



bmb+f - Förderschwerpunkt  
Elementarteilchenphysik  
Großgeräte der physikalischen  
Grundlagenforschung



# Online Data Reduction for the Belle II experiment using DATCON

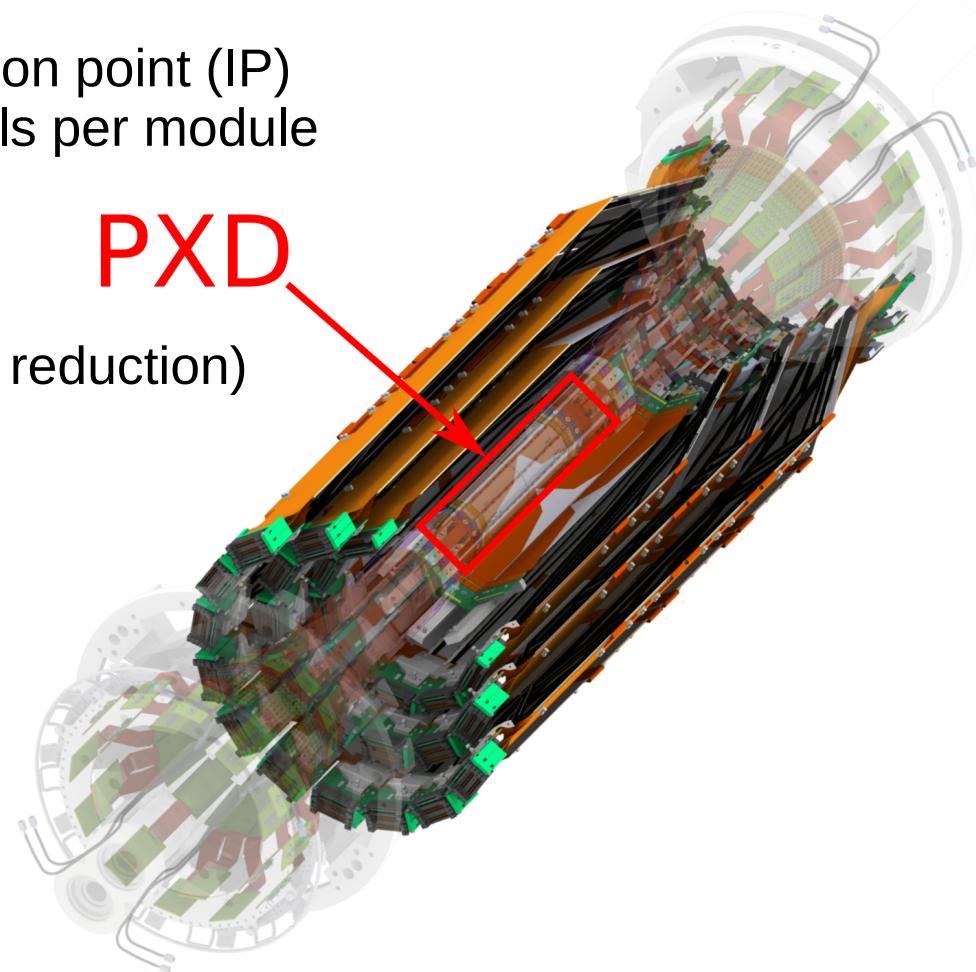
Christian Wessel, Bruno Deschamps,  
Jochen Dingfelder, Carlos Marinas, Florian Bernlochner

University of Bonn

# The Belle II Vertex Detector (VXD)

## Pixel Detector (PXD)

- based on DEPFET technology
- thin detector ( $0.2\% X_0$  per layer)
- 2 layers at 14 and 22 mm from interaction point (IP)
- 40 sensor modules with  $250 \times 768$  pixels per module
- pitch:  $50 \times 55 \dots 80 \mu\text{m}$  (u x v)
- in total 8 million pixel
- maximum data rate of **32 GB/s**  
**(90% of detector data rate without data reduction)**



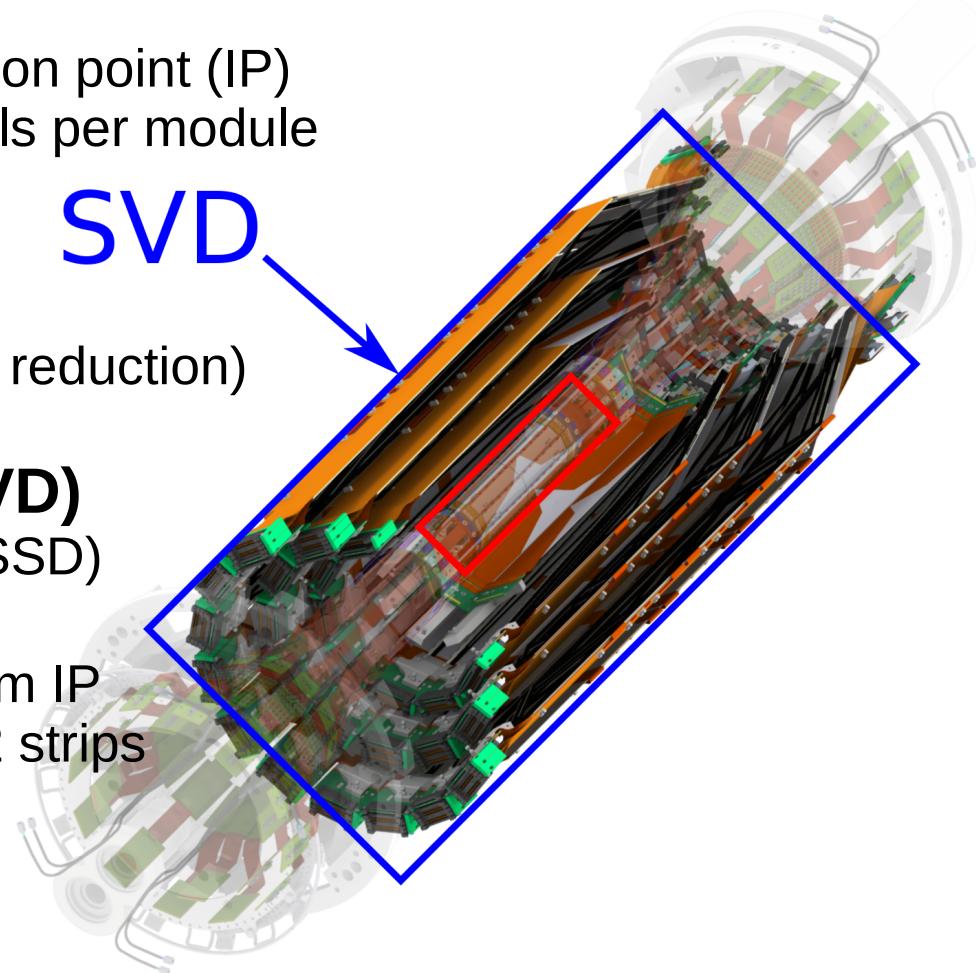
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## Silicon Strip Vertex Detector (SVD)

- Double-sided Silicon Strip Detector (DSSD)
- $0.6\% X_0$  per layer
- 4 layers at 39, 80, 104 and 135 mm from IP
- 172 sensors with  $768 \times 768 / 768 \times 512$  strips
- pitch  $50 \times 160 / 75 \times 240 \mu\text{m}$  (u x v)
- in total 240k strips



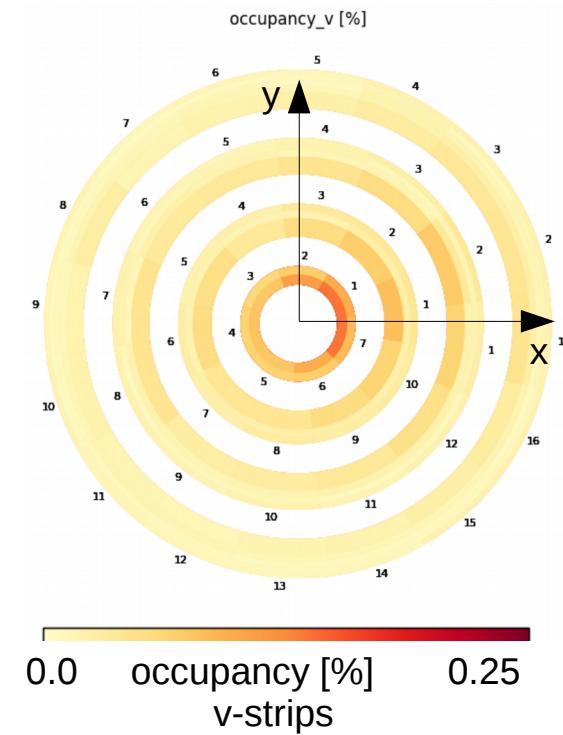
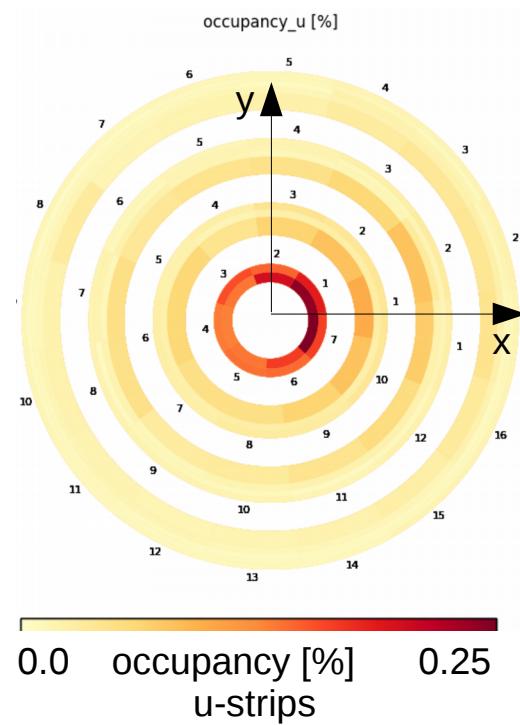
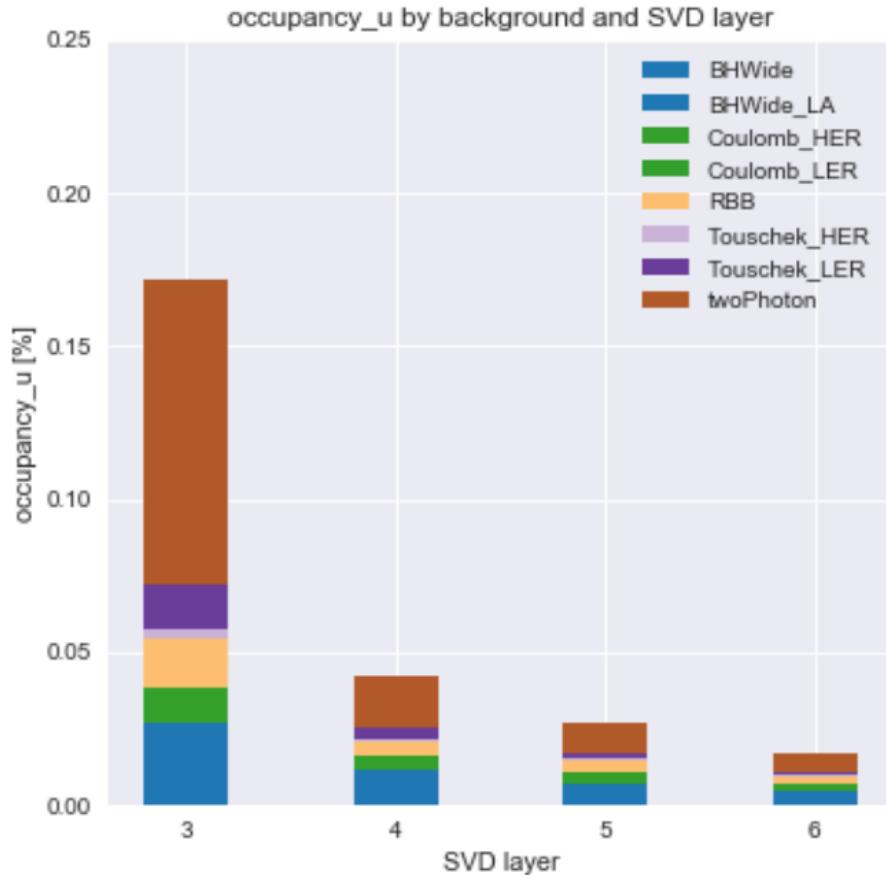
- Two photon QED process:  $e^+e^- \rightarrow e^+e^-e^+e^-$
- Touschek: intra-bunch scattering of equally charged particles
- Radiative Bhabha:  $\gamma$  interact with magnets and produce neutrons
- Coulomb scattering: interactions with remaining gas in beam pipe
- Synchrotron radiation: deflection in final focussing magnets

## Why Data Reduction?

- Maximum occupancy the PXD R/O can cope with is 3%
- Maximum data rate of PXD is **32 GB/s** (1 MB/event)
  - not feasible to store all pixel data
  - **Data reduction is required**  
(factor of **~10** at 3% PXD occupancy)

# Beam induced Background – SVD

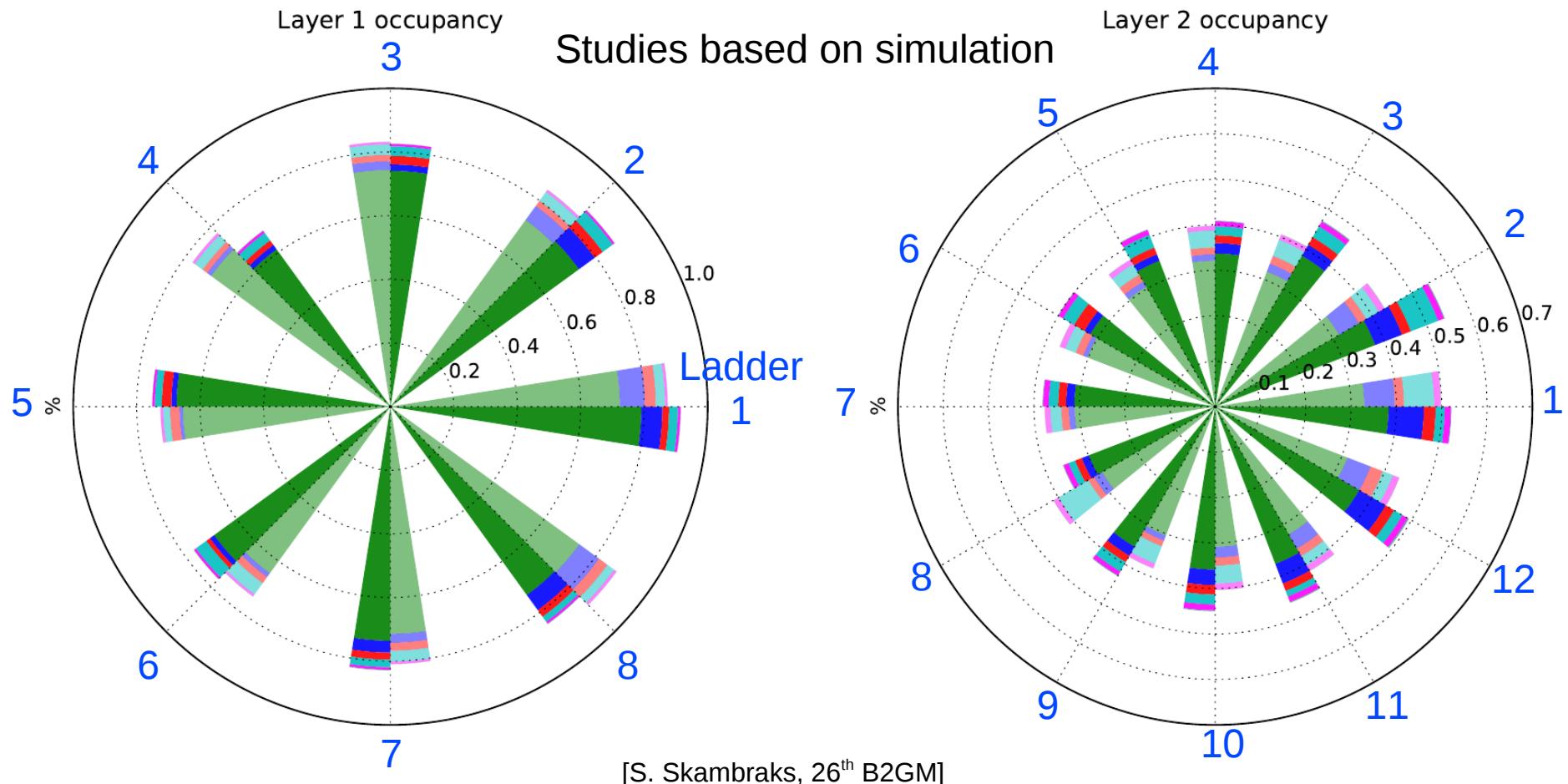
Studies based on simulation



[P. Kvasnicka, 26<sup>th</sup> B2GM]

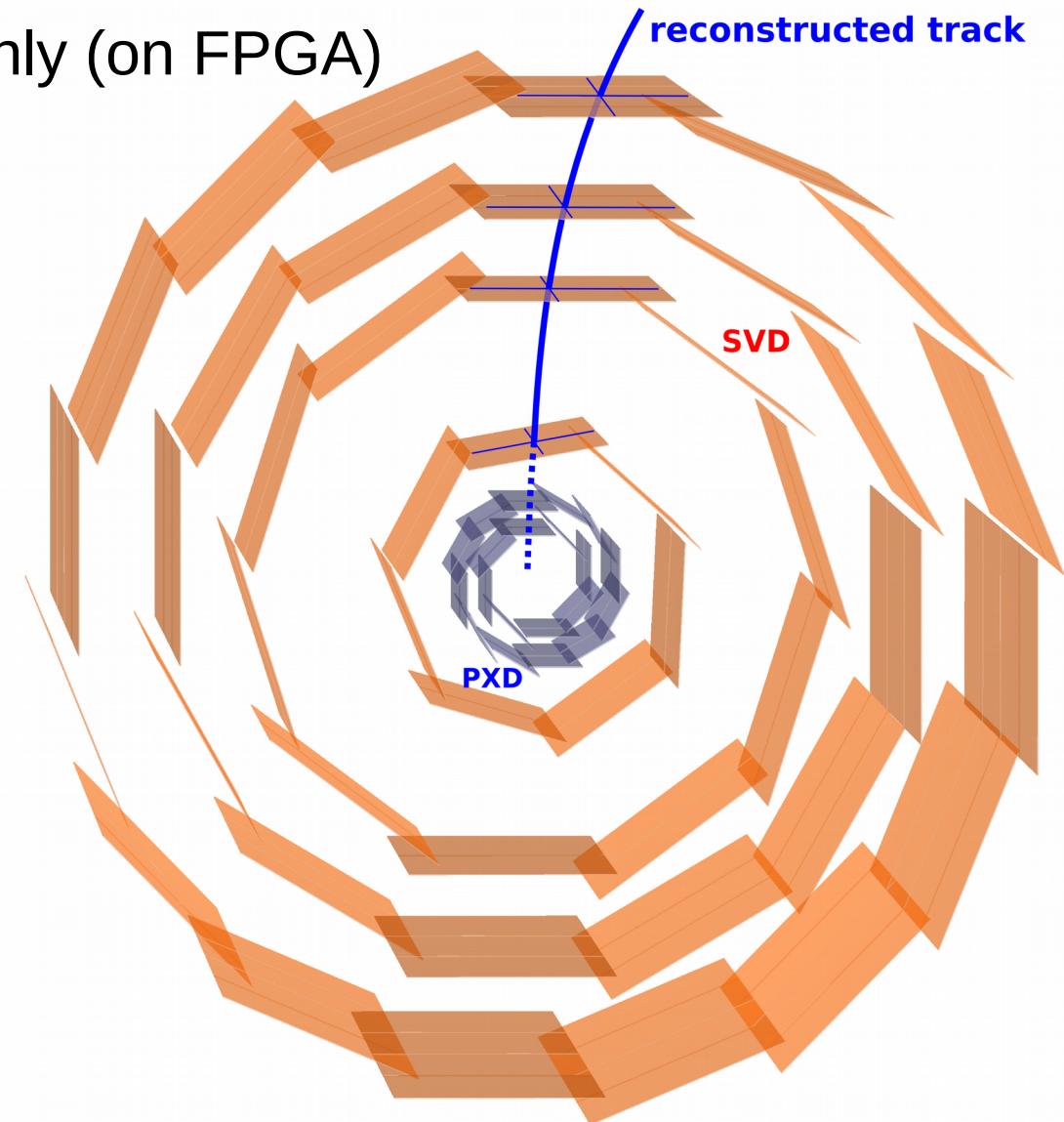
# Beam induced Background – PXD

TwoPhoton, fwd	Touschek, fwd	Coulomb, fwd	BBBrem, fwd	BHWide, fwd	BHWideLA, fwd
TwoPhoton, bwd	Touschek, bwd	Coulomb, bwd	BBBrem, bwd	BHWide, bwd	BHWideLA, bwd



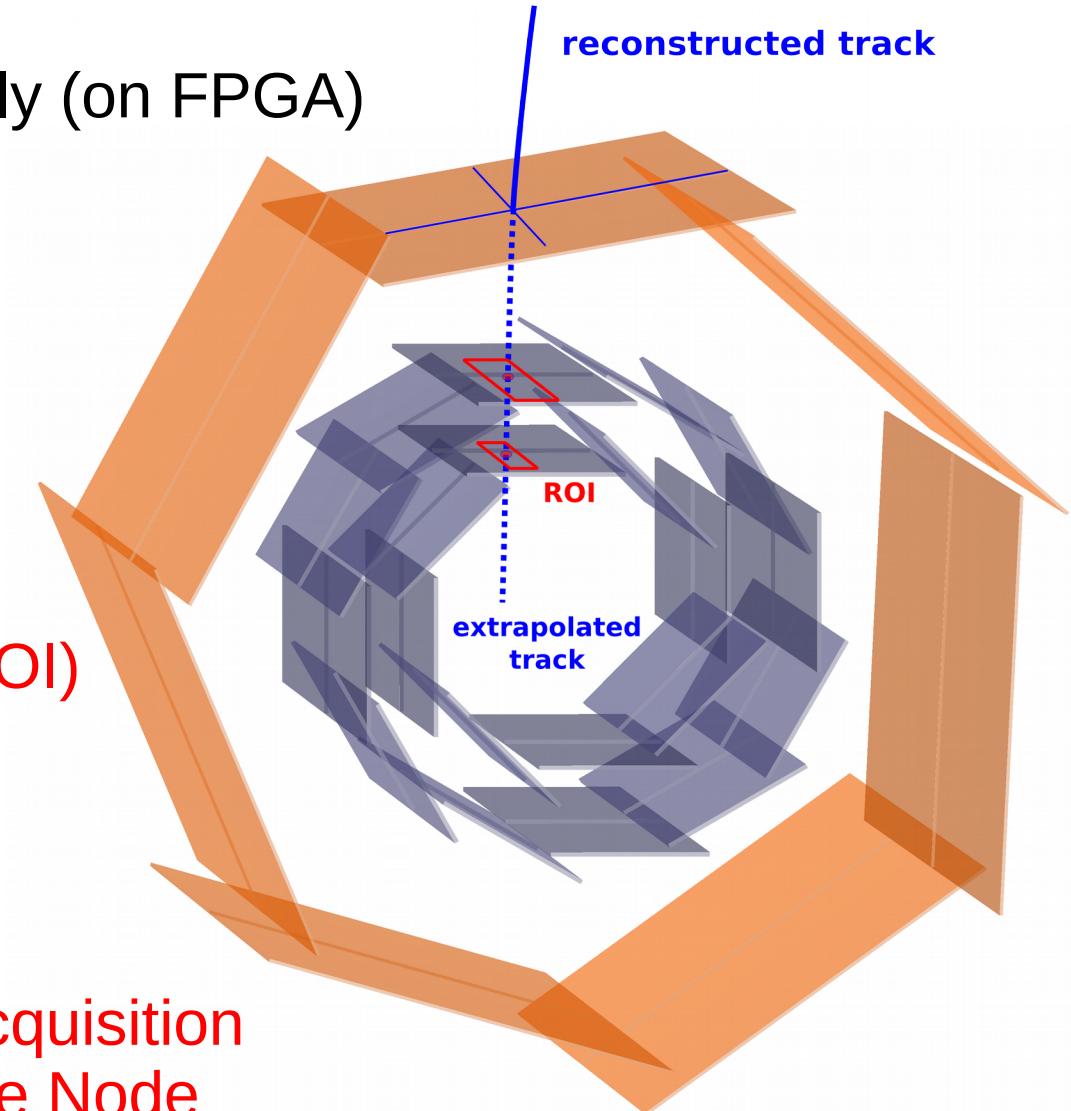
# Tracking and Extrapolation - Concept

- Tracking based on SVD hits only (on FPGA) using Hough Transformation
- Extrapolation to PXD:  
Assuming a circular track in xy-projection intersecting with detector plane



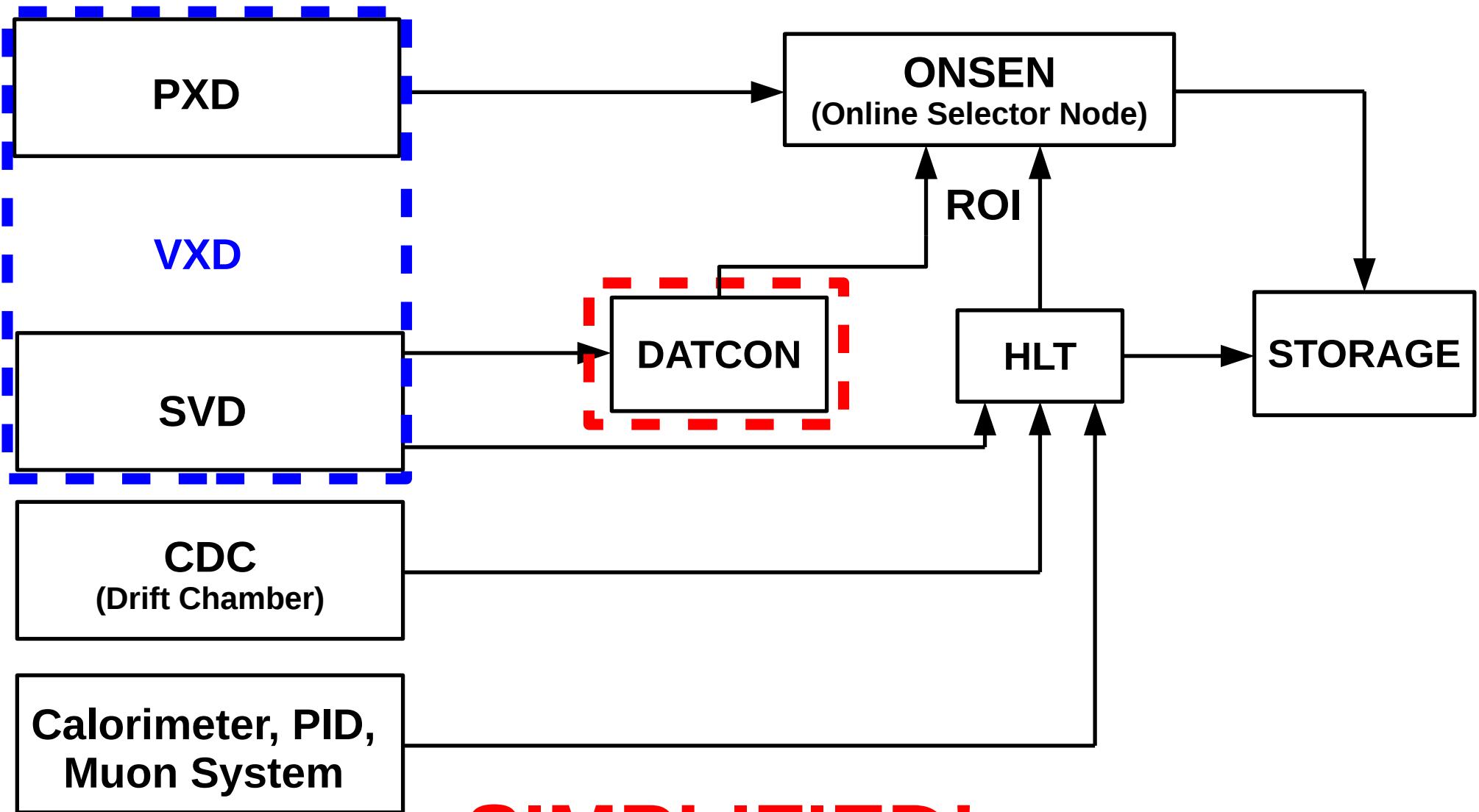
# Tracking and Extrapolation - Concept

- Tracking based on SVD hits only (on FPGA) using Hough Transformation
- Extrapolation to PXD:  
Assuming a circular track in xy-projection intersecting with detector plane
- Calculate **Region of Interest (ROI)**
- Only save PXD hits inside ROI, discard all the rest



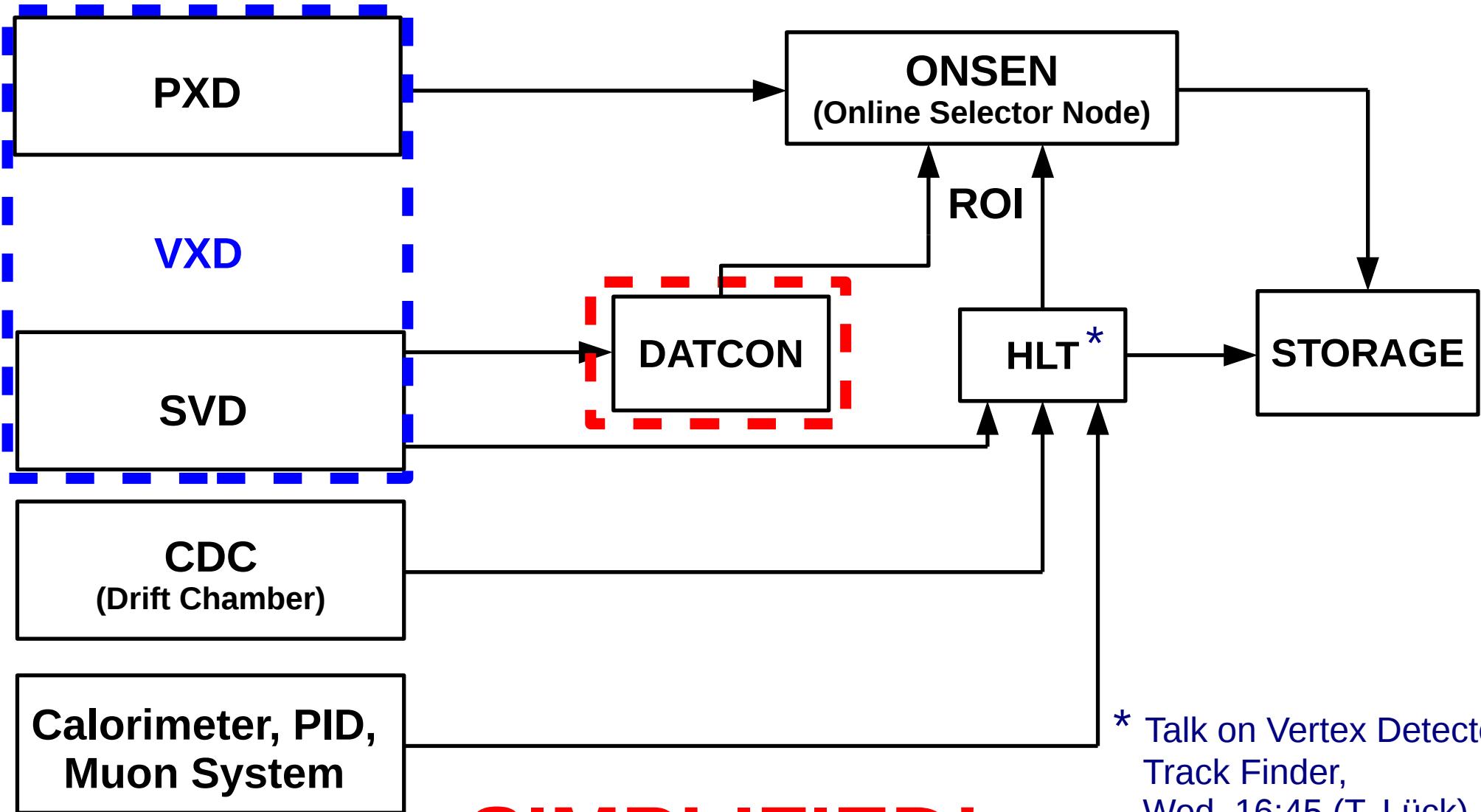
One system: **DATCON – Data Acquisition  
Tracking and Concentrator Online Node**

# The Belle II DAQ System



**SIMPLIFIED!**

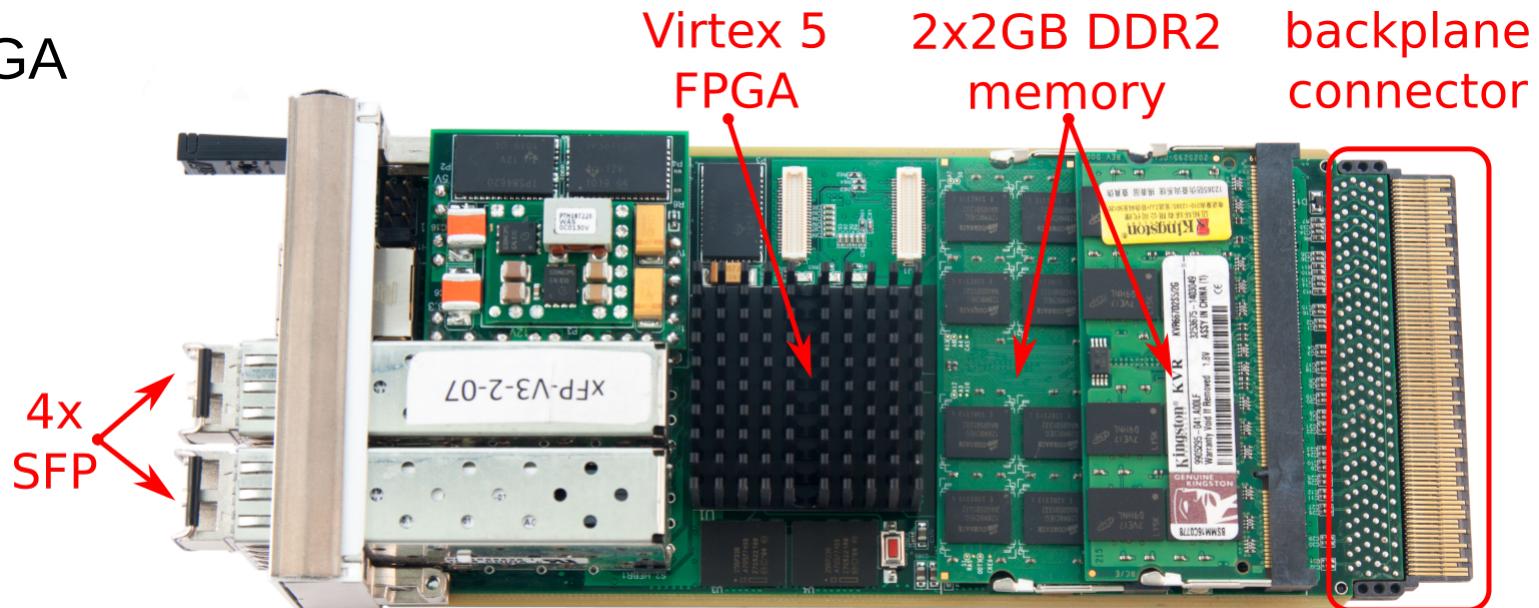
# The Belle II DAQ System



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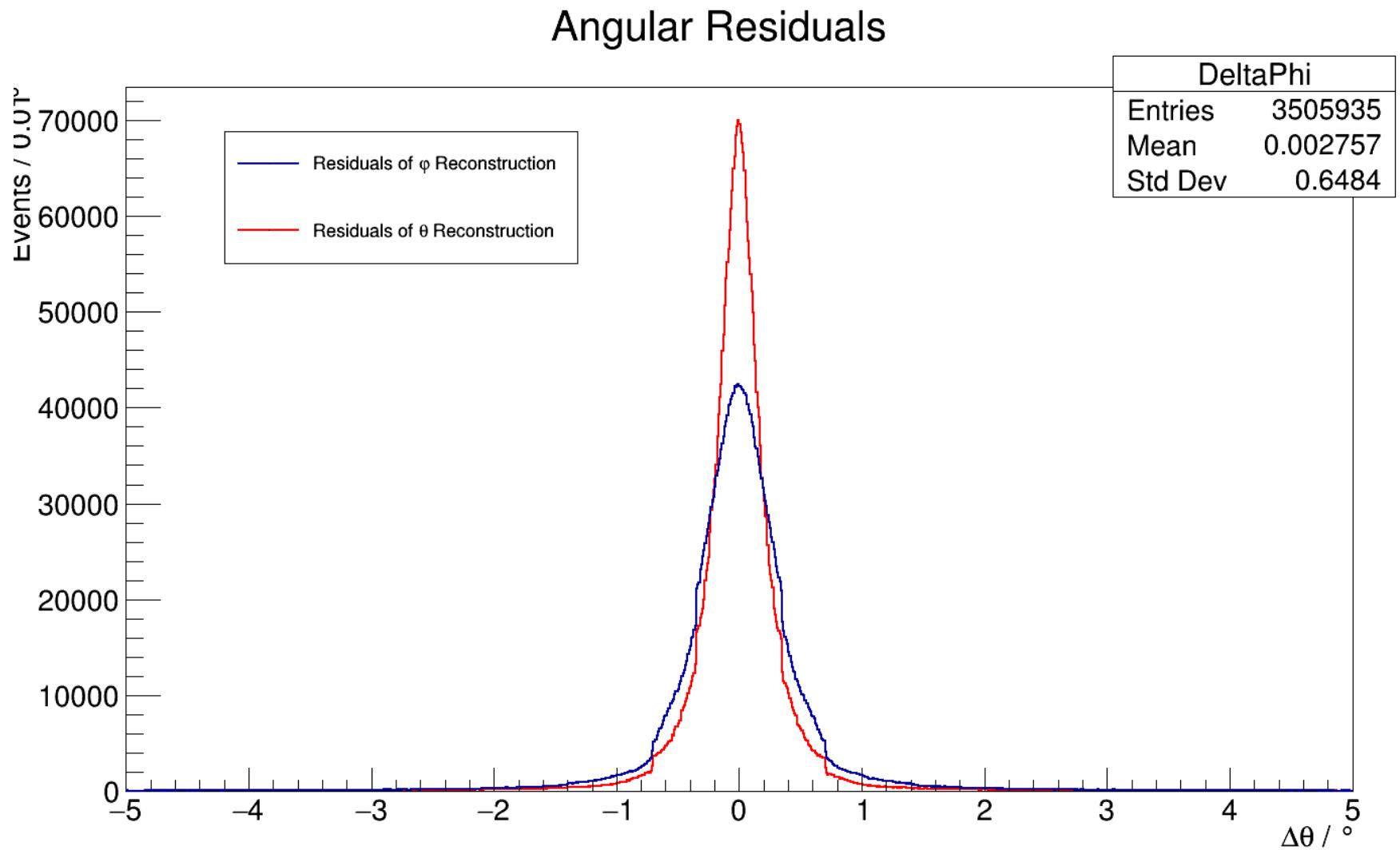
\* Talk on Vertex Detector  
Track Finder,  
Wed. 16:45 (T. Lück)

- Development of algorithms C++ in the Belle II Software and Analysis Framework (BASF2)
- Simulation of generic Y(4S) events (results shown for 100k events)
- Optimization of the C++ algorithms based on simulations
- Transfer to FPGA



# Tracking Performance – $\Upsilon(4S)$ Events

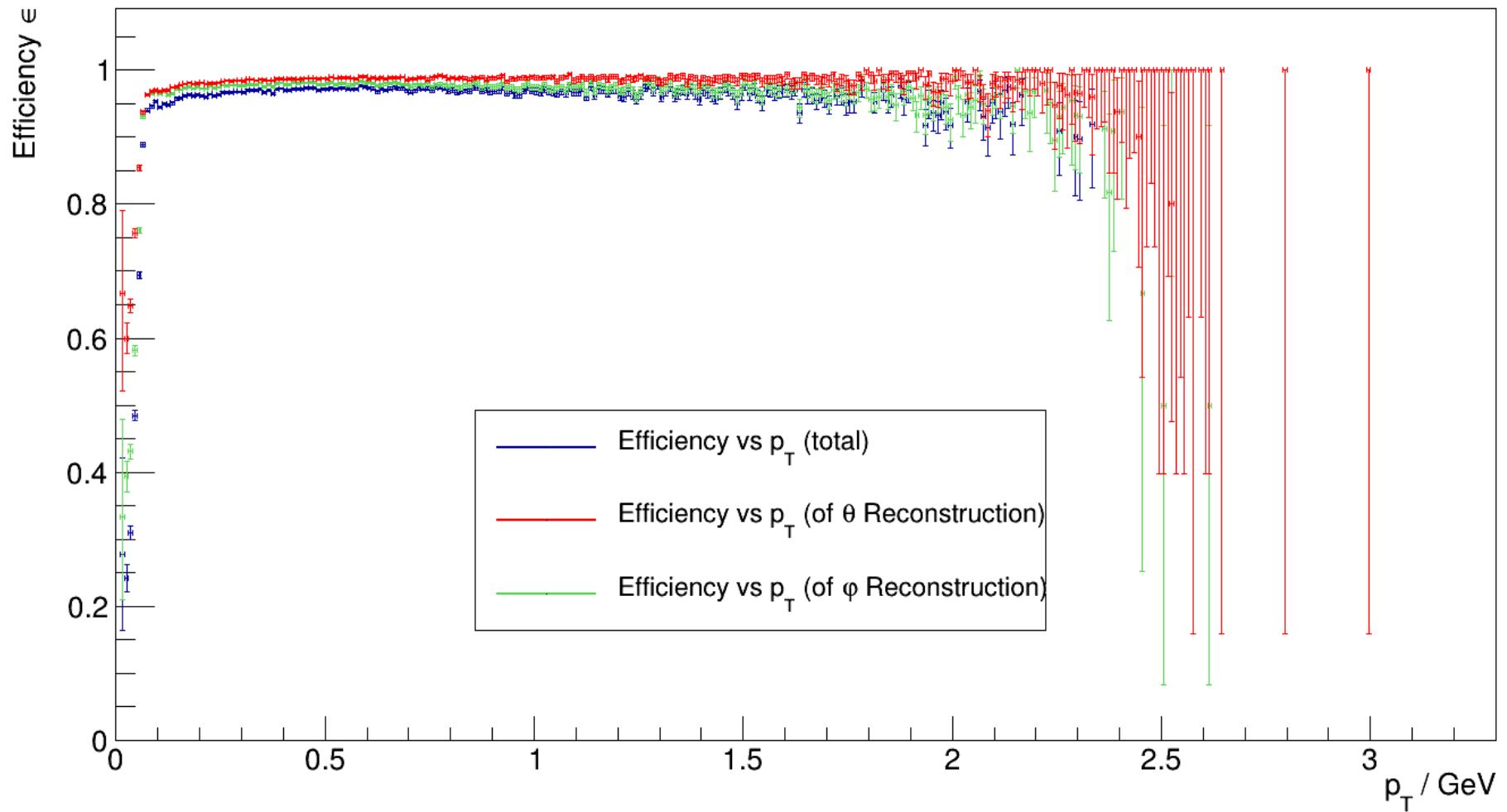
Very precise reconstruction – most angular residuals  $< 1^\circ$



# Tracking Performance – $\Upsilon(4S)$ Events

Efficiency of the track reconstruction: 96%

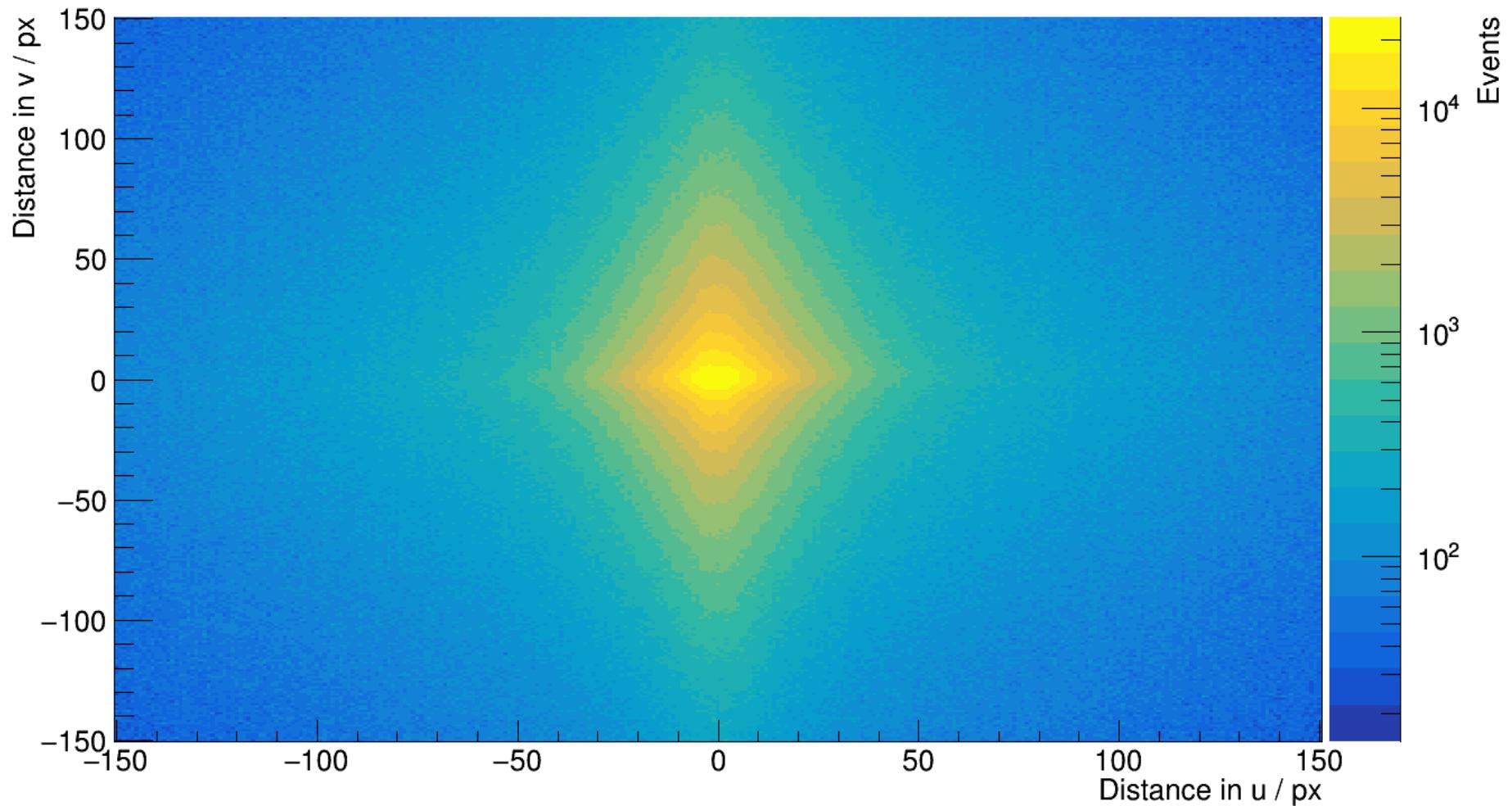
Efficiency vs  $p_T$



# Tracking Performance – $\Upsilon(4S)$ Events

Residuals (extrapolated hit – MC hit) on the PXD

Residuals in u and v



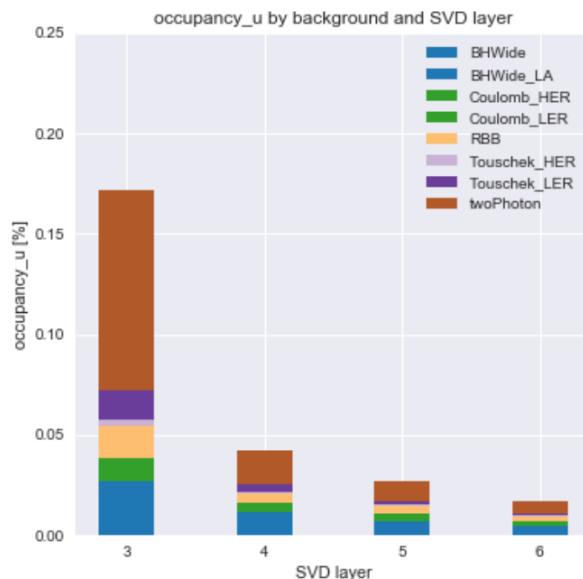
- Online track reconstruction and track extrapolation is feasible on FPGA
- Track reconstruction efficiency of 97% for generic Y(4S) events, 99% for 12 electrons, muons or pions per event
- ROI finding efficiency of 89% for generic Y(4S) events, 96% for 12 electrons, muons or pions per event
- Narrow distributions for angular and extrapolated hit residuals
- Complementary approach to HLT for low  $p_T$  tracks



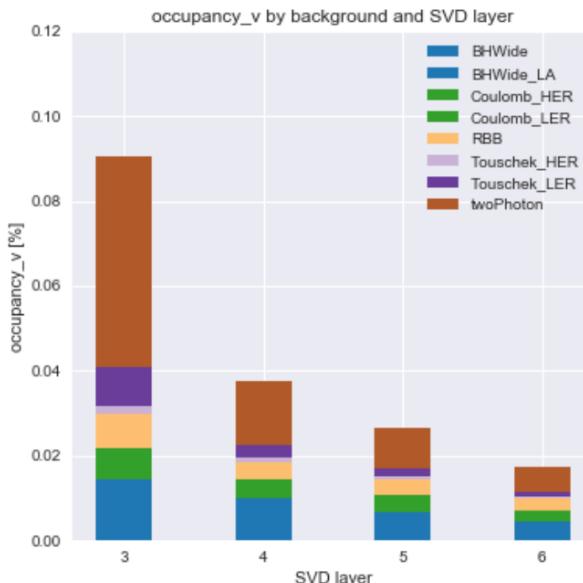
Thank you for  
your attention!



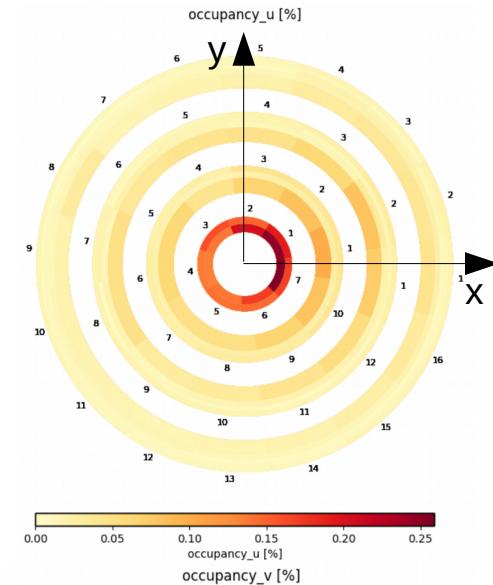
# Beam induced Background – SVD



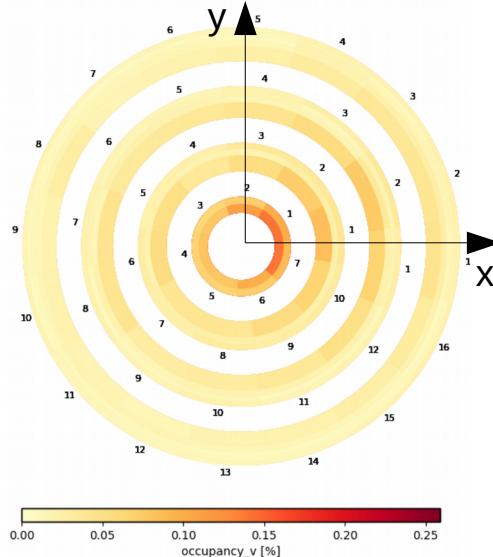
u-strips  
(along z axis)



v-strips  
(along r-phi)

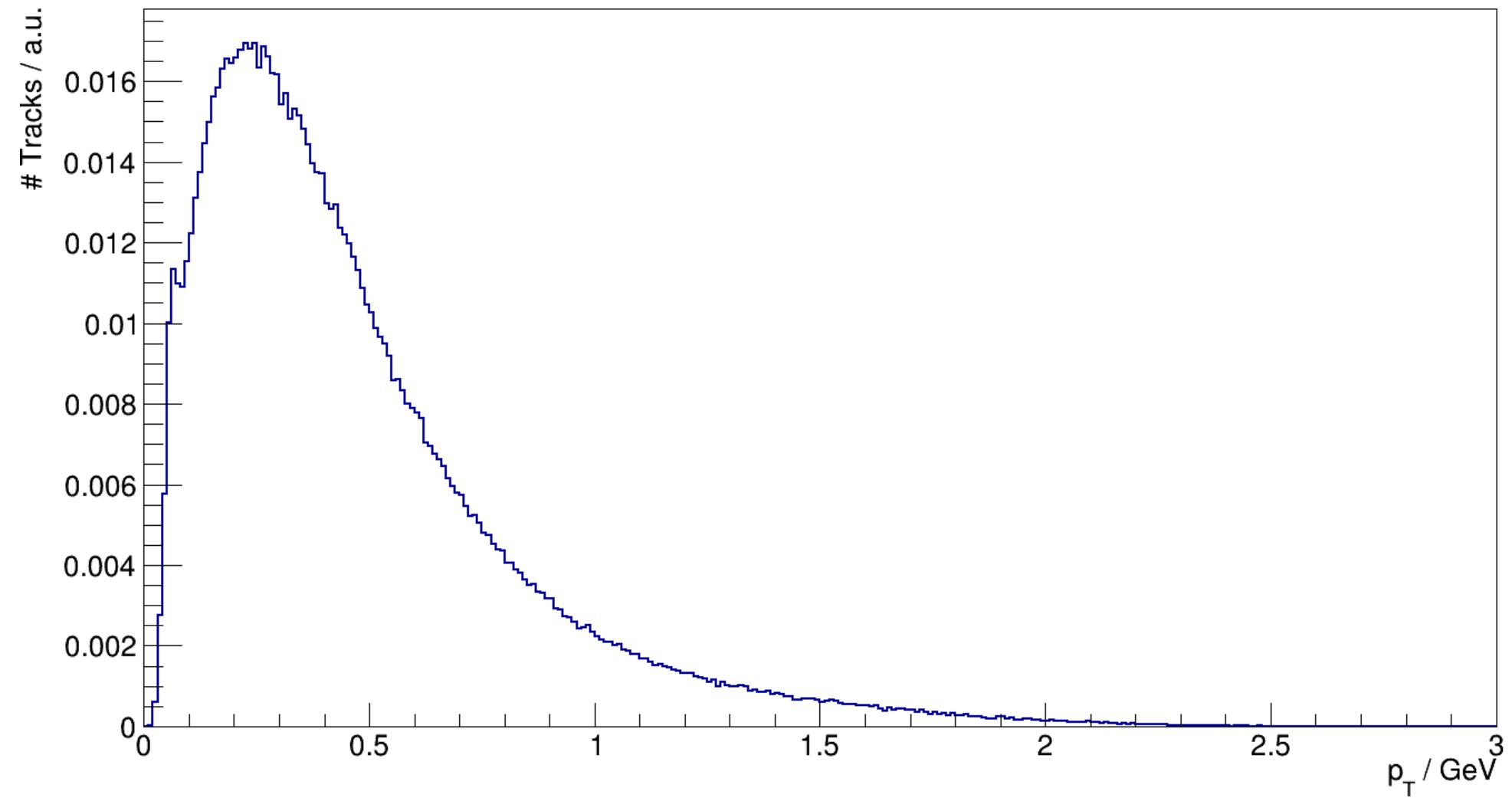


[P. Kvasnicka, 26<sup>th</sup> B2GM]

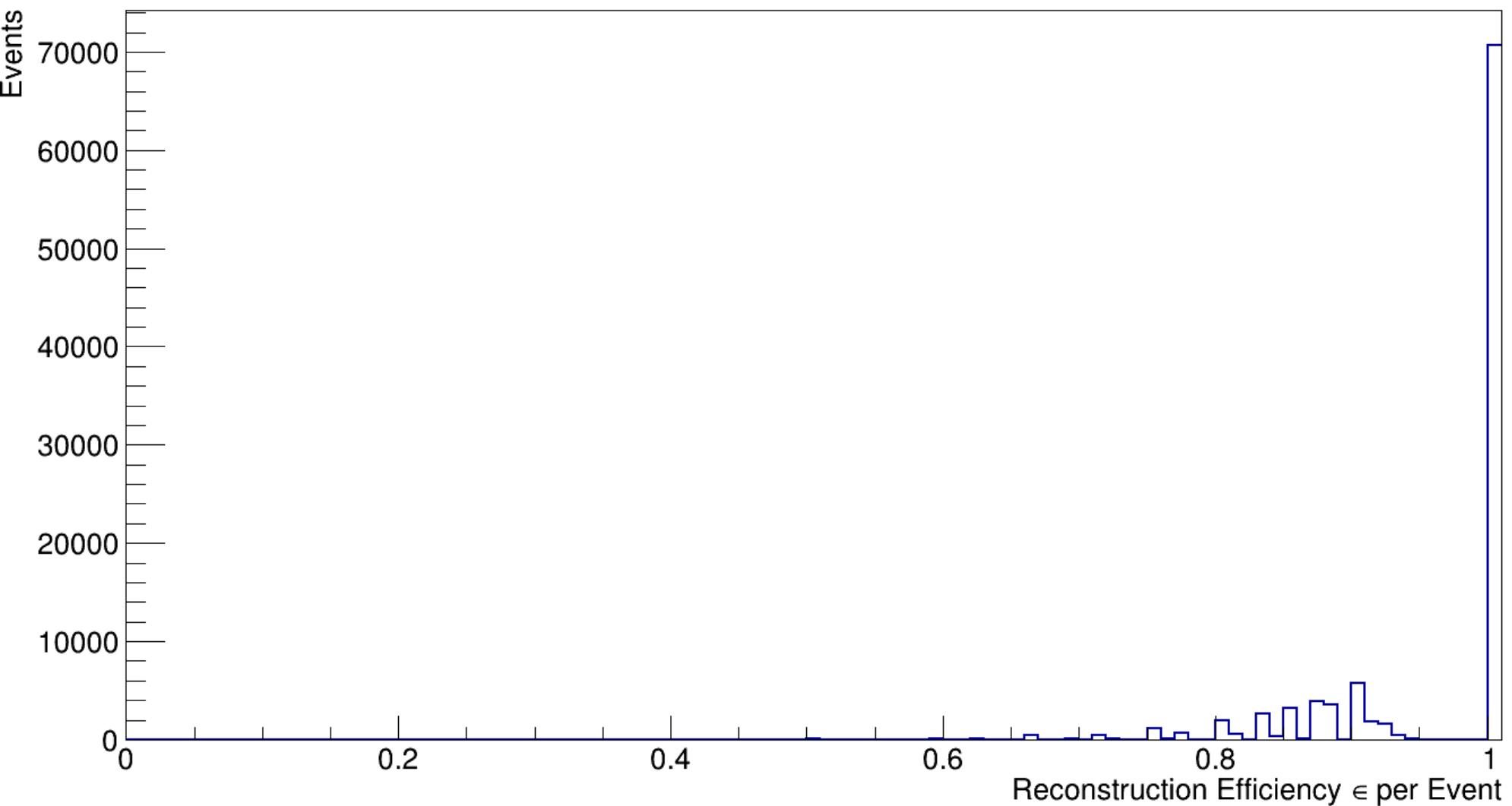


# Tracking Performance – $\Upsilon(4S)$ Events

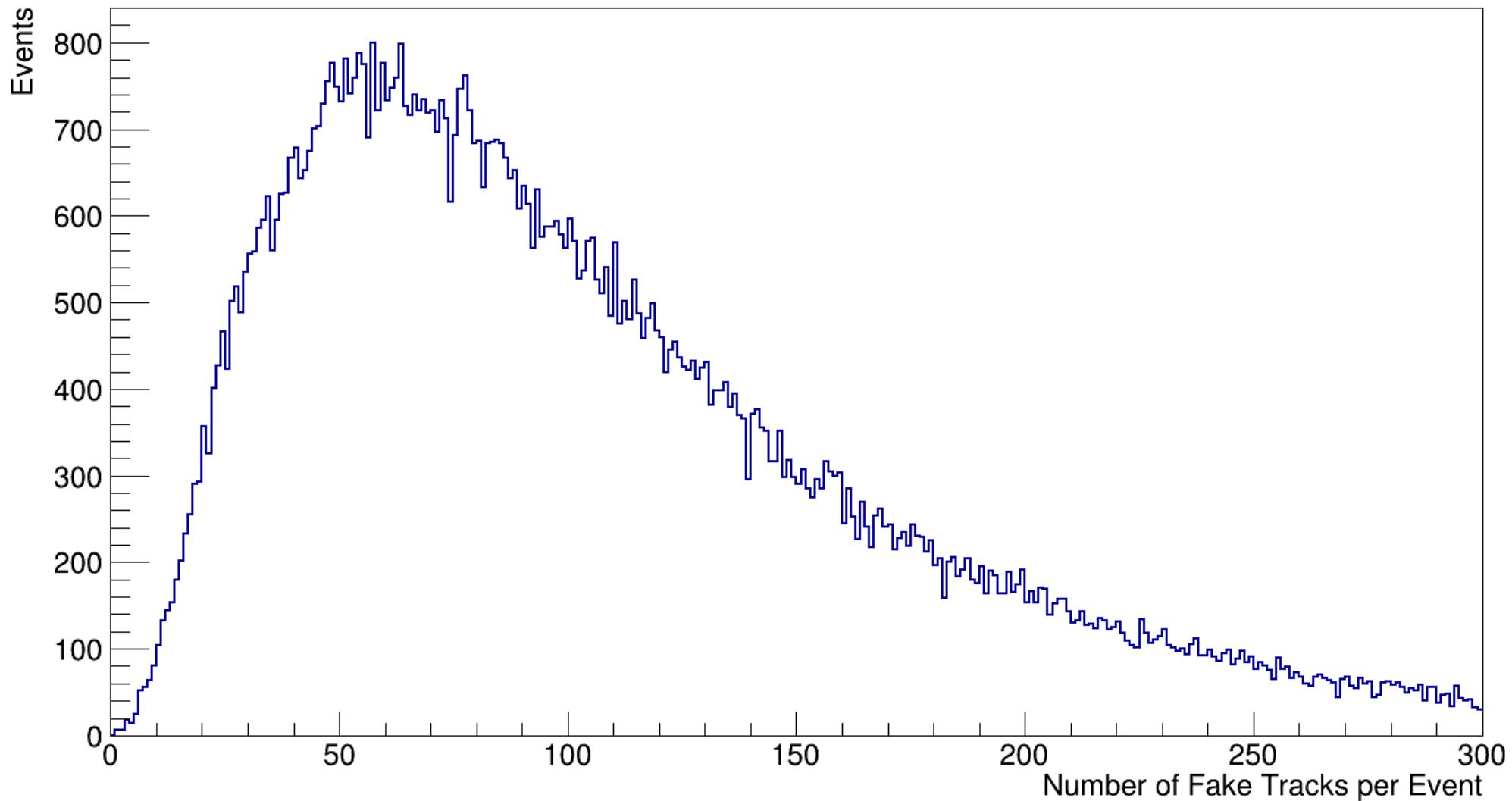
## Normalized $p_T$ Distribution



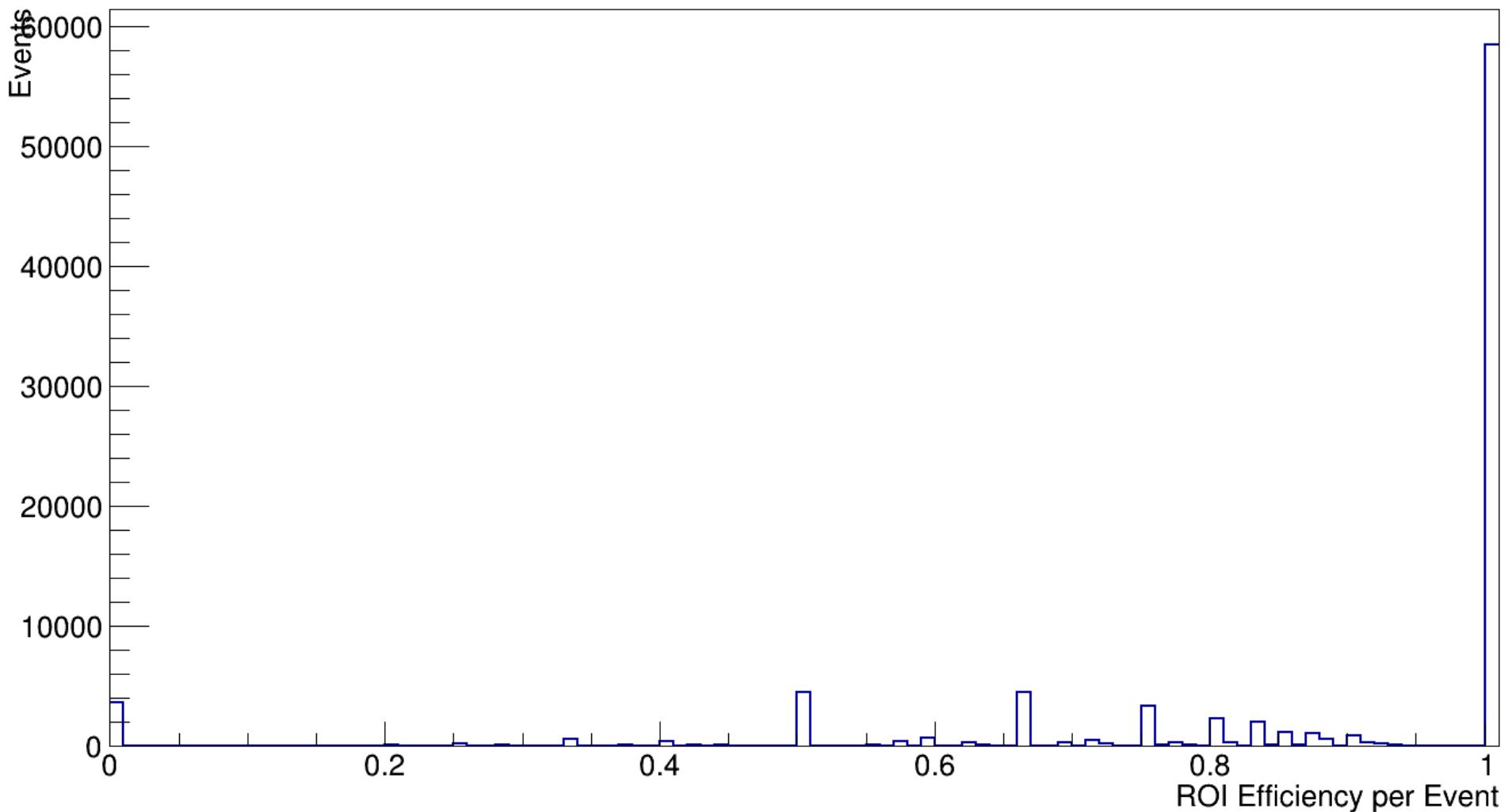
# Tracking Performance – $\Upsilon(4S)$ Events



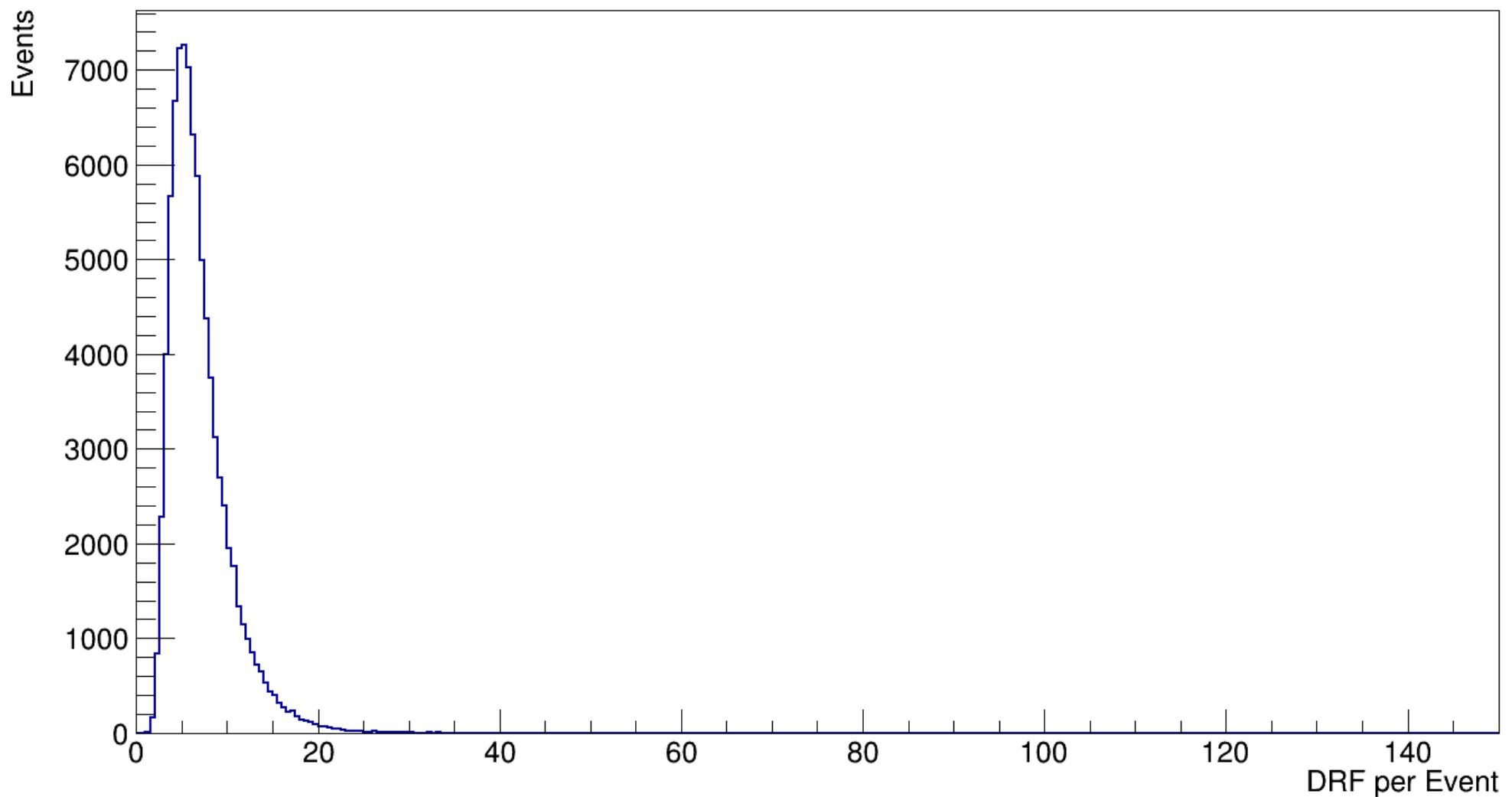
# Tracking Performance – $\Upsilon(4S)$ Events



# Tracking Performance – $\Upsilon(4S)$ Events



# Tracking Performance – $\Upsilon(4S)$ Events



# Example Hough Space – 5 Muons

