 tracks, SuperB Simulation)

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

Scale to **KEKB**:

Factor 1000 less

- L ~ 10 /nbs ($10^{32} cm^{-2} s^{-1}$)
- Integration time = 2 μs **(SVD)**

Assumption that 1 track hits the 1st SVD layer only once:
3 hits/track

Belle

0.8 tracks/SVD frame

SuperB MC : 13 tracks/frame on average

(radius correction included)

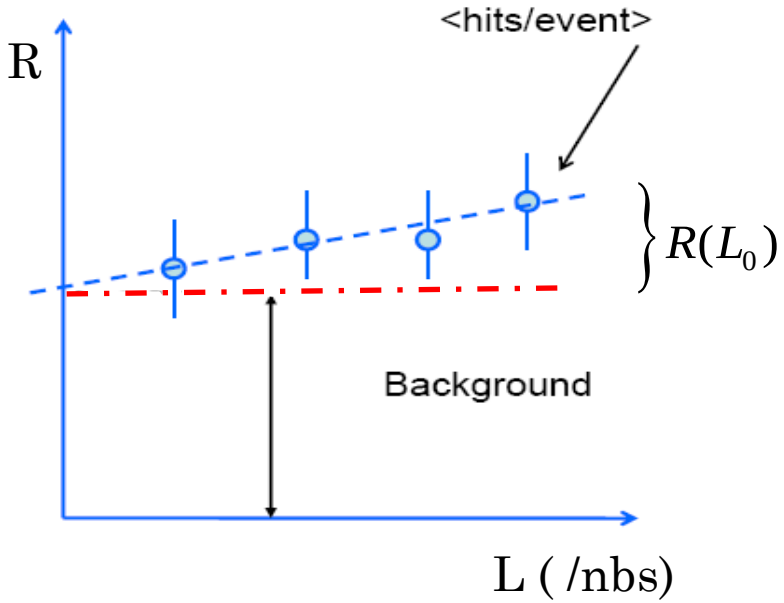
Can we measure this small effect?

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 non – QED machine background

Background events generated by 3 sources:

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

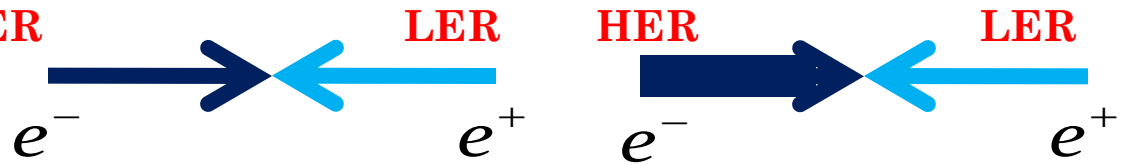
depends only on luminosity and not on the particular beam setting

Performed QED experiments

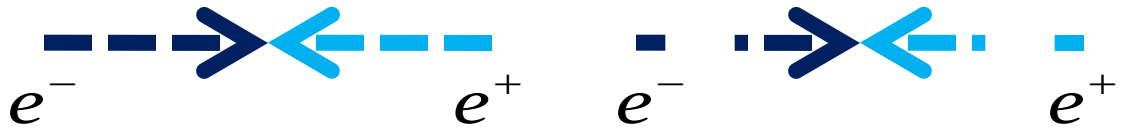
Random Trigger Runs and Data Sample :

Exp. A (separate the beams vertically)

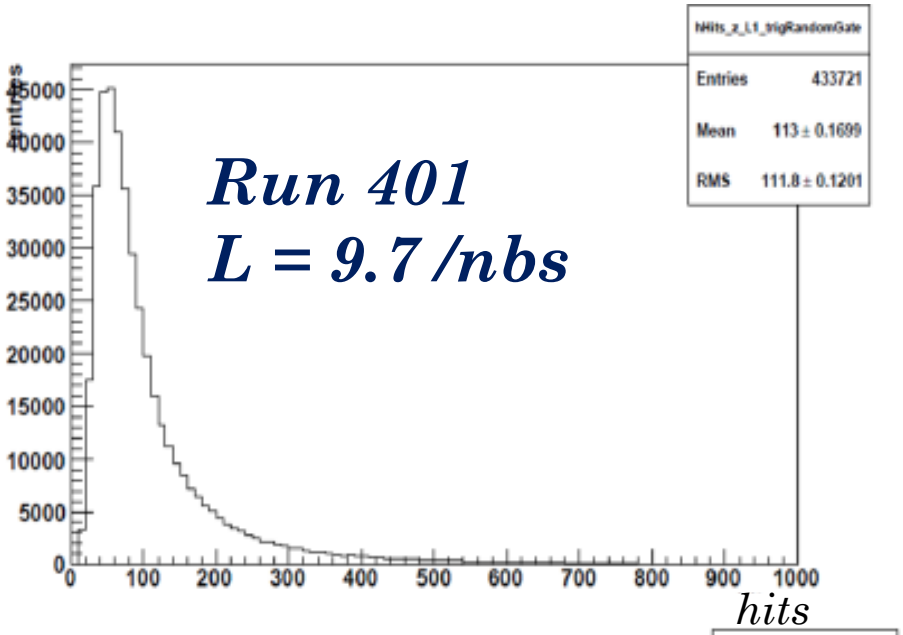
Exp. B (increase vertical beam size in HER)



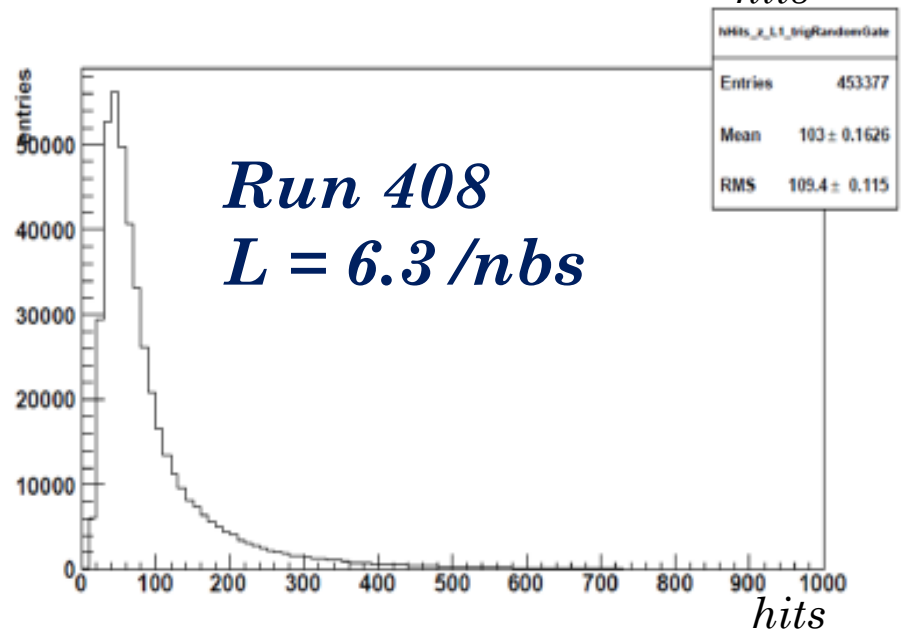
Exp. C (change beam currents by stopping injection)



Hit Multiplicity in SVD



Run 401
L = 9.7 /nbs



Run 408
L = 6.3 /nbs

SVD hit multiplicity in the 1st SVD layer

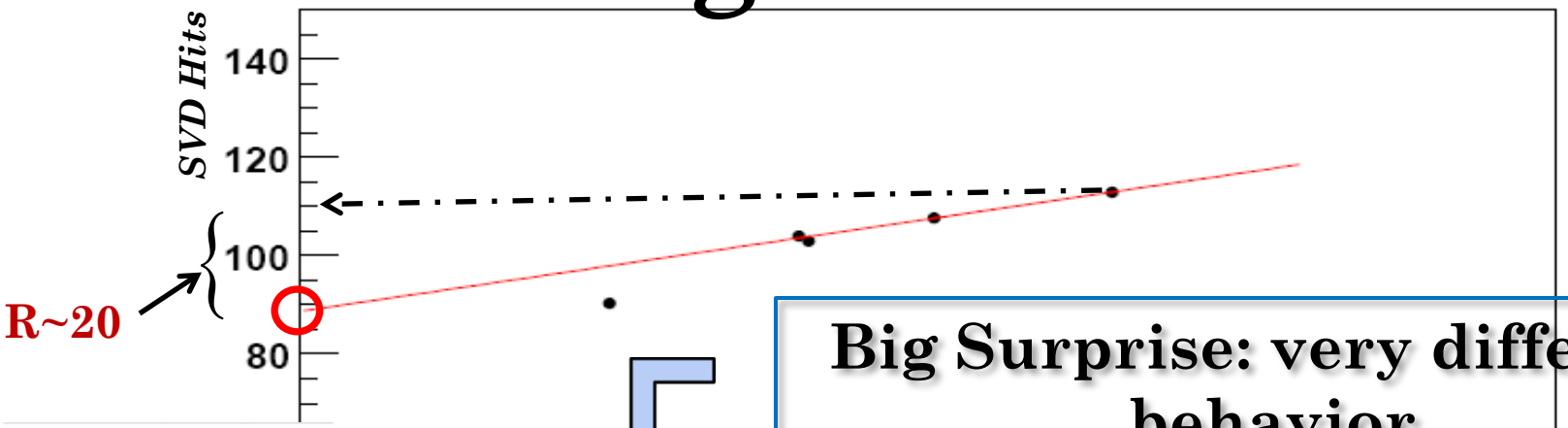
$$R = < N_{hits} > = 113$$

Hit Rate decreases

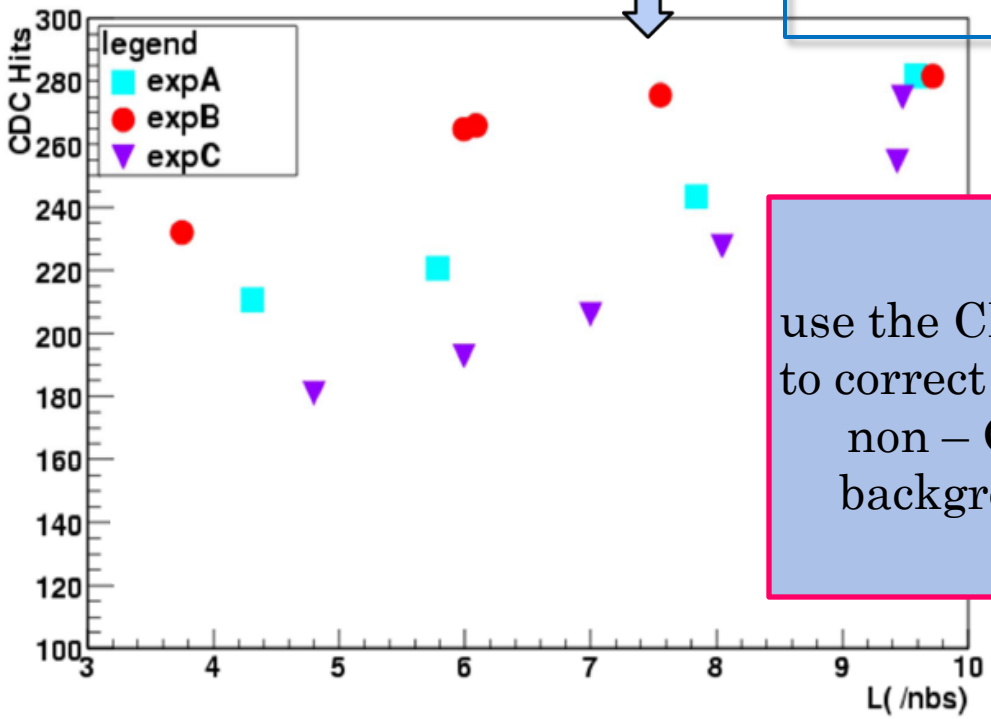
$$R = < N_{hits} > = 103$$

we really see an effect !

Luminosity Of Observed Background Hits



Big Surprise: very different behavior

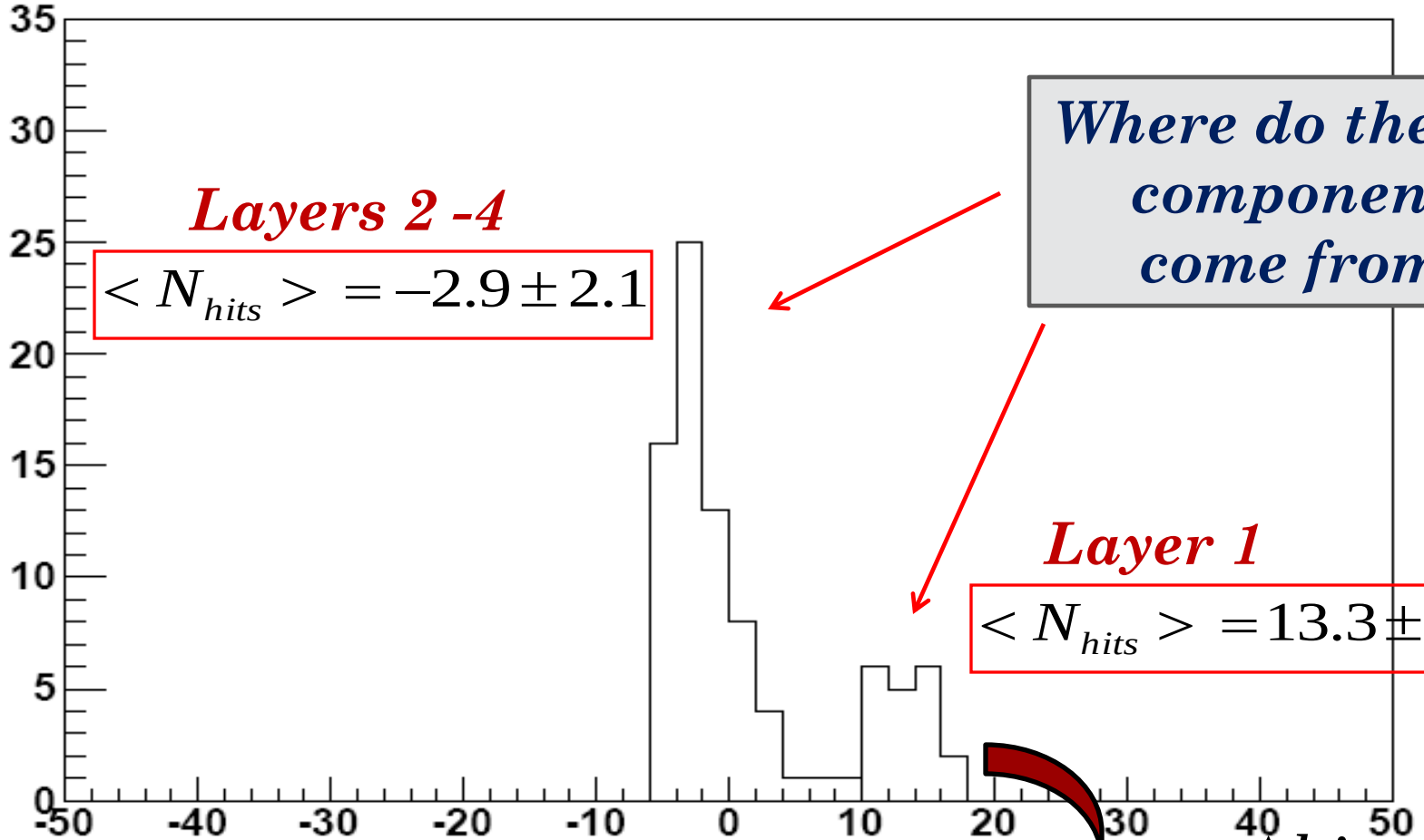


use the CDC hits to correct for the non – QED background

$$Nsvd_{hits\_corr.} = Nsvd_{hits} \times \frac{Ncdc_{hits\_max}}{Ncdc_{hits}}$$

Observed Excess Of Hits For All Measurements

- *All Layers and All Experiments included*



Layers 2 -4

$< N_{hits} > = -2.9 \pm 2.1$

Where do the two components come from?

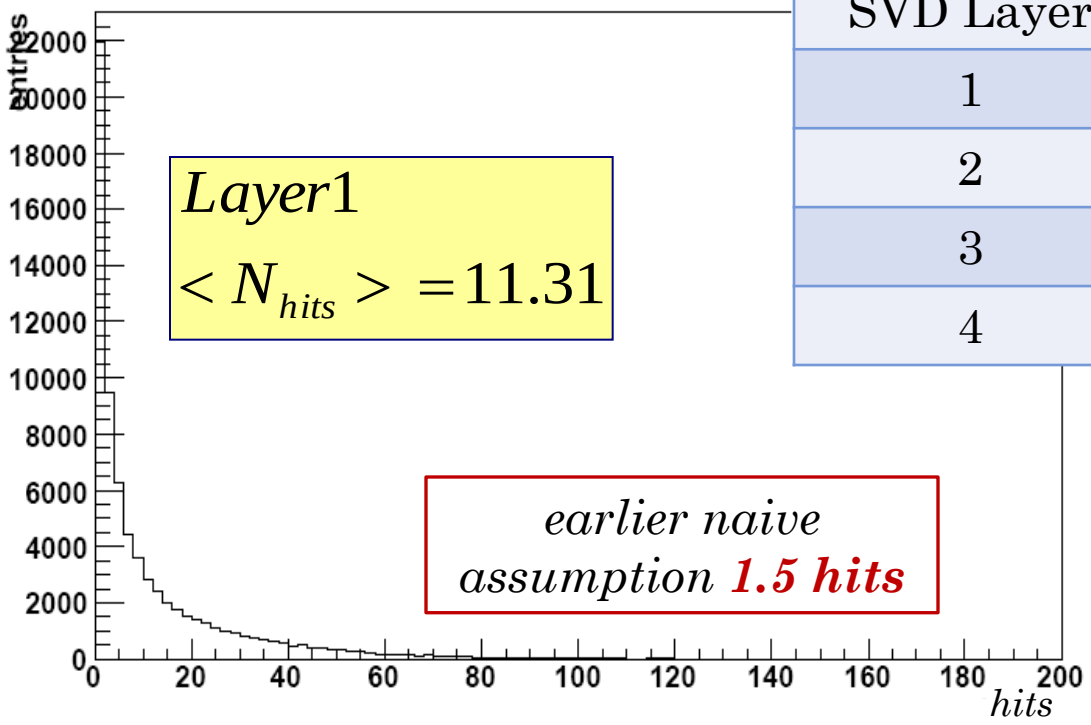
Layer 1

$< N_{hits} > = 13.3 \pm 2.6$

Can Layer 1 peak come from QED?

Use 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

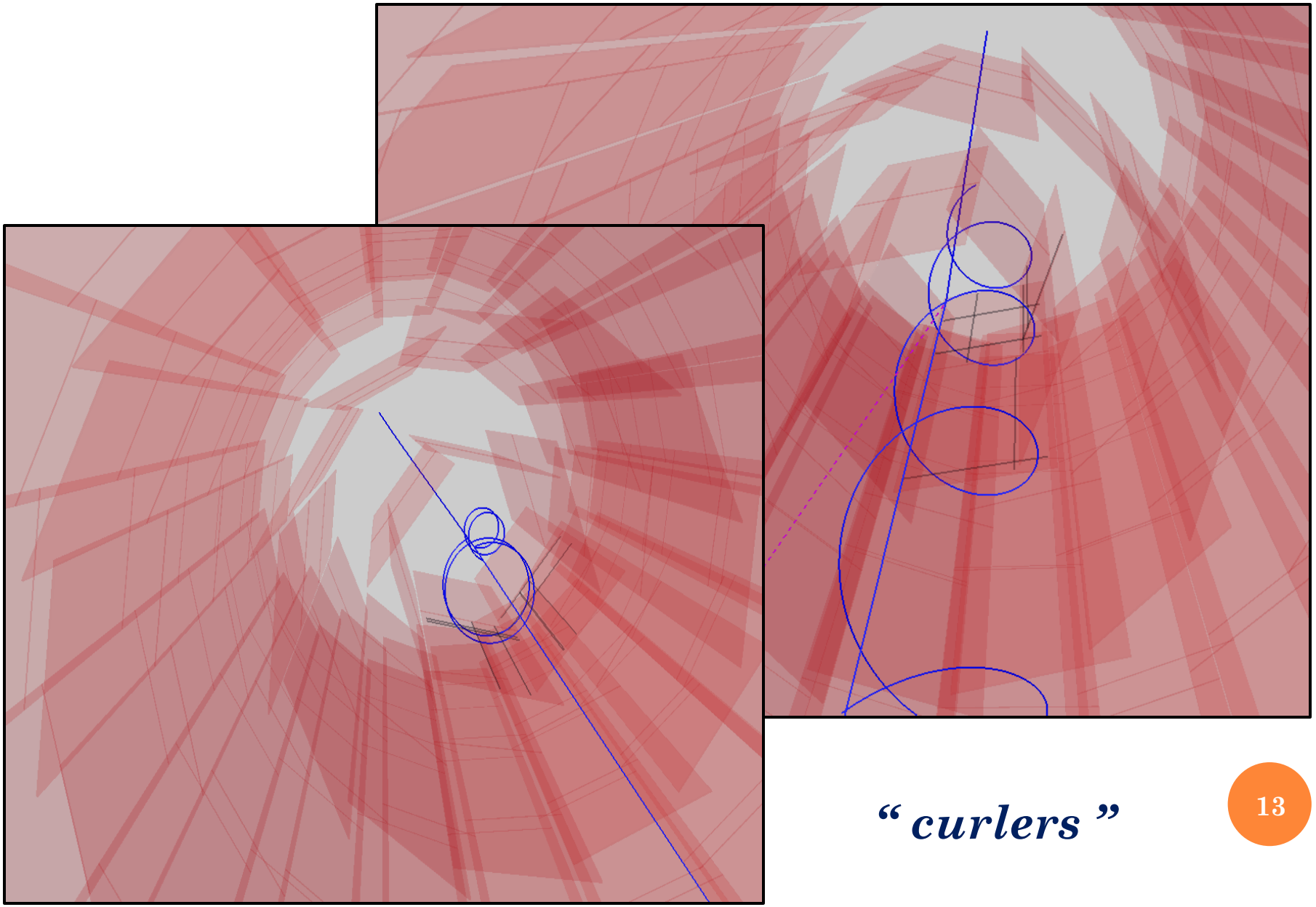
Simulation shows discrepancy from naive expectation

1st SVD layer

Naive Expectation: 1 track hits 1st SVD layer only once

Simulation: 1 track hits 1st SVD layer more than once

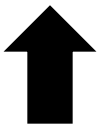
Event Display



“curlers”

Comparison Between Data And Monte Carlo

MC vs. Data	Data		KW	SuperB (BDK)
	average	QED		
Hits (1st SVD layer)	~ 100	13.3 ± 2.6	11.31	181
Hits (2nd – 4th SVD layer)	~ 45	-2.9 ± 2.1	2.38	38.1
Occupancy (1st SVD layer)	**0.4%**		**0.3%**	**5.5%**
			tolerable	*deadly*



The expectation fully consistent with experiment, SuperB is completely excluded

Summary and Conclusion

- Strong discrepancies in MC predictions for QED Background between Belle II and SuperB

- Use measurements with different beam tunings to extract QED background hits in SVD2

- Measurements show additional luminosity – dependent background which is clearly observed in the CDC

- Δhits for layer 1 of SVD2 very different from prior expectation (outer layers in agreement) $\longrightarrow$ " curlers "

- Full MC simulation explains this observation and gives consistent picture of measurements

- Comparison of measured Δhits with predictions of different MC generators is consistent, allows complete exclusion of SuperB prediction

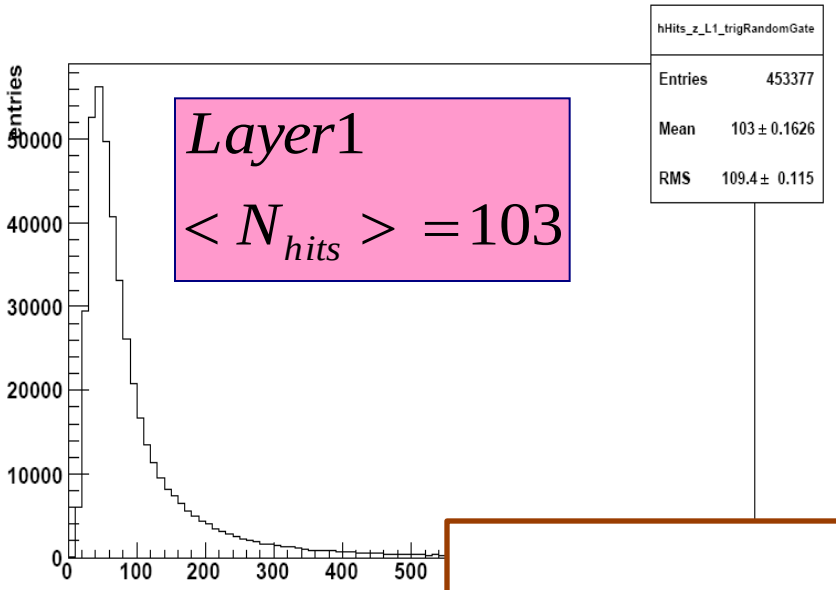
- Expected occupancy from QED for layer 1 is only 0.3 % $\rightarrow$ safe operation

Thank you for your attention

Back Up

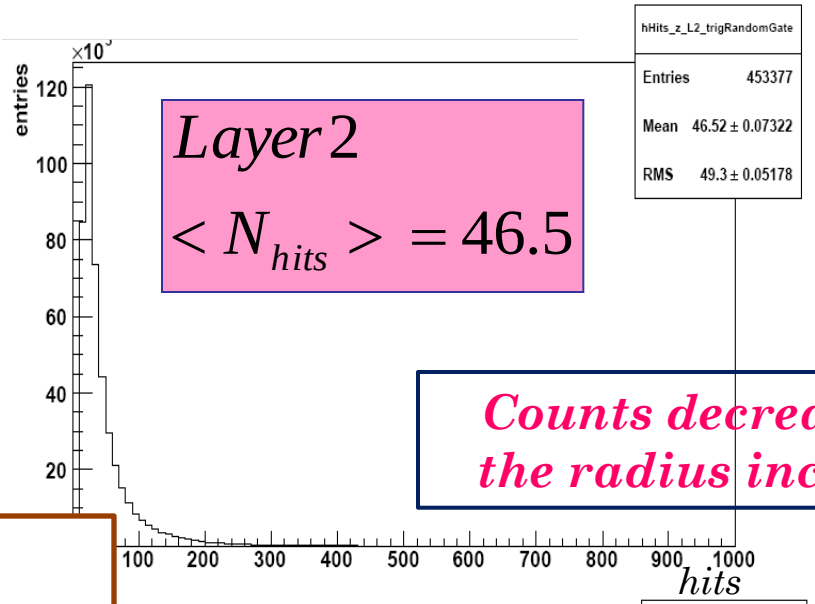
Experiment B – Run 408

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



$Layer1$

$< N_{hits} > = 103$

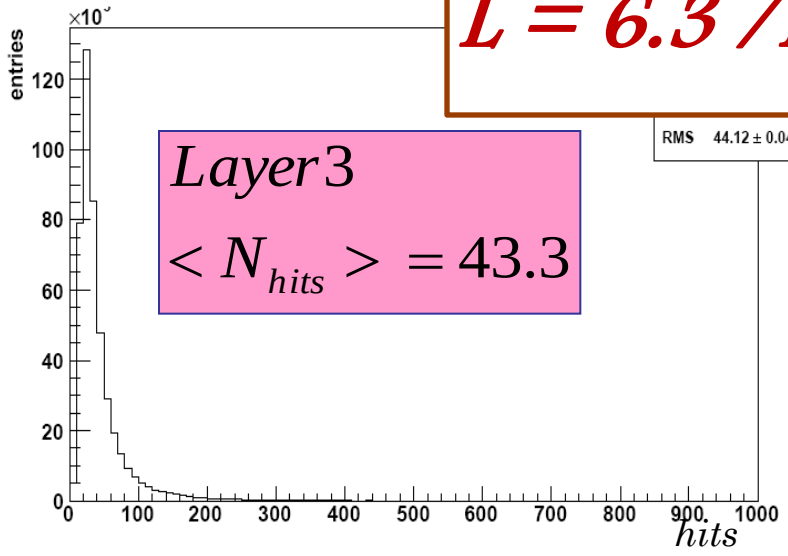


$Layer2$

$< N_{hits} > = 46.5$

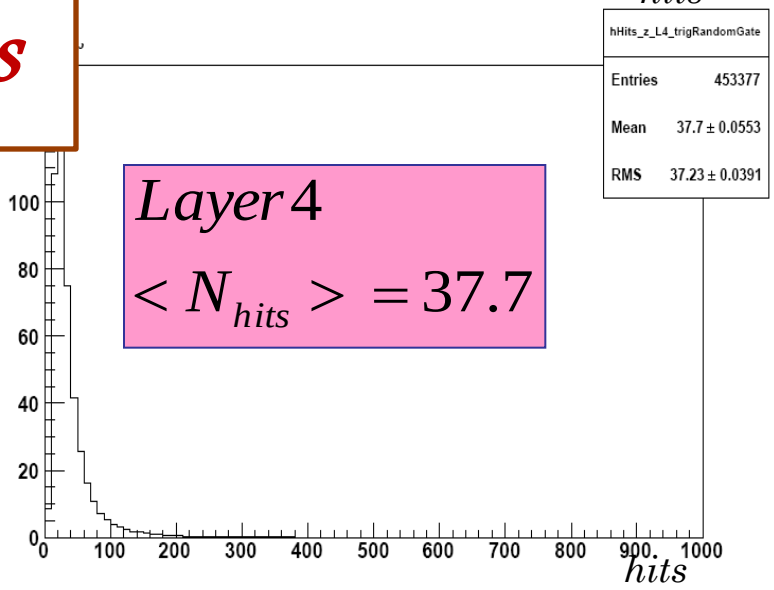
Counts decrease as the radius increase

$L = 6.3 / nbs$



$Layer3$

$< N_{hits} > = 43.3$

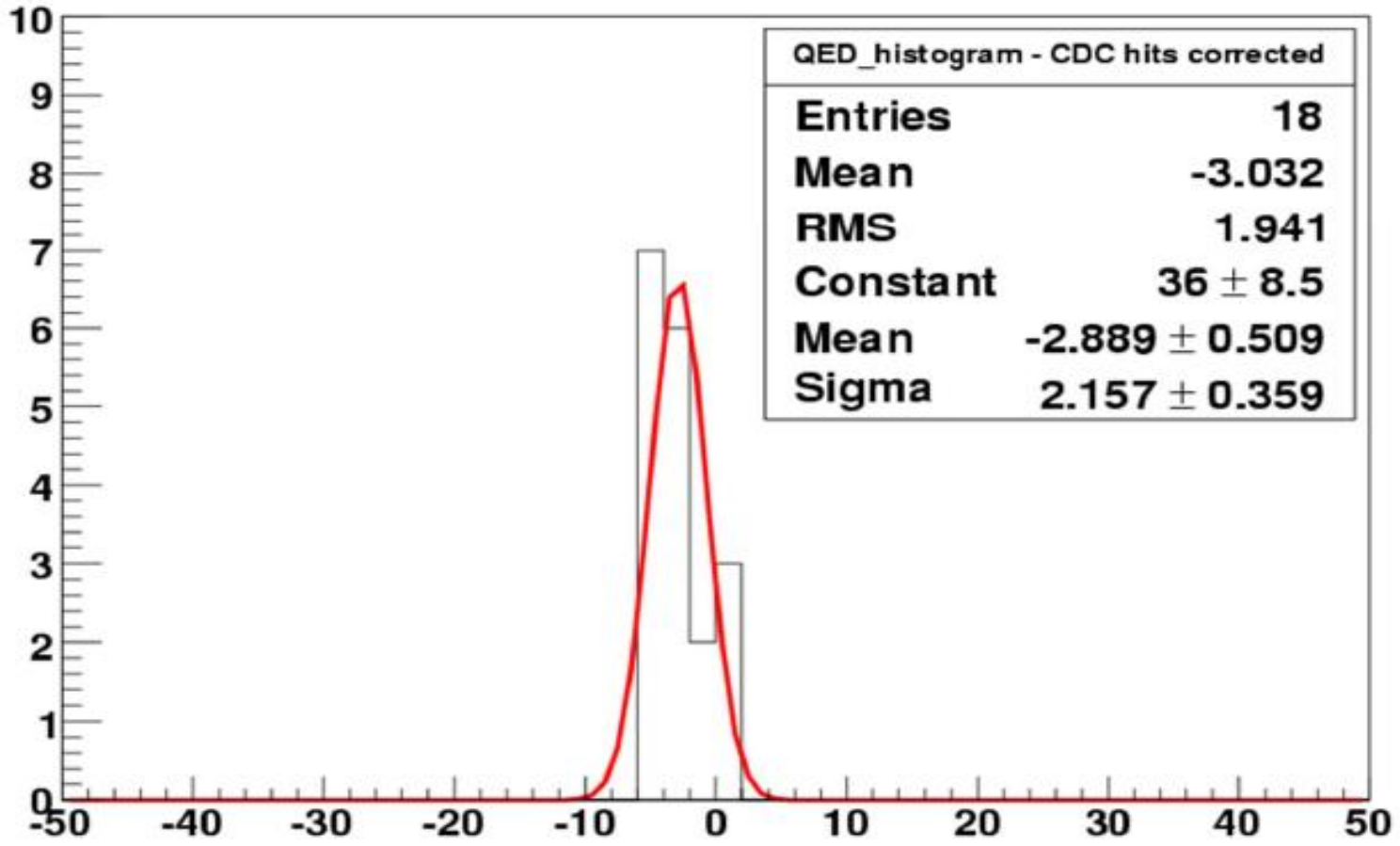


$Layer4$

$< N_{hits} > = 37.7$

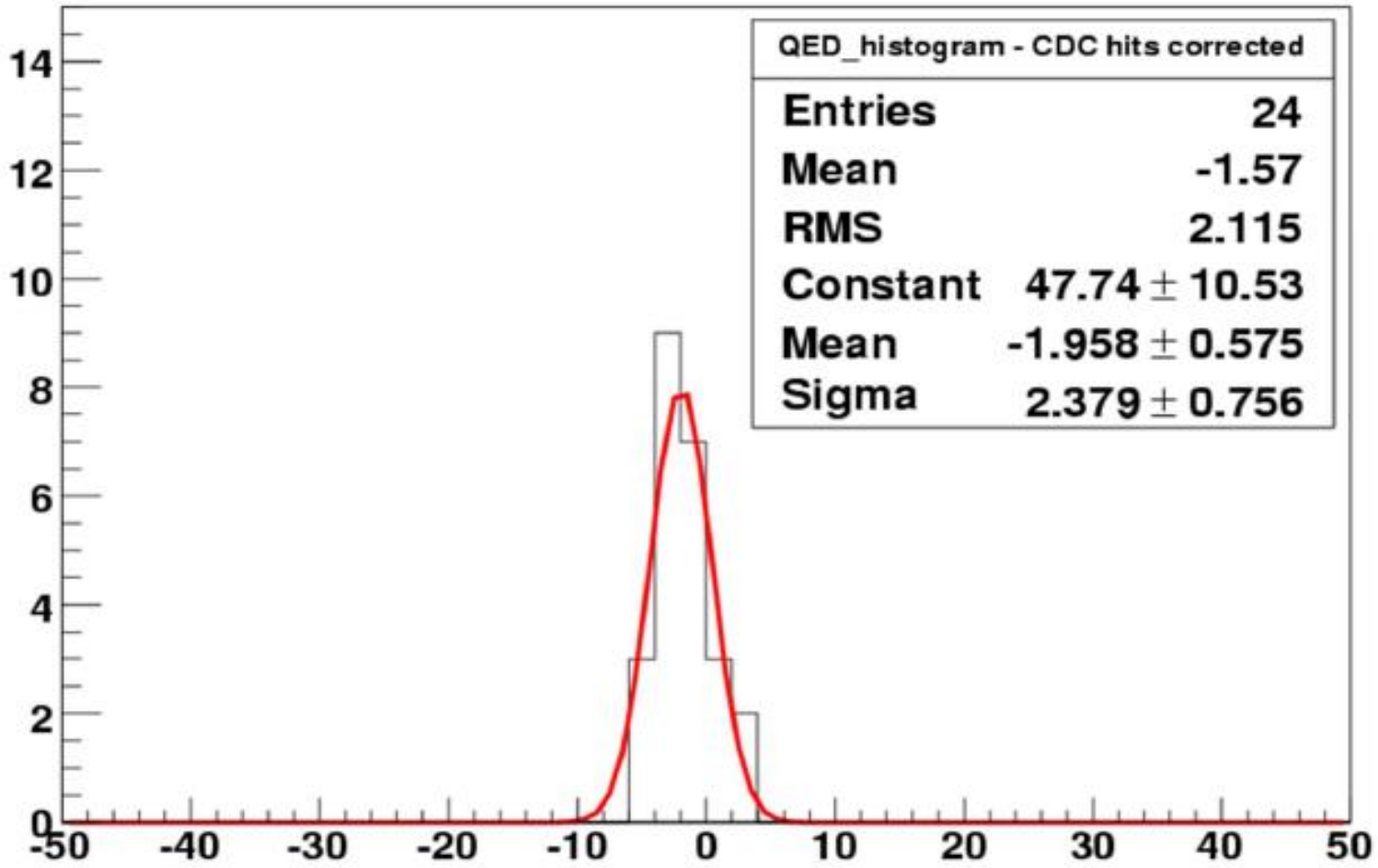
CDC Hits Corrected SVD Hits

- 2^{nd} – 4^{th} SVD layer – Experiment A



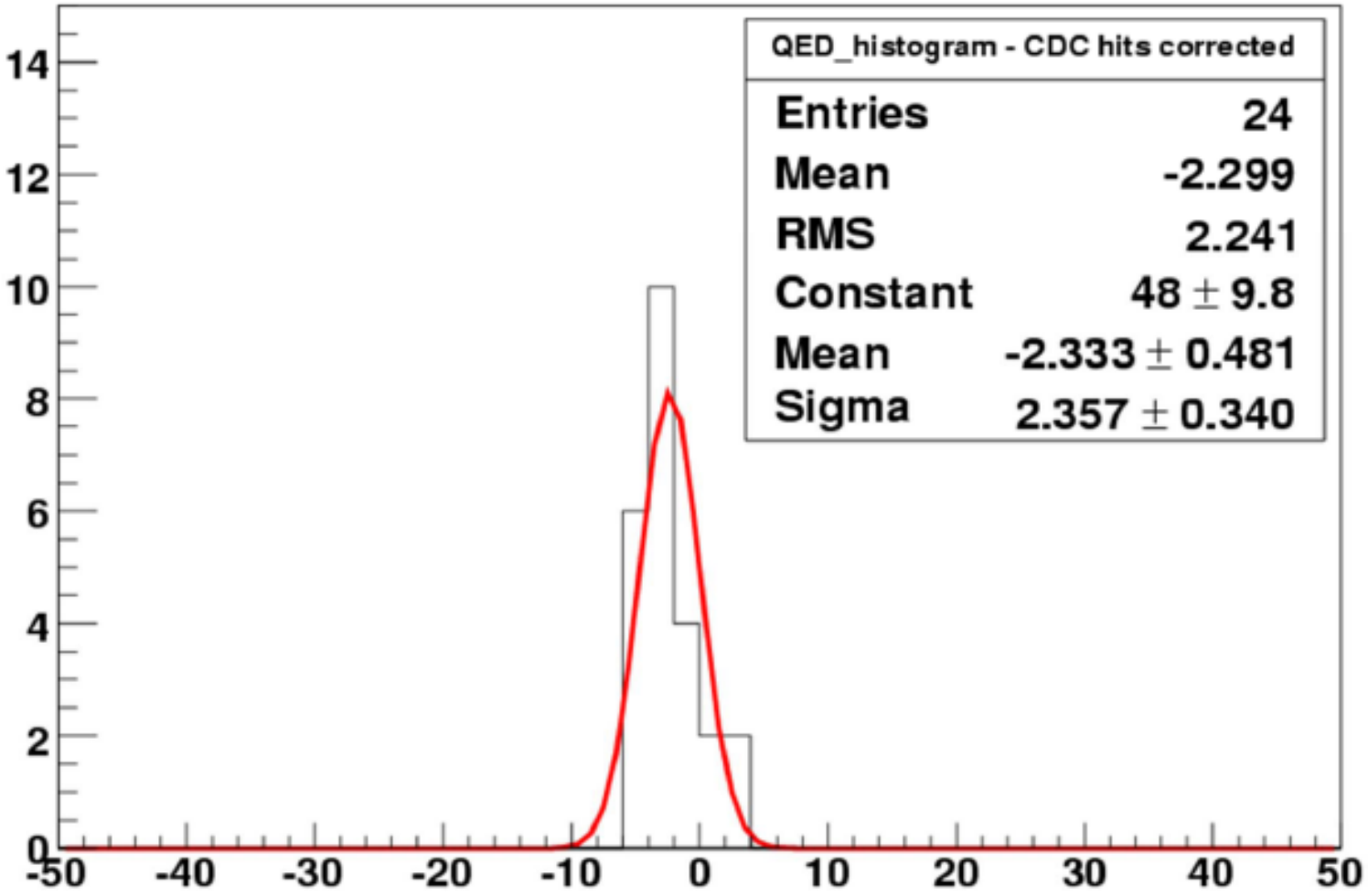
CDC Hits Corrected SVD Hits

- 2^{nd} – 4^{th} SVD layer – Experiment B

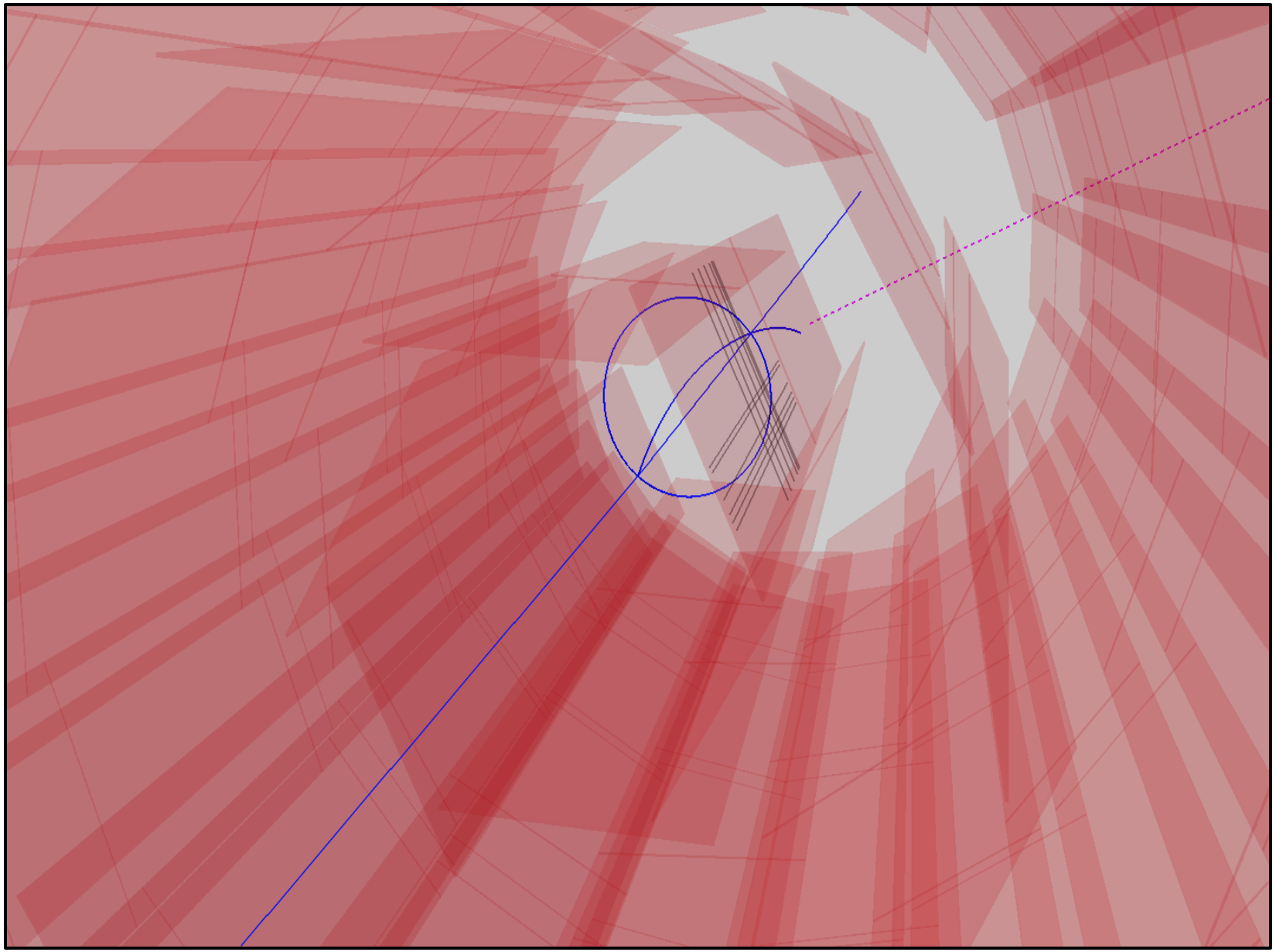


CDC Hits Corrected SVD Hits

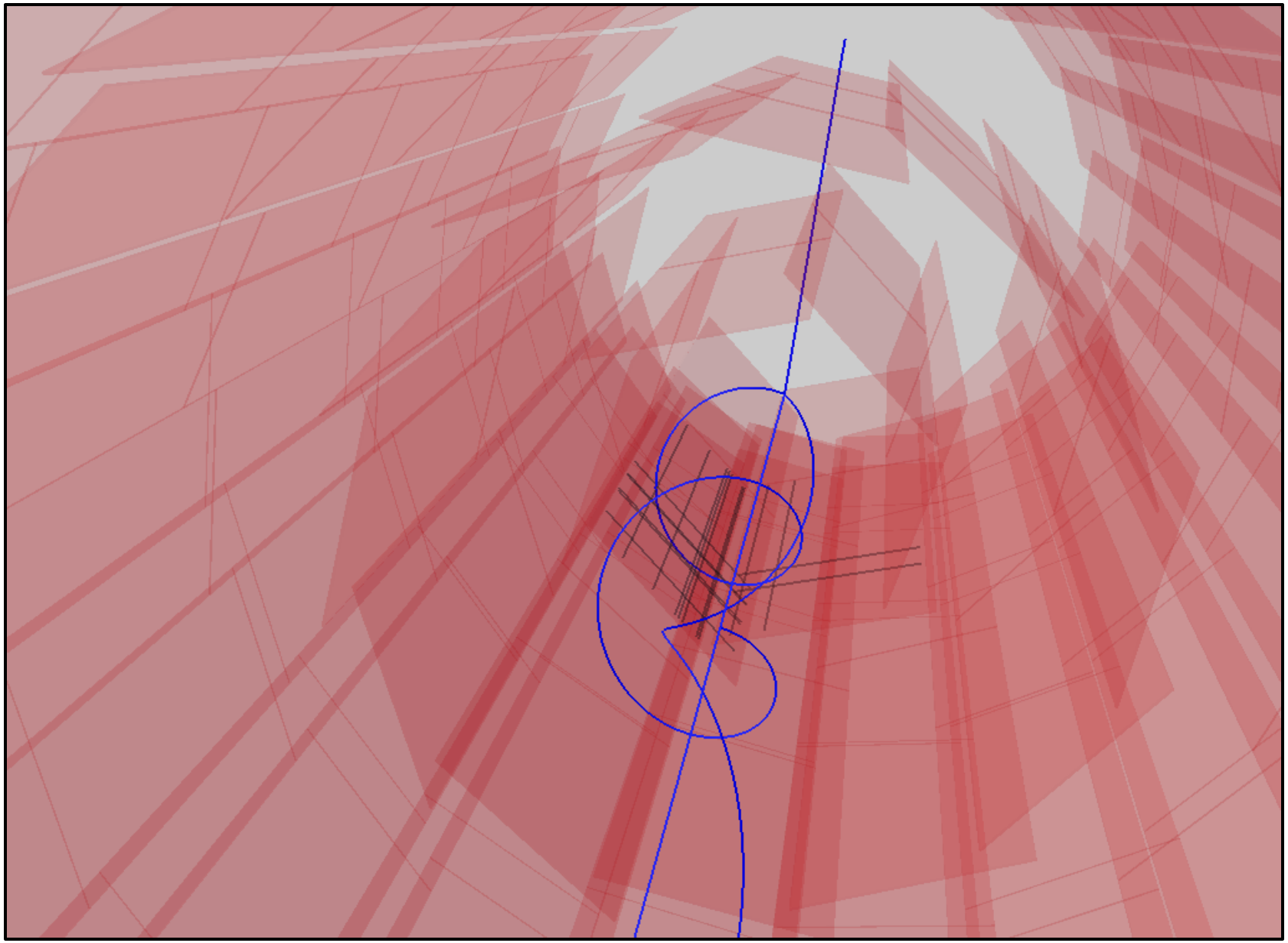
- 2^{nd} – 4^{th} SVD layer – Experiment C



Event Display



Event Display



Event Display