PXD Performance at High QED Occupancies

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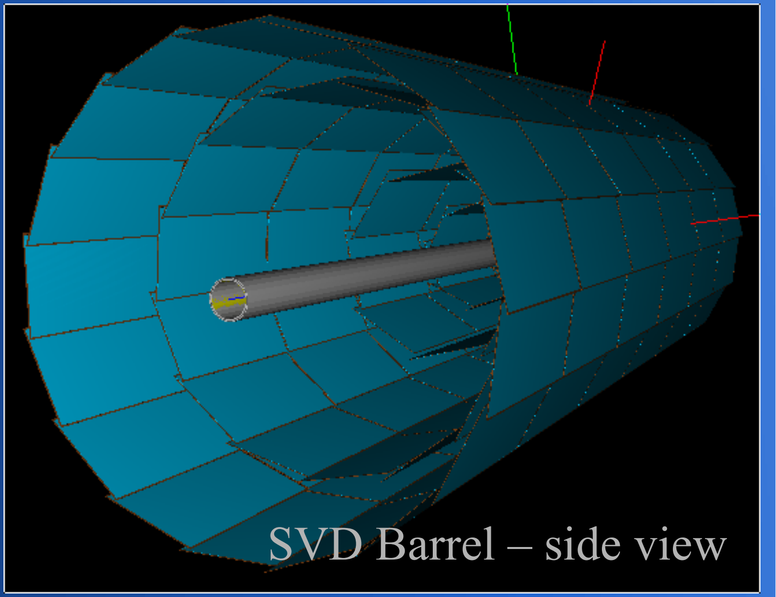
Outline

- Simulation settings:
  - Mokka geometry & generator settings
  - Marlin: merging signal & background, digitization, silicon tracking
- Performance studies:
  - PXD with/without ADC – in-plane resolution studies
  - PXD in large QED background (~% PXD occupancy) - impact parameter studies

Mokka – Geant 4 Geometry & Settings

- Mokka geometry model: ***VTXBelleII_SVDBarrel_PXD075um1600_Model_NB***
  - ***PXD:*** 2 layers of Depfets @ 14, 22 mm (1st layer flipped)
    - **active part:** layers → ladders → Si sensors (75 μm)
    - **passive parts:** Si rims (450 μm) + gap inbetween sensors , i.e. passive Si (550 μm) + Si support bridge (750 μm) + 12 switchers (350 μm)
  - ***SVD:*** 4 layers of DSSDs @ 38, 65, 115, 140 mm
    - **active part:** layers → ladders → Si sensors (Hamamatsu, i.e. 320 μm sensors) x **passive part:** Si rims

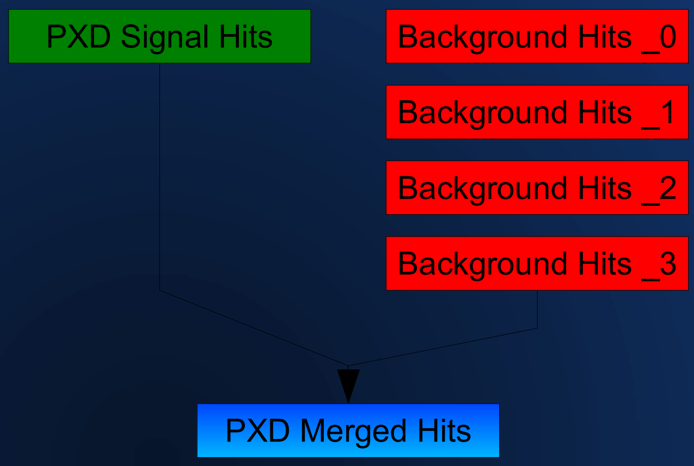
	R [mm]	***# ladders***	***# sensors***
SVD layer 1	38.00	8	2
SVD layer 2	65.00	8	3
SVD layer 3	115.00	14	5
SVD layer 4	140.00	17	6



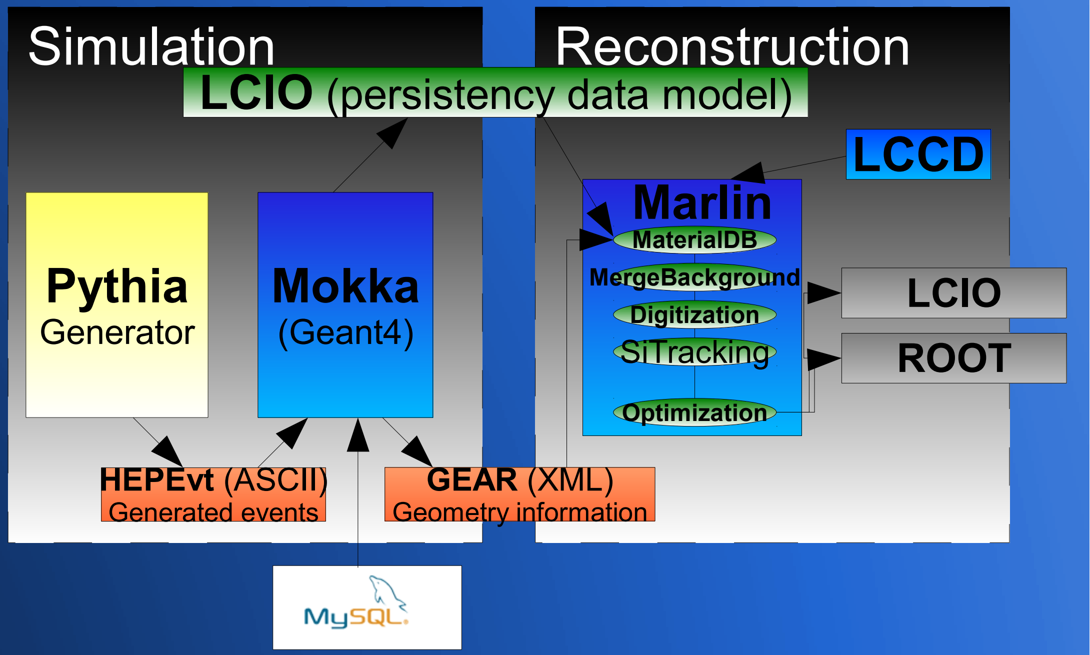
- Mokka particle gun: 0.2, 0.5, 1, 2, 3, 4 GeV pions, distr. randomly in φ & ϑ

Marlin & MergeBackground processor

- Marlin processor: ***MergeBackground***
  - merges together:
    - collection of signal hits (physics events)
    - collection of background hits (QED background) → overlay several *.slcio files in order to get required (expected) occupancy



ILC Software Scheme



Marlin & SiTracking processor

- Marlin processors: ***SiPxlDigi & SiStripDigi***
  - digitization & clustering (hits within integration time worked out only)
    - **PXD**: 20μs x **SVD**: 20ns (no pile-up), limit 160ns
- Marlin processors: ***SiTracking***
  - **FindHitSectors -** find triplet combinations (SVD only) & test them based on helix hypothesis
  - **BuildTrackSegments** – use closest approach to find remaining hits & refit using helix
  - **MakeTrack** – merge split tracks, refit with Kalman f.
  - **Extrapolate to PXD**, assign hits & refit with Kalman
- **Comments:** SVD time window of 20ns achievable only when no signal pile up appears and fitting procedure using 3 samples around peak works, otherwise 50ns window or even higher appears → here, based on discussion with SVD people, limit of **160ns simulated**

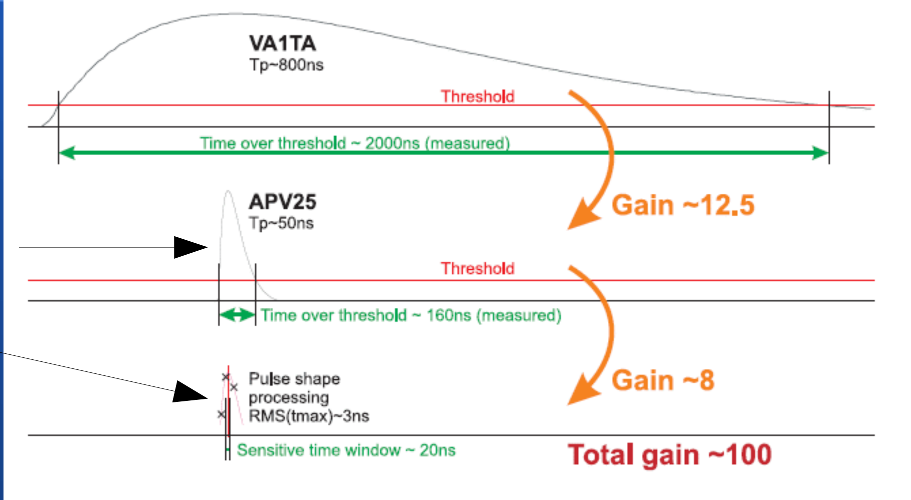
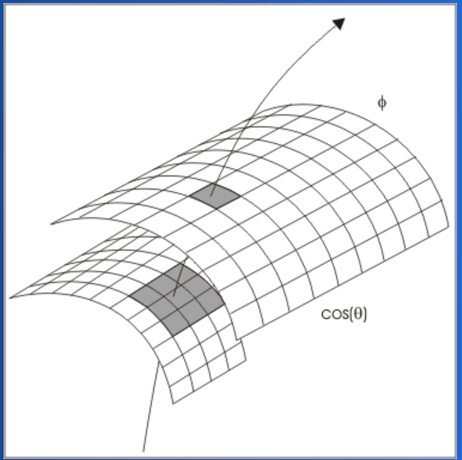


Figure 5.30: Occupancy reduction potential with the APV25 and hit time finding.

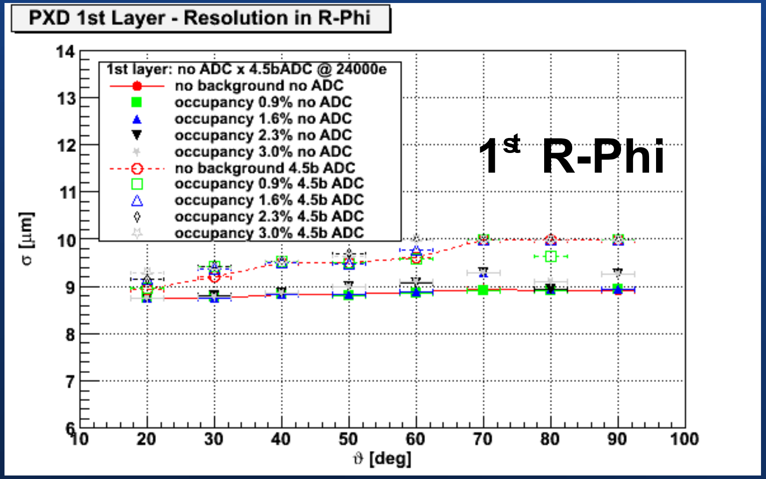


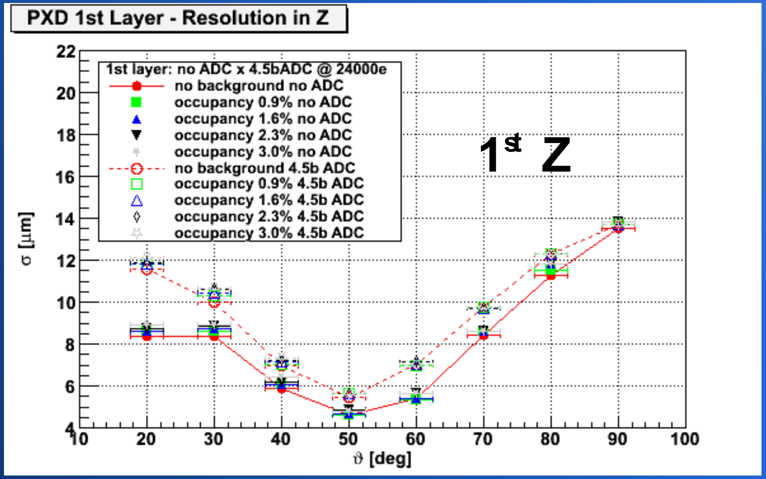
PXD Performance @ Large Occupancies

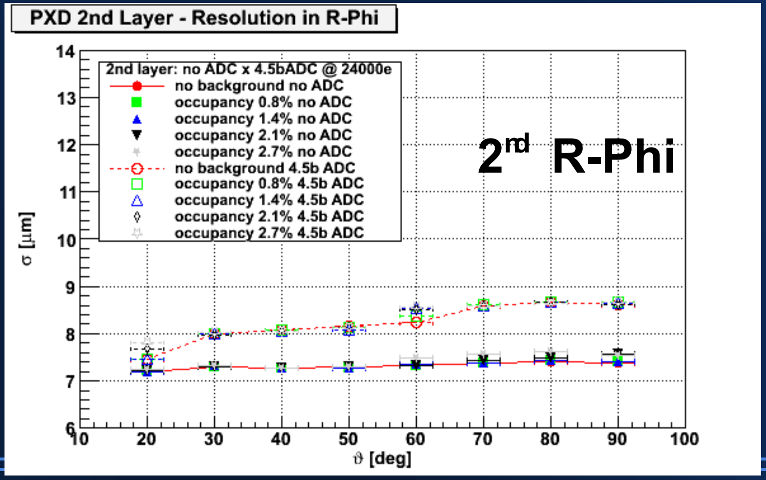
- Single pion tracks @ 0.2, 0.5, 1.0, 2.0, 3.0, 4.0 GeV simulated randomly in the acceptance region of Si tracker (PXD + SVD with barrel-like forw. region)
- Signal (pions) & background hits (Belle II QED background – KoralW simulator) @ following occupancies merged:
  - 0 % (no background) – PXD w/wo ADC
  - 0.9% @ 1st PXD layer, 0.8% @ 2nd PXD layer, (0.13% correspond to electronics noise)
  - 1.6% @ 1st PXD layer, 1.4% @ 2nd PXD layer, (-”-)
  - 2.3% @ 1st PXD layer, 2.1% @ 2nd PXD layer,(-”-)
- Impact parameter resolution studies for PXD with integr. time of 20μs & SVD with integr. time of 160 ns performed (SVD with 20ns – no significant impact visible)
- Analysis based on quantiles method used: RMS = $|(q_{0.84} - q_{0.14})|/2$ (68% area), where const. comb. background subtracted first (average value outside of signal window $|\sigma|$>0.8mm subtracted), quant. errors estimated using Maritz-Jarrett method → very robust & stable approach (fitting method estimating RMS90 showed to be unstable ...)

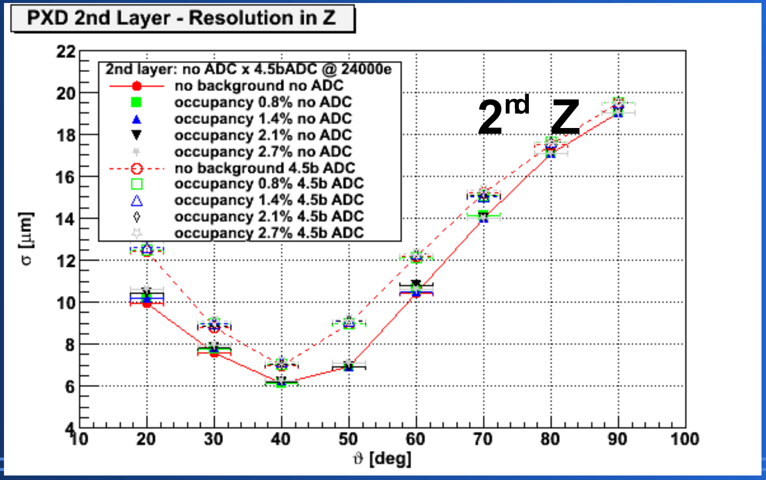
Results: PXD In-Plane Resolution in R-Phi & Z @ Large Occupancies

- Left: 1st & 2nd PXD layer in R-Phi (ADC x no ADC) x Right: in Z



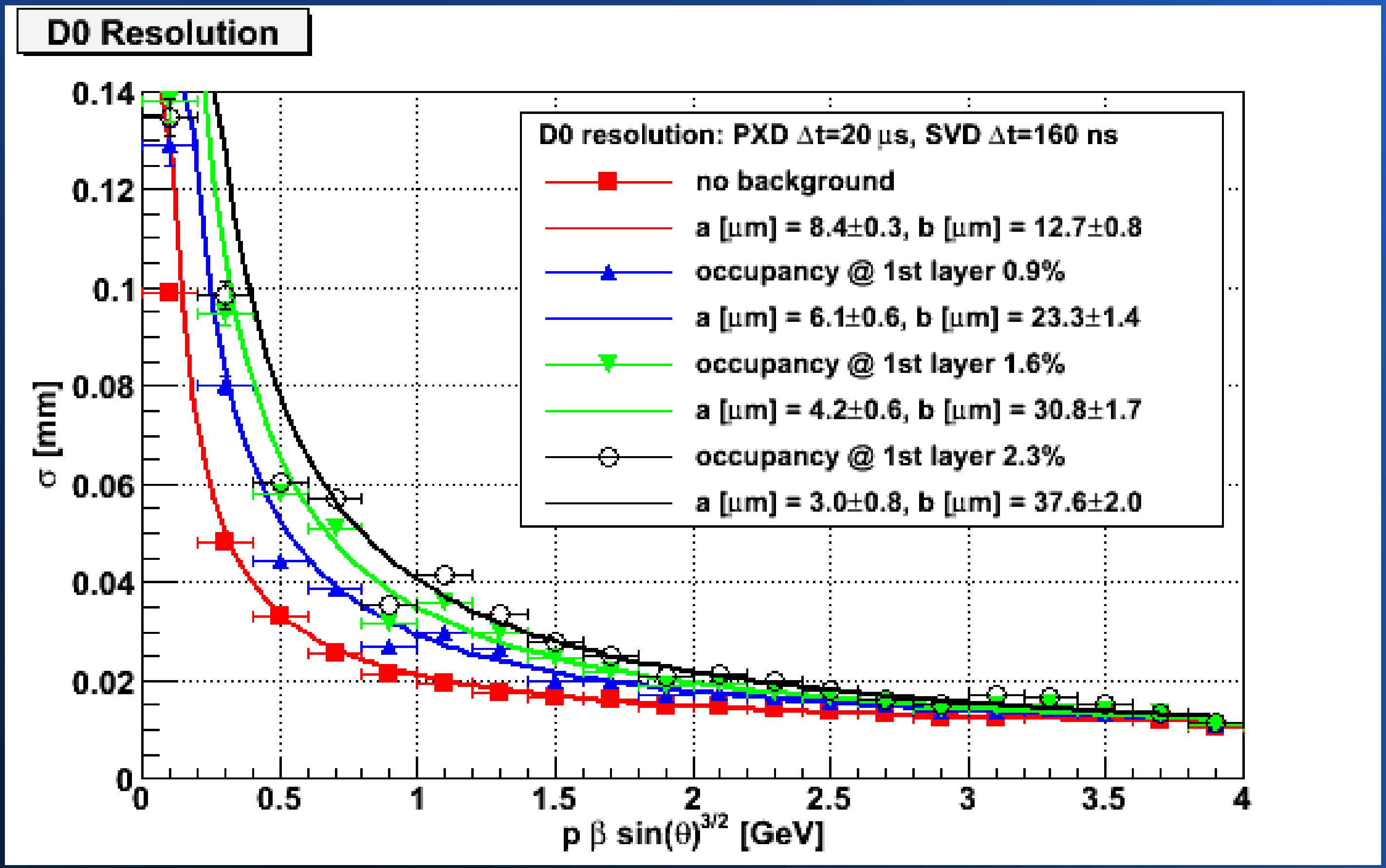


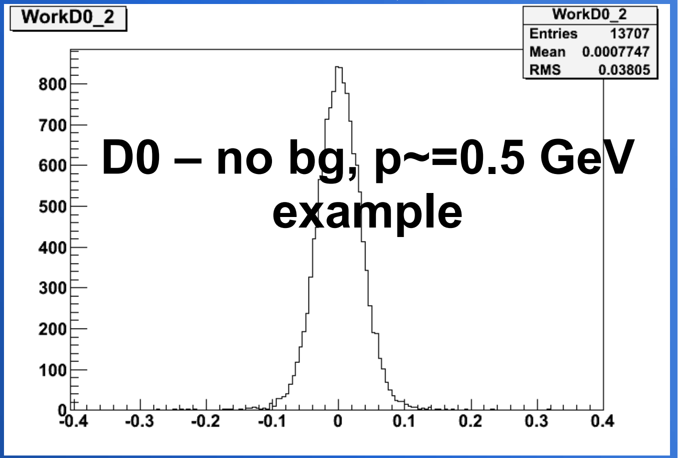


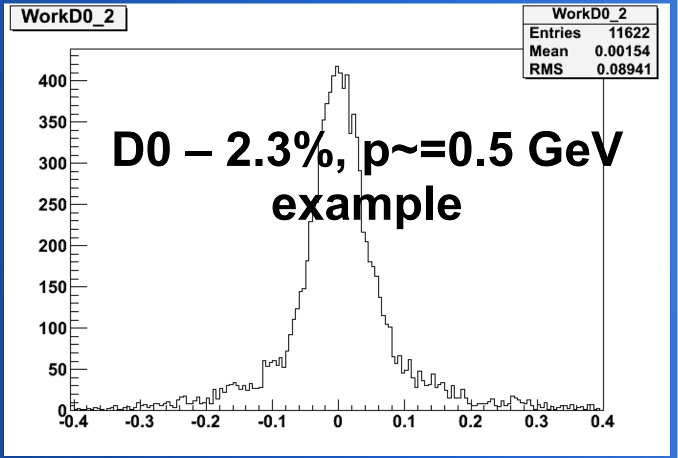


Results: D0 Impact Parameter Studies

- Tracking in PXD + SVD – fit with: $\sigma = a \oplus b/p^{\sim}$ ($p^{\sim}$ = pseudomomentum)

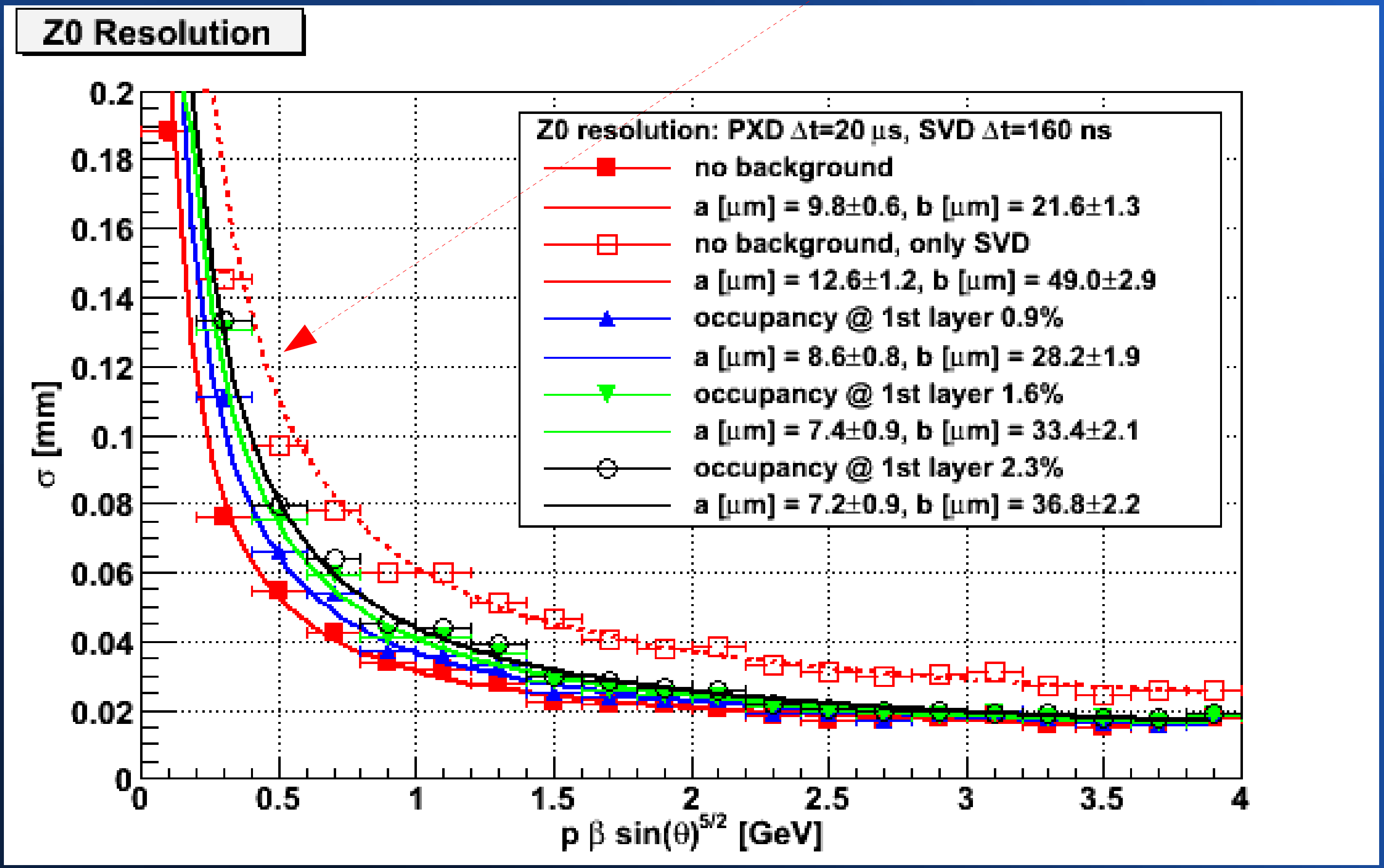


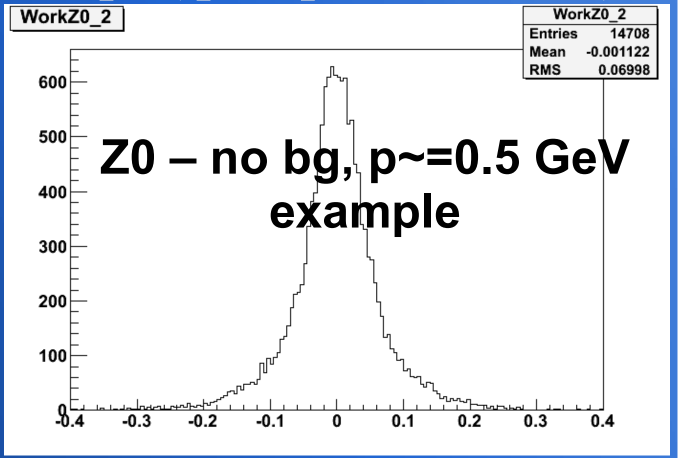


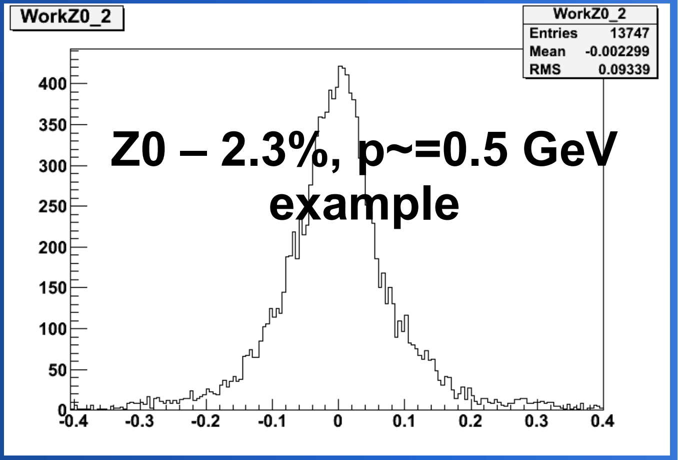


Results: Z0 Impact Parameter Studies

- Tracking in PXD + SVD X SVD only – fit with: $\sigma = a \oplus b/\tilde{p}$ ($\tilde{p}$ = pseudomom.)

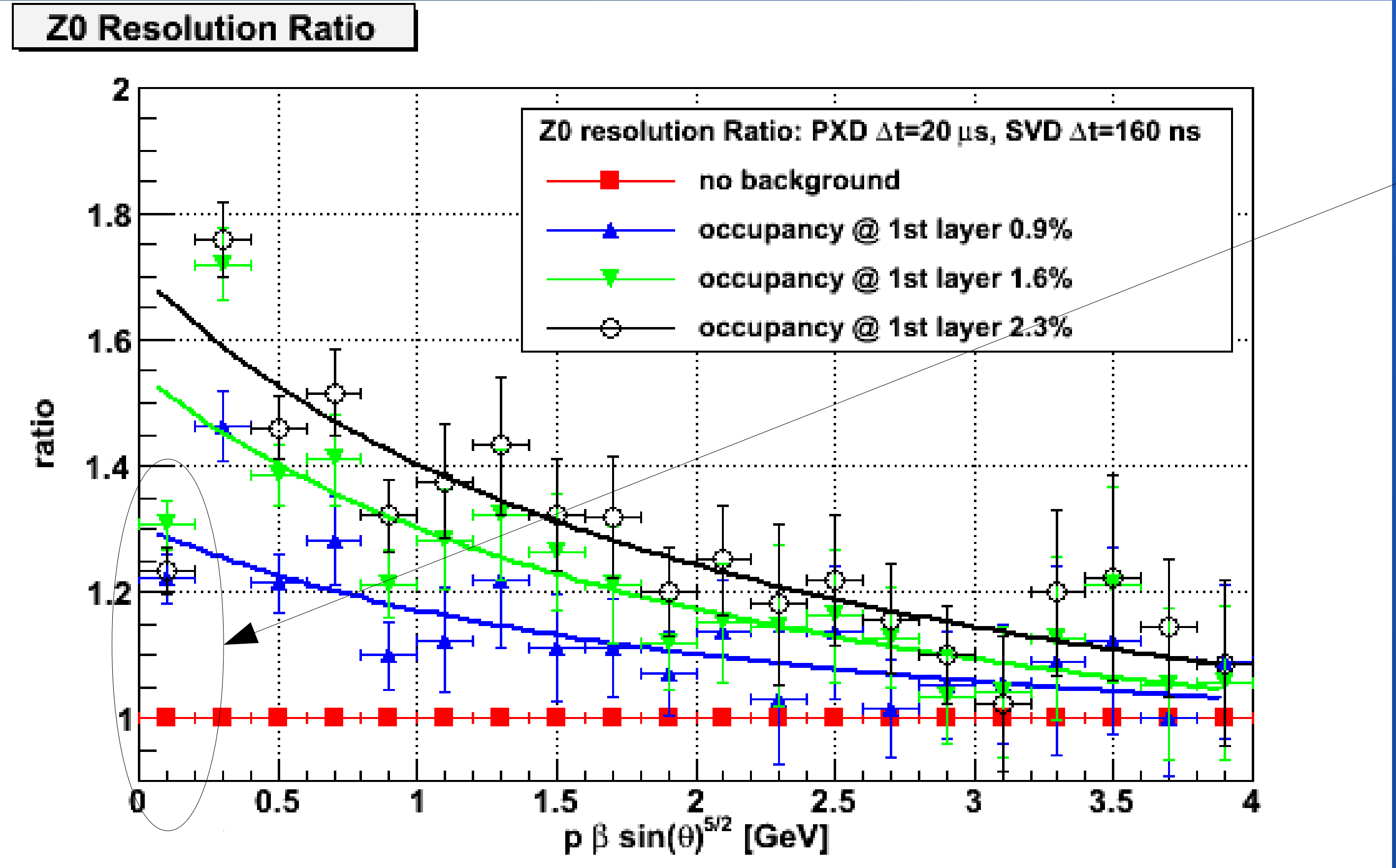






Results: Impact Parameter Ratios

- Ratio of Z0 imp. parameters for different levels of QED background→curve obtained as a ratio of the curves from the Z0 fits → resolution degrades by tenths of percent!



- Results for relatively low pseudo-momenta seem to be biased → could be explained by unreliable Si tracking in low energy region
- Other results – within the error in very good agreement with the fit
- Degradation is pseudo-momenta dependent
- D0 fit reliable only in simulated energy window (const. term is dependent on bg. level, which shouldn't) → only Z0 param. shown ...

Conclusions

- PXD performance @ high QED occupancies studied:
  - In order to see the limits, the SVD time window set to 160 ns (pulse time over threshold), the real time window might be dependent on the background level (pulse piles-up effect), without the pile-up 20 ns time window achievable → PXD performance under those conditions shown at 7th B2GM: no significant degradation in resolution seen (SVD track picks up the correct PXD hit(s) when extrapolation performed)
  - Due to “SVD tracking only & extrapolation to PXD detector” algorithm, the PXD helps even for relatively high occupancies ~ 2.3% @ 1st layer (wrt SVD standalone tracking)
  - The degradation in Z0 impact parameter is pseudomomenta dependent (energy & ϑ angle dependent) and appears to be at the level of tens percent, for 0.9% occupancy @ 1st layer it stays below 25%