VXD Upgrade information

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26/10/2020

Upgrade Belle II France

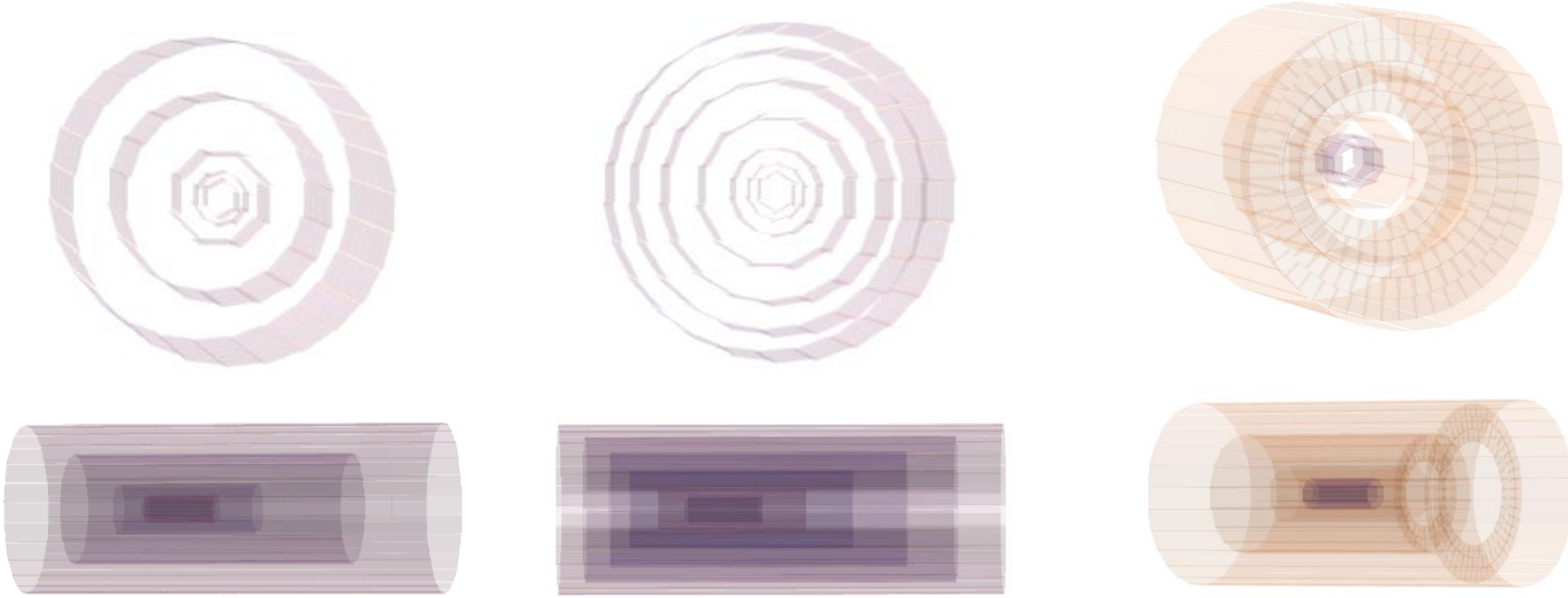
New geometries implemented

- **VTX software upgrade working group**: T. Fillinger, T. Lueck, B. Schwenker, C. Wessel
  - Integrate a new CMOS vertex detector (VTX) into the Belle II software framework
  - Re-use / extend as much of the common software infrastructure as possible
  - Upgrade software developed on separate branch in main repository, no interference with master for Belle II (But the upgrade branch is synced with main branch every few weeks)

- **Confluence page**: https://confluence.desy.de/display/BI/Full+simulation+effort
- **Upgrade branch**: https://stash.desy.de/projects/B2/repos/software/browse?at=refs%2Fheads%2Fupgrade

- 3 new "**VTX**" (*Vertex*) geometries proposed, implemented and connected to existing tracking:

CMOS 5 layers | CMOS 7 layers | CMOS 5 layers + forward discs

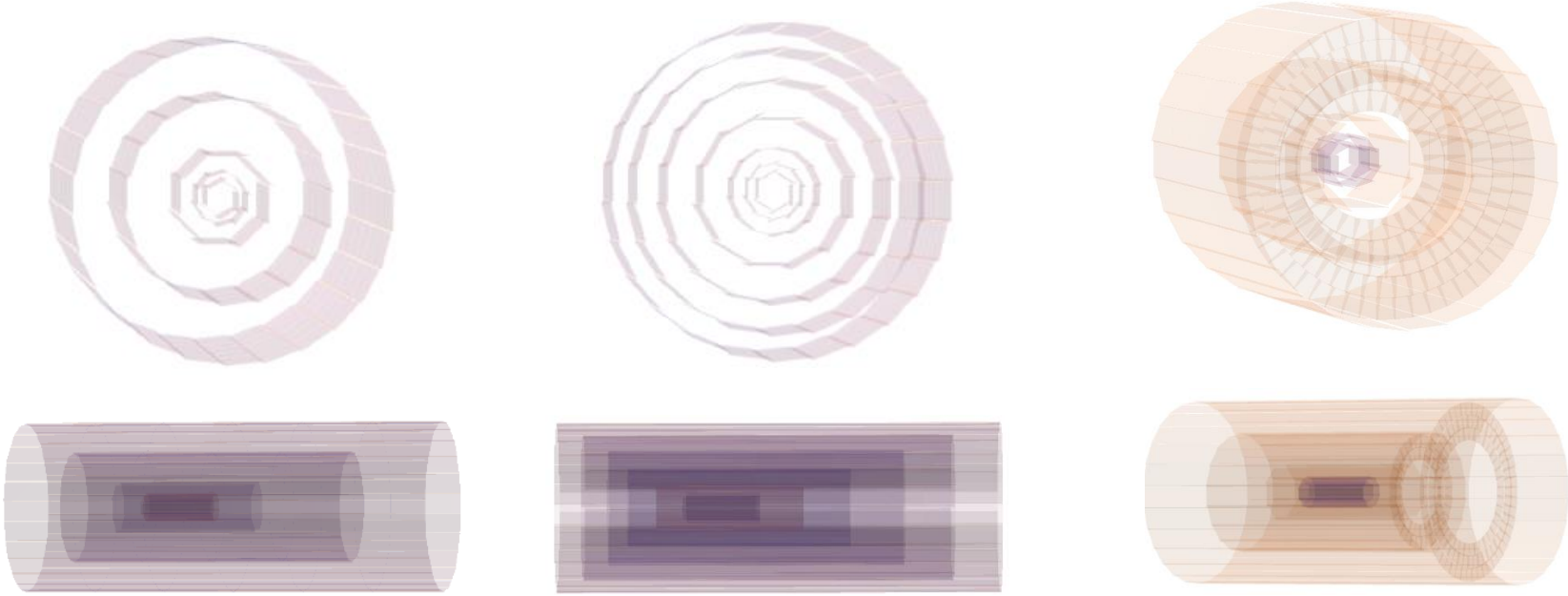


New geometries implemented

- Requirements for the sensors:
  - **Reconstruct the primary vertex:**
    - Radius: first layer at 1.4 cm
    - Material budget: 0.1% / 0.3%
    - Pitches: 33x33 µm
    - Power dissipation < 200 mW/cm²
  - **Acceptance**
    - Radius: last layer at 14 cm
    - Length: from 12 cm to 72 cm
  - **Cope with the high beam-induced background**
    - Integration times < 100 ns

- 3 new "**VTX**" (*Vertex*) geometries proposed, implemented and connected to existing tracking:

CMOS 5 layers | CMOS 7 layers | CMOS 5 layers + forward discs

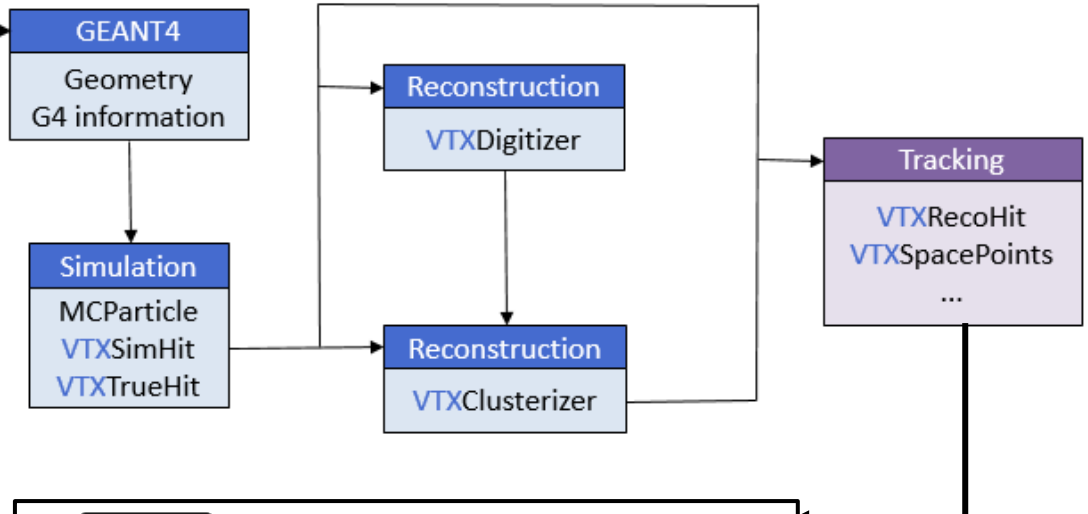


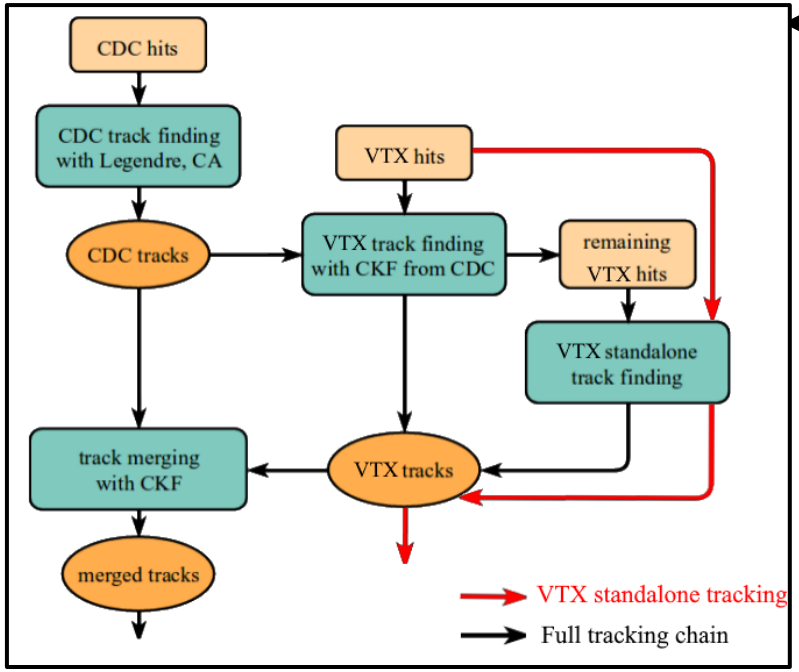
VTX package

- # layers
- layer radius
- # ladders
- angles btw ladders
- shift
- # sensors / ladder
- materials
- size
- active area prop (size, #px..)

in .xml files

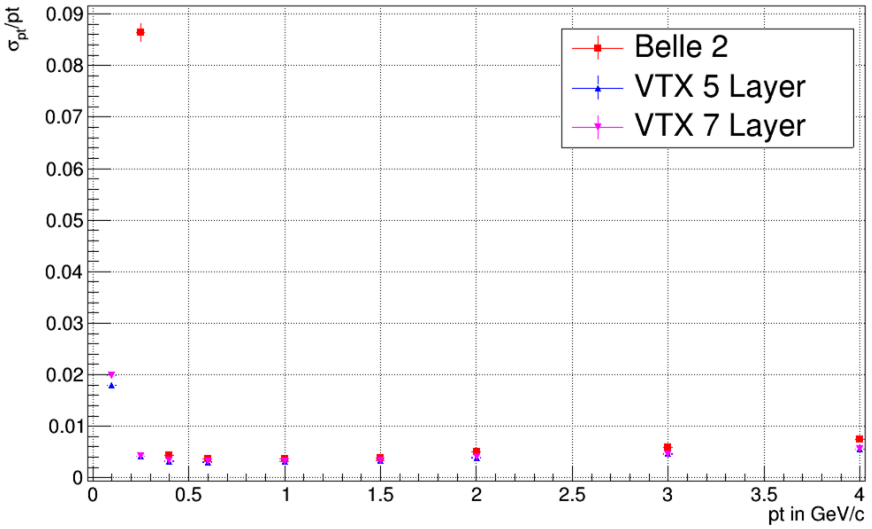
Global tags with the geometries also available



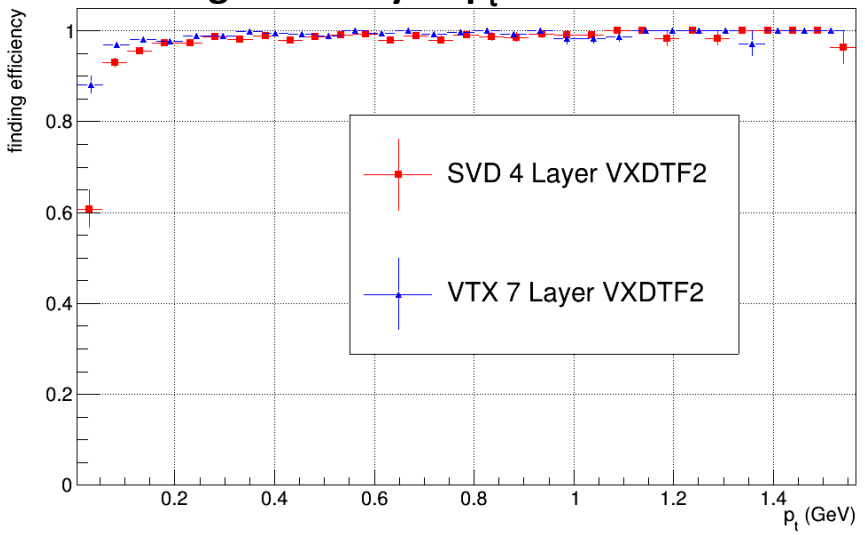


Standalone performance

- **Transverse momentum resolution vs p_t**



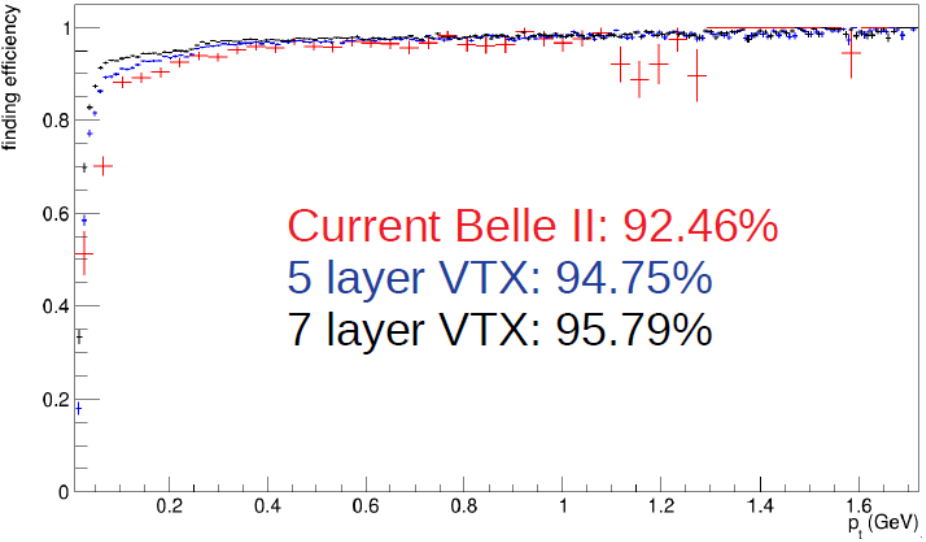
- **Finding efficiency vs p_t**



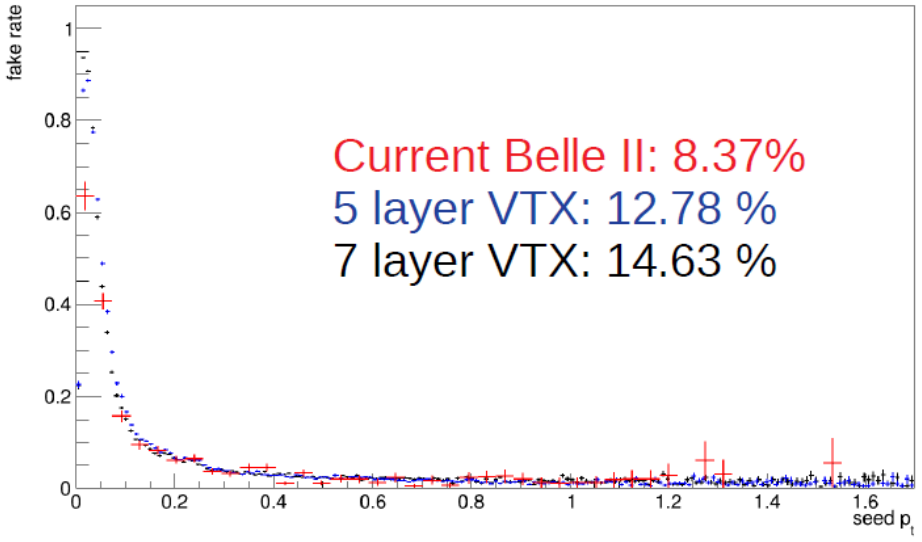
- Better standalone tracking performances than current VXD.
- VTX best resolution at low p_t.
- Similar high finding efficiencies.

Full tracking performance

- **Finding efficiency as a function of p_t**



- **Fake rate as a function of p_t**



- Better full tracking performances than current VXD.
- Slightly higher fake rate.
- Results are promising and the tools are here to study the impact of the different characteristics of the sensors and the geometries.

Use VTX for benchmarks: Remarks

- **Everything still work in progress:**
  - Currently no fixed releases (but can be easily done) nor install via cvmfs, you need a full local installation and the upgrade branch (and we will not merge to master anytime soon).
  - No way to run on the grid if no release, only via bsub on KEKCC.
  - No common place from where to provide produced samples or bkg files (everything is in our personal directories under KEKCC).
  - The background sample produced so far are small, targeting to run with tracking validation scripts. For analysis sample we need more bkg files produced at KEKCC
  - The VTX (+ CDC) reconstructed tracks are written into the mdst dataobjects. No one ever tried yet to run an example analysis with this. (Benjamin will do some test in the coming week).
  - For sure all payloads for MVA based analysis tools will be missing.

Use VTX for benchmarks: How to

- **Use the upgrade branch** https://stash.desy.de/projects/B2/repos/software/browse?at=refs%2Fheads%2Fupgrade

- **Environment variables that should be set from command line before running the script:**

```
export BELLE2_VTX_UPGRADE_GT=  upgrade_2020-09-22_vtx_5layer
                               upgrade_2020-09-22_vtx_7layer
                               upgrade_2020-06-24_vtx_5layer_discs
```

export BELLE2_VTX_BACKGROUND_DIR=

```
/group/belle2/users/benjamin/overlay_vtx_5layer/upgrade_2020-09-22_vtx_5layer/phase3/BGx1/set0
/group/belle2/users/benjamin/overlay_vtx_7layer/upgrade_2020-09-22_vtx_7layer/phase3/BGx1/set0
5layer+discs: In production
```

- **In your simulation files, add at the beginning:**

```
from vtx import get_upgrade_globaltag, get_upgrade_background_files
b2.conditions.disable_globaltag_replay()
b2.conditions.prepend_globaltag(get_upgrade_globaltag())
```

- **Later**:

```
add_simulation(main, bkgfiles=get_upgrade_background_files(), useVTX=True)
add_reconstruction(main, useVTX=True)
```

- **That's it!**

- **Example from validation**: Full Tracking chain: fullTrackingValidationVTXBkg.py
  Standalone tracking: vtxTrackingValidation.py

Conclusion

- Three geometries are implemented in BASF2 and fully connected to tracking
- Validation results are promising
- As we re-use as much of the common software infrastructure as possible
  → Easy to adapt scripts to use VTX
- Everything still **work in progress**
- **All the information here:**

https://confluence.desy.de/display/BI/Full+simulation+effort

Thank you for your attention

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Upgrade Belle II France

Backup

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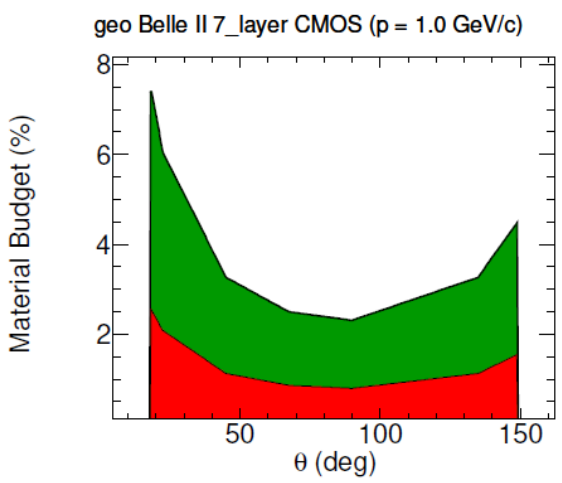
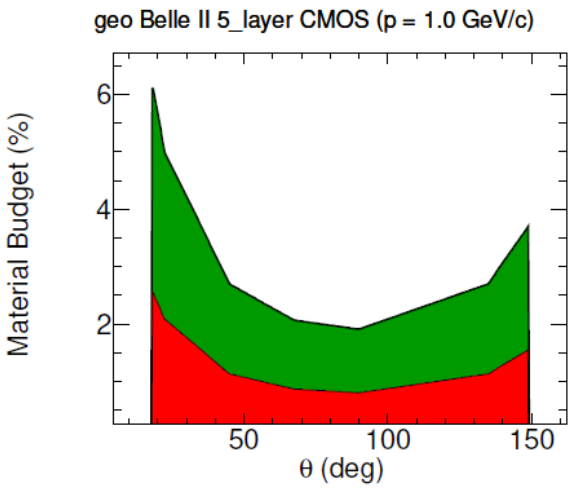
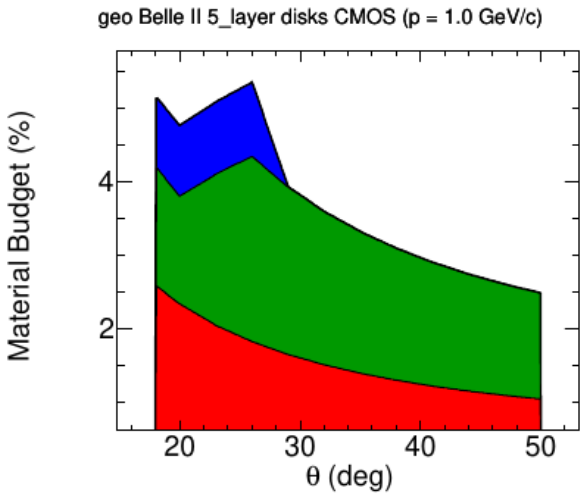
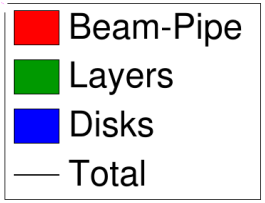
Material budget of the VTX

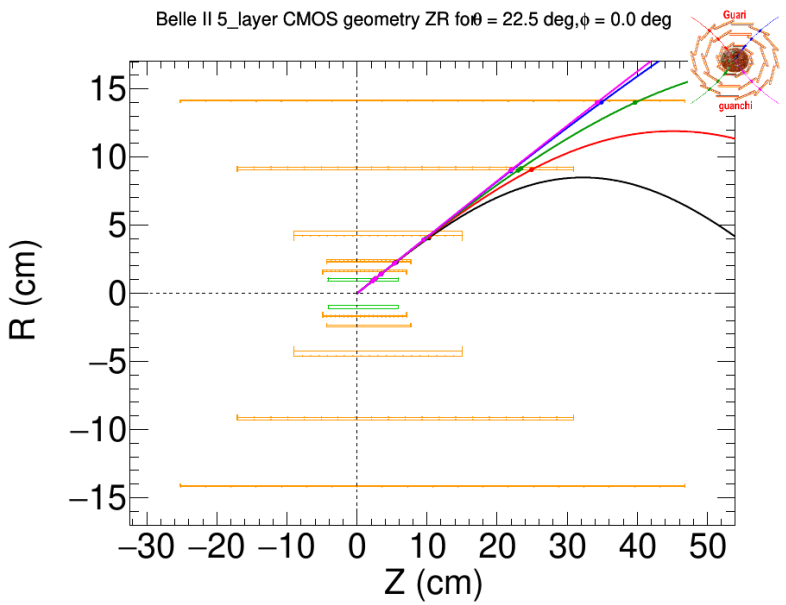


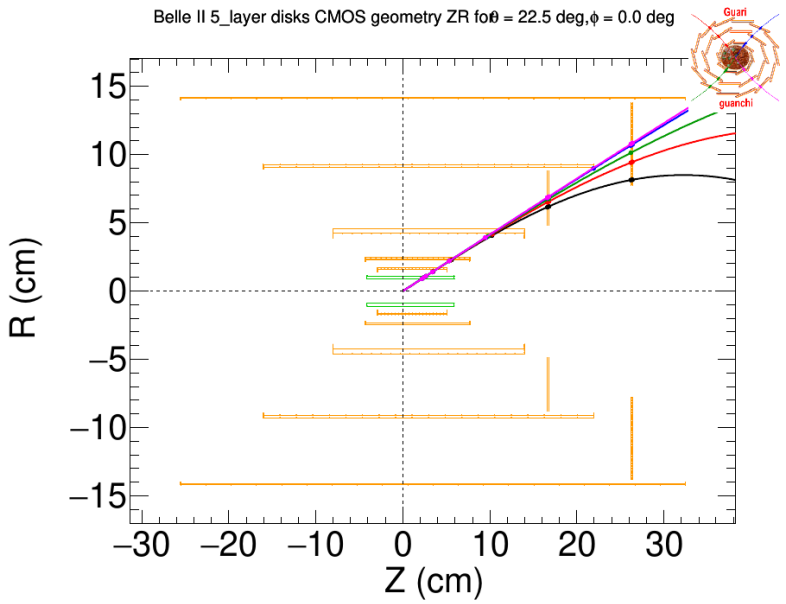




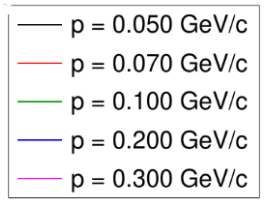


Material budget of the VTX





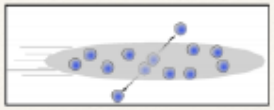
- Geometry with disk increases acceptance for low momentum tracks at small angles but according to simulations, performances doesn't improve compared to CMOS 5 layers.



Background production

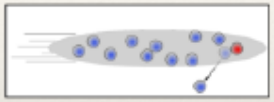
Machine background

Touschek scattering: single Coulomb scattering event between two particles of the same bunch, that are lost.



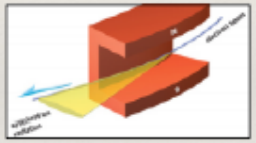
$$R_{Tou} \propto \frac{1}{\sigma E^3 n_b} I_{beam}^2$$

Beam-gas scattering: Coulomb elastic scattering or bremsstrahlung with residual gas atoms.



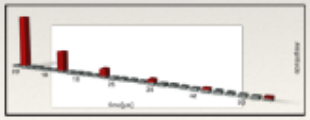
$$R_{bg} \propto IP$$

Synchrotron Radiation (SR): photon emission from beam particles when subject to acceleration.



$$W_{SR} \propto \frac{E^4}{\rho^2}$$

Injection background: injected bunch performing betatron oscillation around the stored bunch, resulting in particle losses especially in the interaction region.

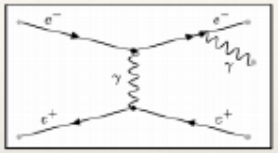


$$R_I \propto R_{inj}$$

Luminosity background

Radiative Bhabha: neutron production from emitted photons (shields used for mitigation); off-energy primary particles lost in final focus magnets.

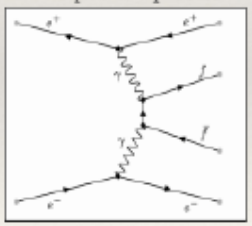
Radiative Bhabha



$$R_{RB} \propto L$$

Two photons process: low momentum electron-positron pairs that can generate multiple hit in the VerteX Detector.

Two photons process



$$R_{RB} \propto L$$

- New geometry requires new production of Bkg files
- Production of simulated background hit for overlay on KEK cluster
  - Not many files needed for checking validation plots.
- Adaption of scripts checked with Bkg librarian
  - For nominal Belle II BG (x Scale)
  - Detailed Belle II MagneticField
  - Current accelerator simulation (SAD files, 17th campaign)
  - Generator for rad. Bhabha and Two photon process
  - Simulated hits passed to VTX digitizer

Improved VTX Digitizer

Based on digitizer for DEPFET pixels in the Belle II software. Refactored code for charge collection and digitization. Blue parameters adjustable.

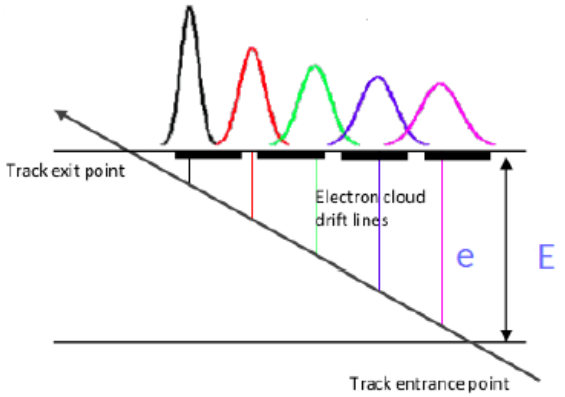
- Check if the particle hit is inside the integration time window T_{int}
- Split the path of the particle in the VTX active thickness E into segments and drift the charges from the center of each segments.
  - The transverse diffusion (coefficient D) follows a gaussian with a width defined as :
    sigmaDiffus = sqrt (D * e /2)

- Integrate charges per pixel and add the noise to the charge
- Subtract hit threshold
  Charge -= chargeThreshold

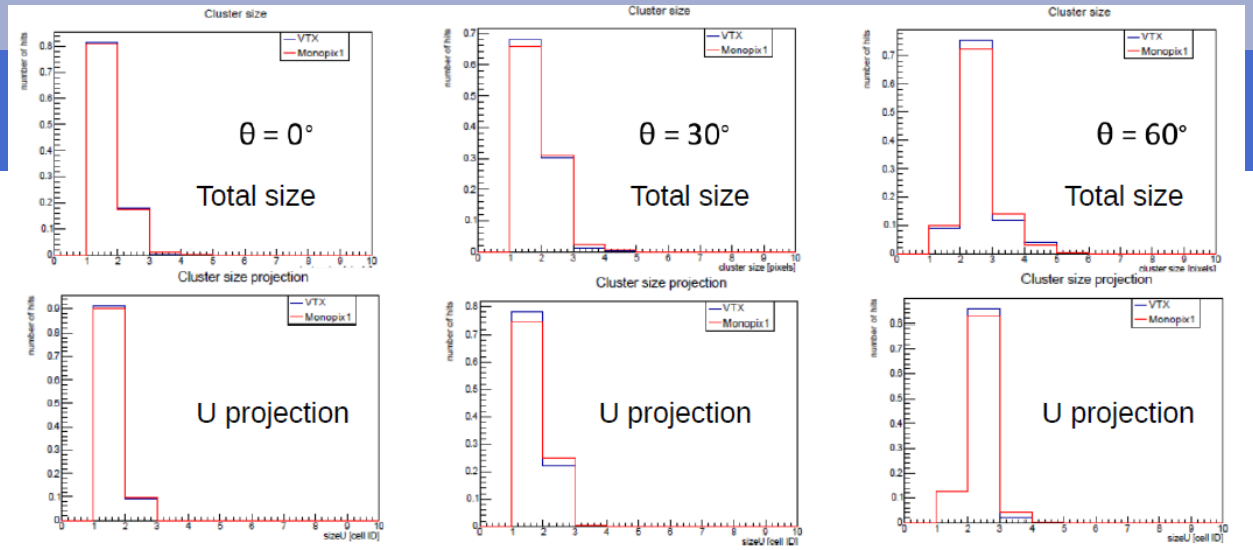
- Check if Charge > 0
- Amplify and digitize charge
  Charge = Charge/ ElectronToToT

- Clipping of ToT codes
  Charge = charge % MaxToT

- Store the digit



Digitizer



Monopix1 : test beam results