UII Global Optimisation Framework
Future VELO Scenarios

29/03/23

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+ Tim, Laurent, Kazu & many others…

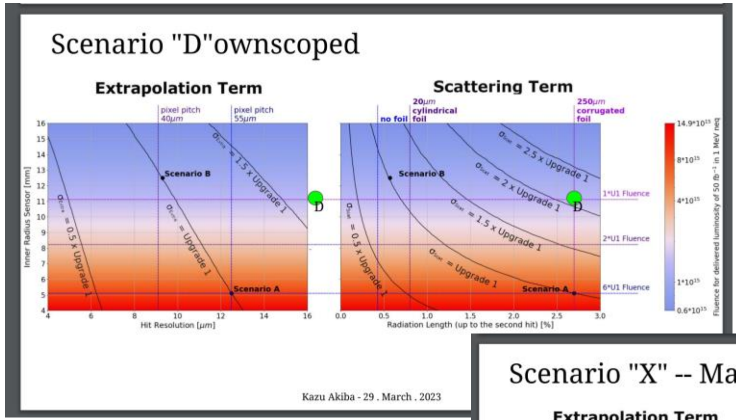
Global Optimisation Simulation Tool

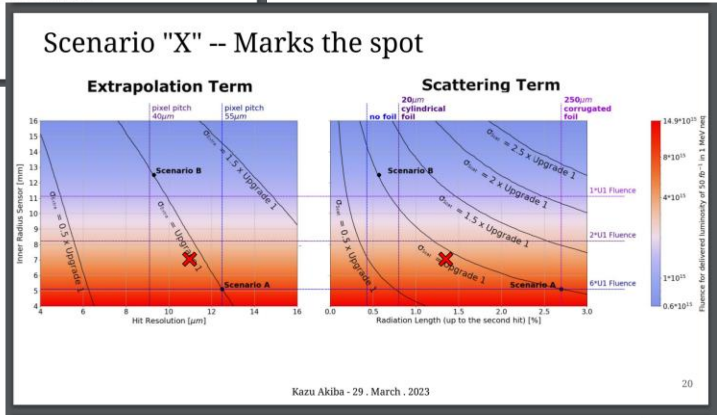
<u>Aims</u>

- Create tool to **evaluate global physics performance as well as individual sub-detector metrics** after geometry changes in a quick and consistent way
- Use the latest and greatest simulation versions and detector models as baseline
- Use LHCb core software where possible (Gauss, Moore)

<u>This Presentation</u>

- Developments made within the VELO UII Simulation group applying these aims to iterate on VELO designs
- Specifically **Scenario A vs B vs D(escoped)**
- How this can extend beyond the VELO



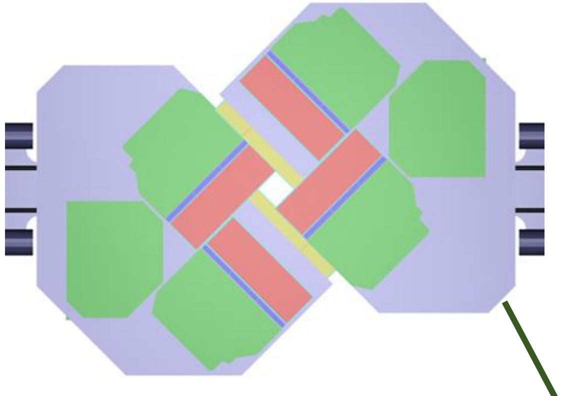


See [Kazu's talk](#)for more info on the specifications behind these scenarios…

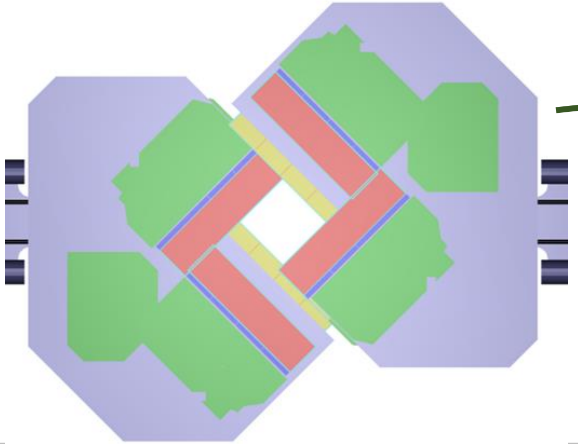
Adaptable Simulation Chain

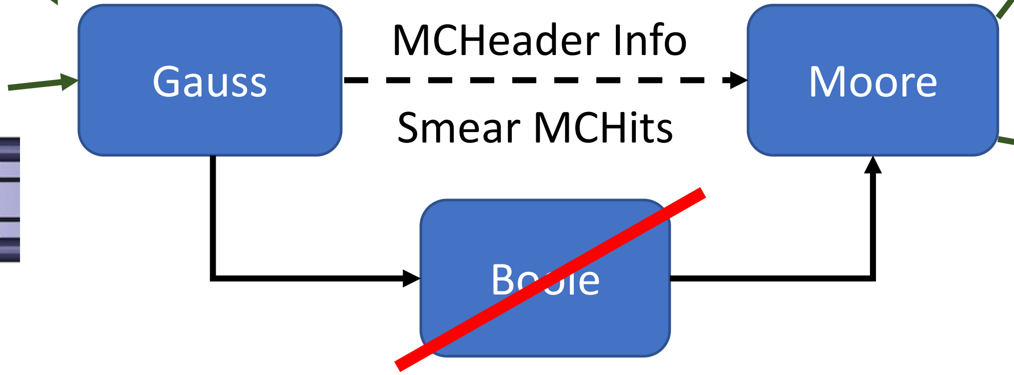
- Chain packaged into one repo with installation instructions
- Works with lb-stack-setup
- Custom Gaussino, LHCb, Rec Branches

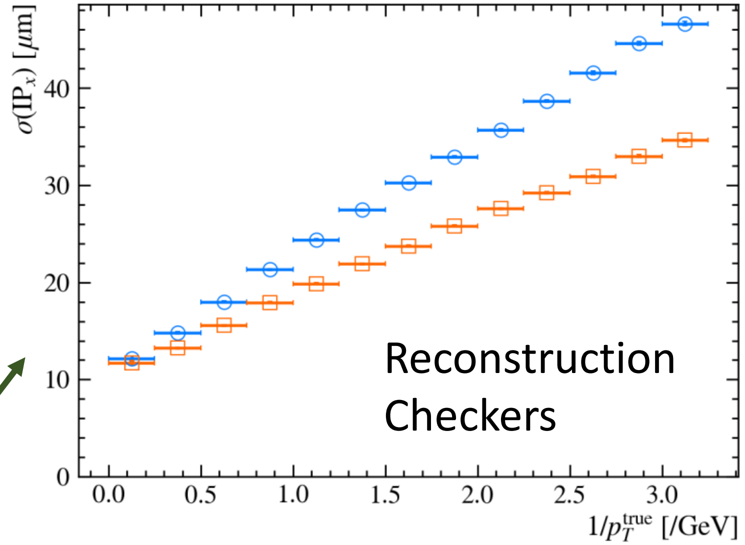
- Gauss-on-Gaussino w/ **Sim 11 & DD4Hep**
- Boole is skipped using "**Fake Clustering**"
  - Run Moore directly on Gauss output
  - Input (σ_{xy}, σ_t) -> Smear Hits -> Fake Clusters -> Tracks
  - Fitted tracks emulated using downstream momentum parameterisation
- Output a combination of **standard reconstruction checkers** + a "U2 Tuple" that allows flexible analysis + **physics reconstruction** if run with specific event types.

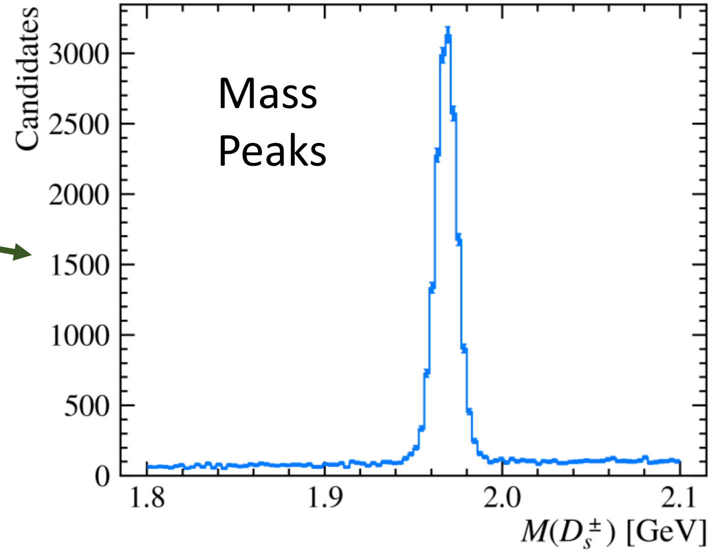


Different Geometries







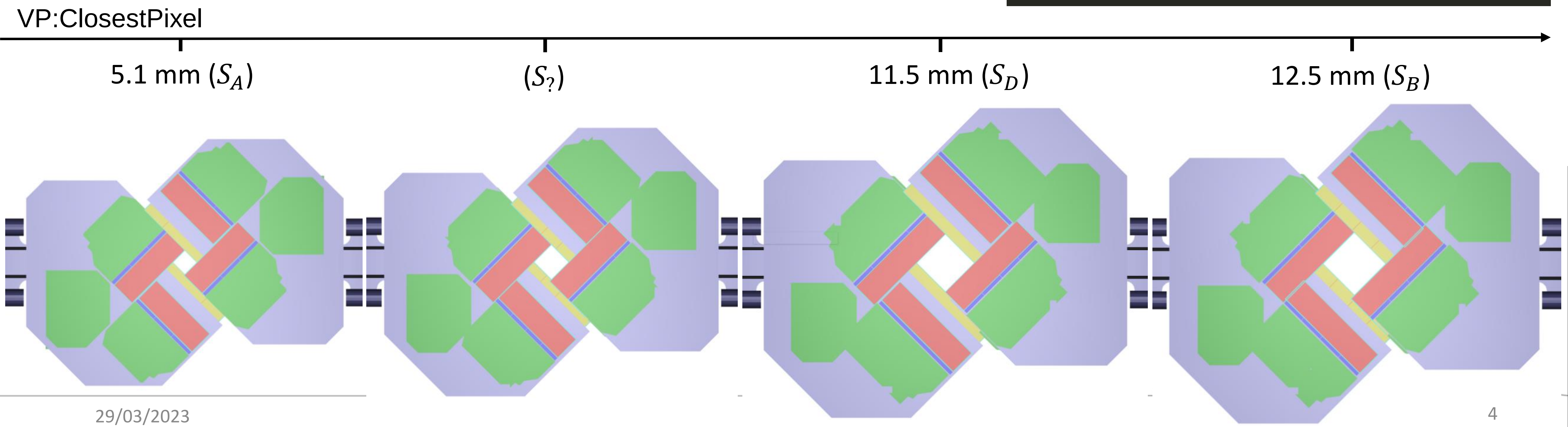


Parameterised VELO Model

- [Parameterised S_B Detector Branch]

- UI Velo model adapted to allow quicker development of "Scenarios"
- **Cylindrical Foil** used (if not studying U1 geometry) to speed up iteration
- Geometry controlled by 5 main parameters:
  - **Closest Sensor to IP** (5.1 mm for UI)
  - **Pixel Pitch** (55 μm for UI)
  - Number of ASICs
  - **Cylindrical Foil thickness** & clearance from closest sensor
- Individual rotation of station about z-axis also possible

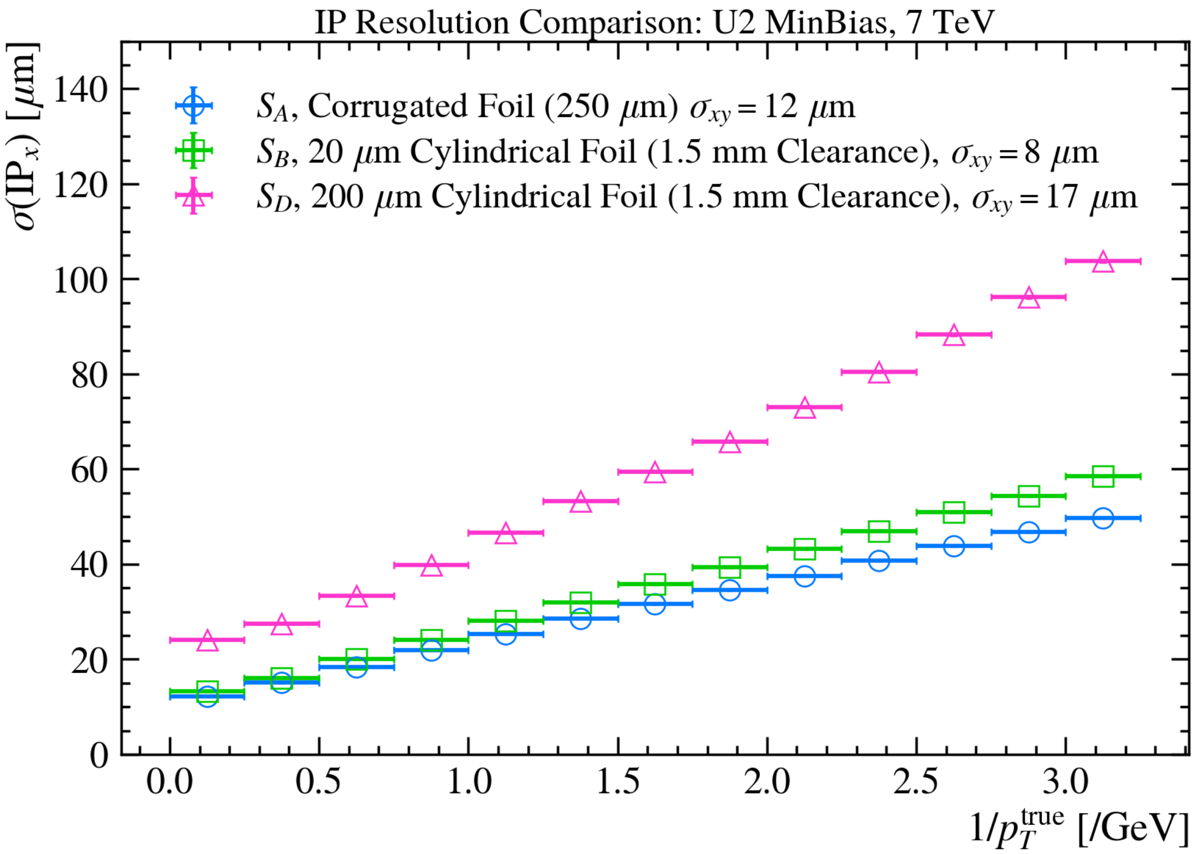
```
<!-- DEFINING PARAMETERS -->

<constant name="VP:ClosestPixel"        value="12.515*mm"/>

<!-- Pixel size -->
<constant name = "VP:PixelSize"         value = "0.040*mm"/>

<!-- Target Number of Chips, set to 0 for auto-->
<constant name = "VP:TargetNChips"         value = "0"/>

<!-- For the Cylindical Foil, placed here for convinience -->
<constant name="VP:CylindRFFoilThickness" value="0.020*mm"/>

<!-- Distance from closest pixel to foil -->
<constant name="VP:CylindRFFoilClearance" value="1.5*mm"/>
```

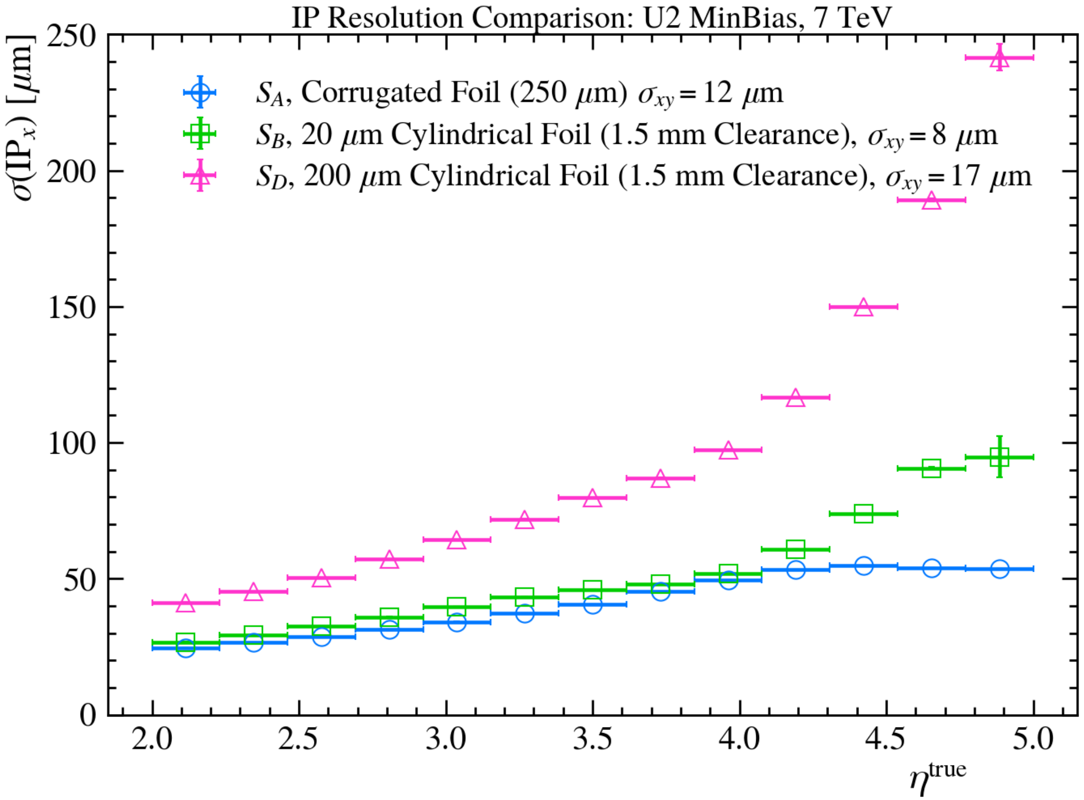


IP Resolution

Properties ↓ Scenario →	S_A	S_B	S_D
Inner Radius (Closest pixel)	5.1 mm	12.5 mm	11.5 mm
Pixel Pitch (Hit Resolution)	55 (12) μm	40 (8) μm	60 (17) μm
Timing Resolution	50 ps	50 ps	200 ps
Foil Type	Corrugated	Cylindrical	Cylindrical
Foil Thickness	250 μm	20 μm	200 μm

- Scenario A & B clearly outperforming D
- Scenario B reliant on UTF (Ultra-Thin-Foil)





Vertex Reconstruction Efficiency

Properties ↓ Scenario →	S_A	S_B	S_D
Inner Radius (Closest pixel)	5.1 mm	12.5 mm	11.5 mm
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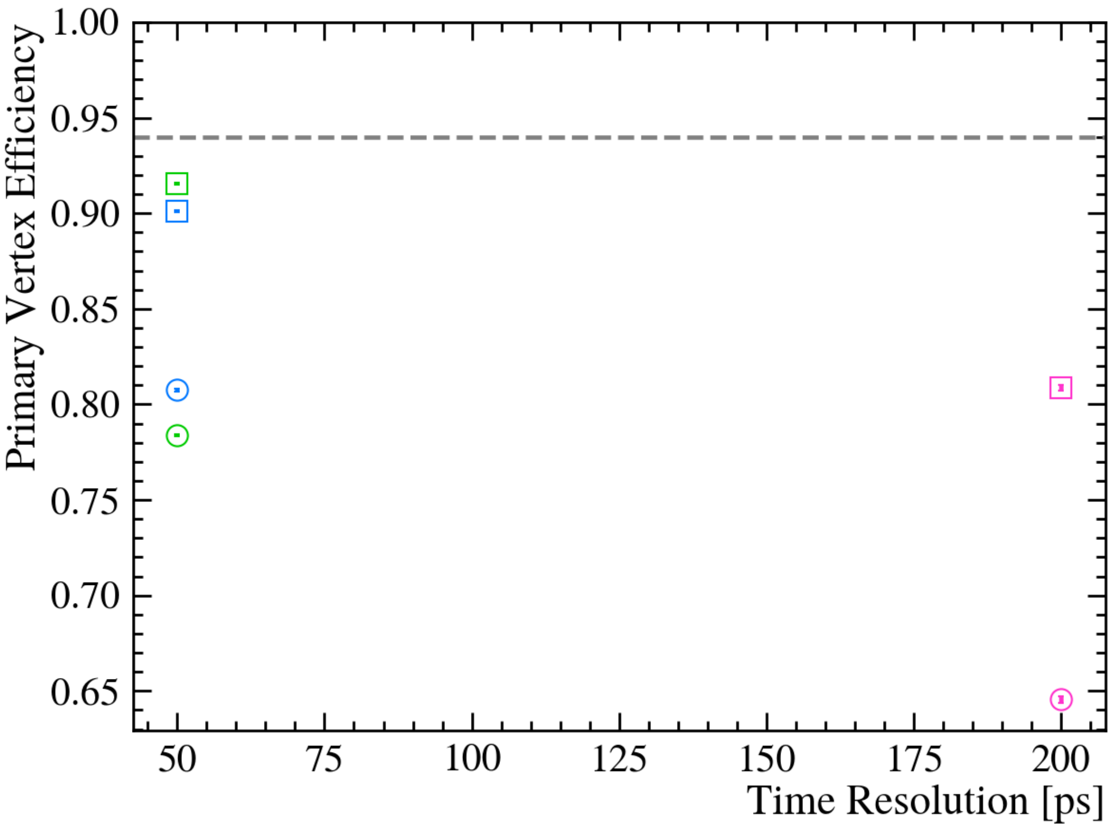
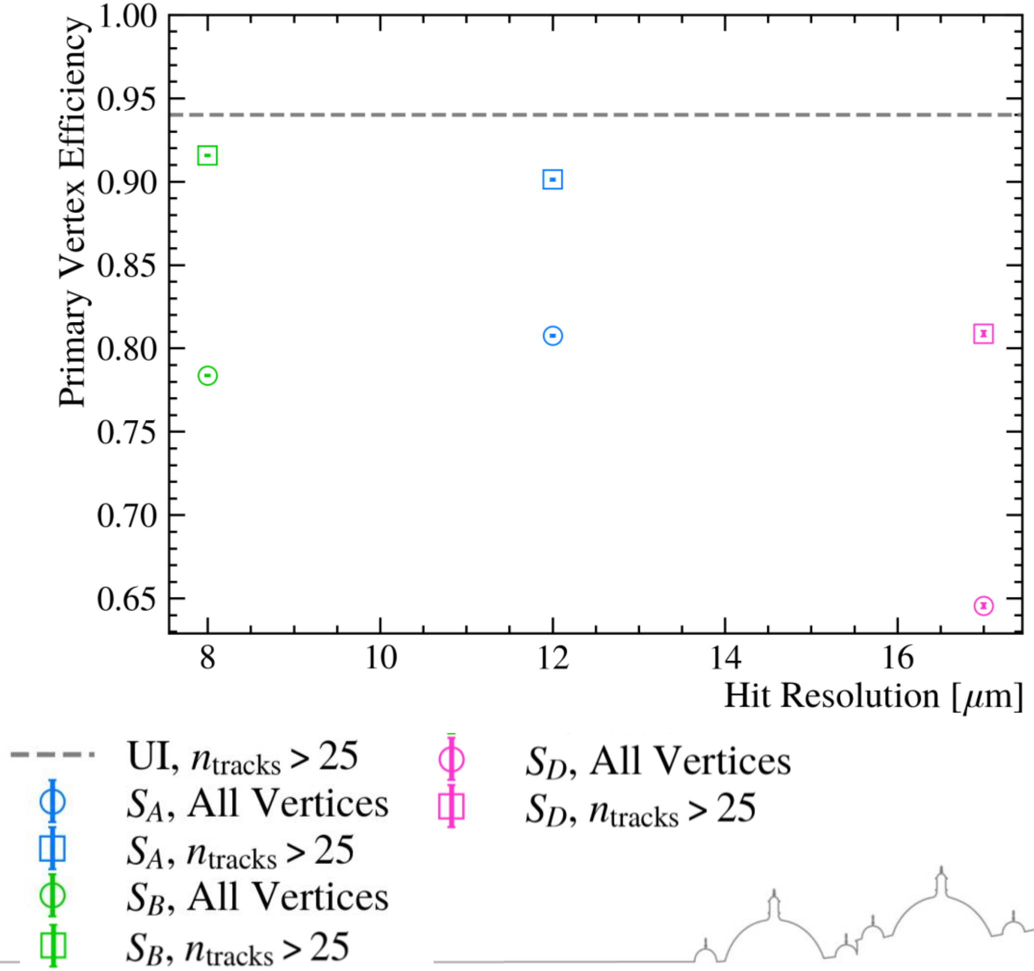
- Retaining near-UI primary vertex efficiency reliant on timing, scenario D would lead to significant degradation.
- Flexible chain, Moore can be re-run with any (σ_{xy}, σ_t) to optimise Scenarios.

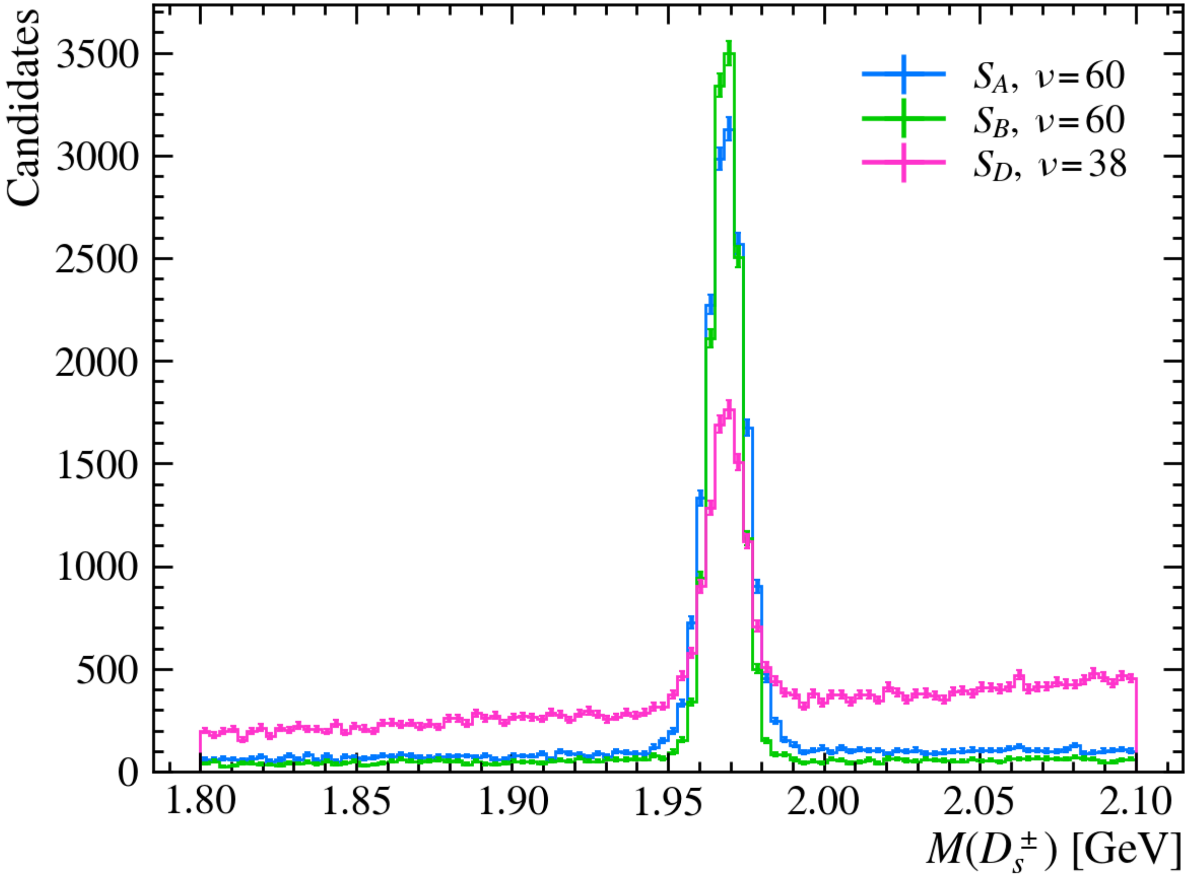
S_A/S_B: ν = 60
S_D: ν = 38

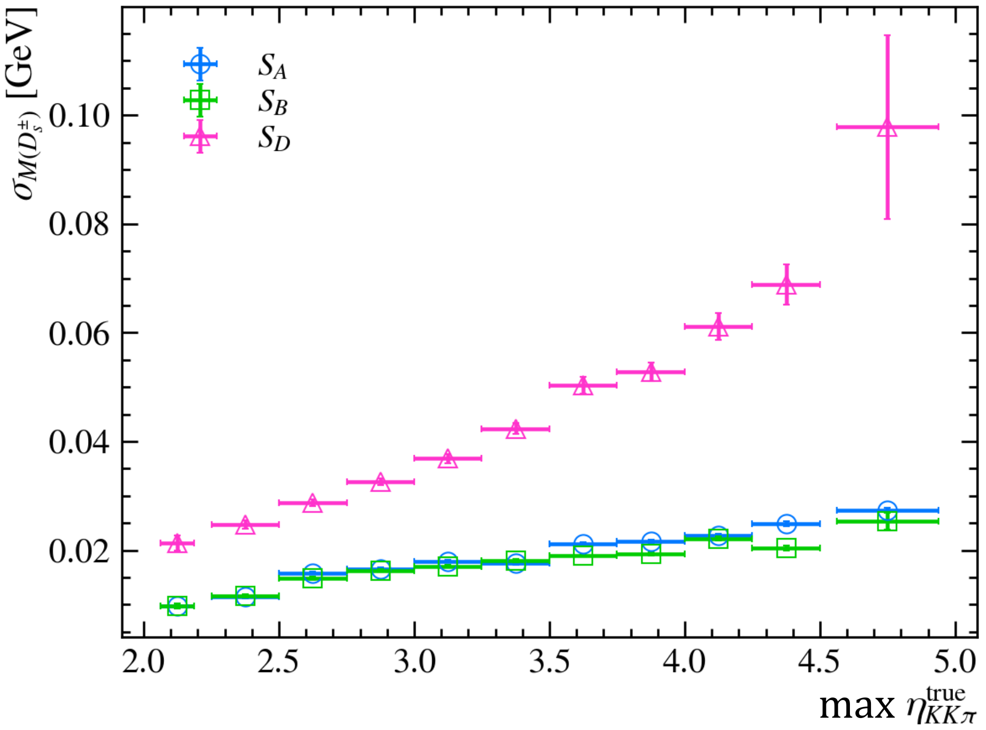




$B_s^0 \to D_s^{\pm}(\to K^+K^-\pi^{\pm})\pi^{\mp}$ Reconstruction

- Event type: 13264021
- Assume perfect PID on final state particles
- **50K Events generated** (ν = 60 for S_A/S_B, ν = 38 for S_D)
- Loose selection applied
- **“Combinatorial background” from other pile-up PVs**





- **Smaller pitch in S_B recovers mass resolution**
- S_D resolution consistently poor

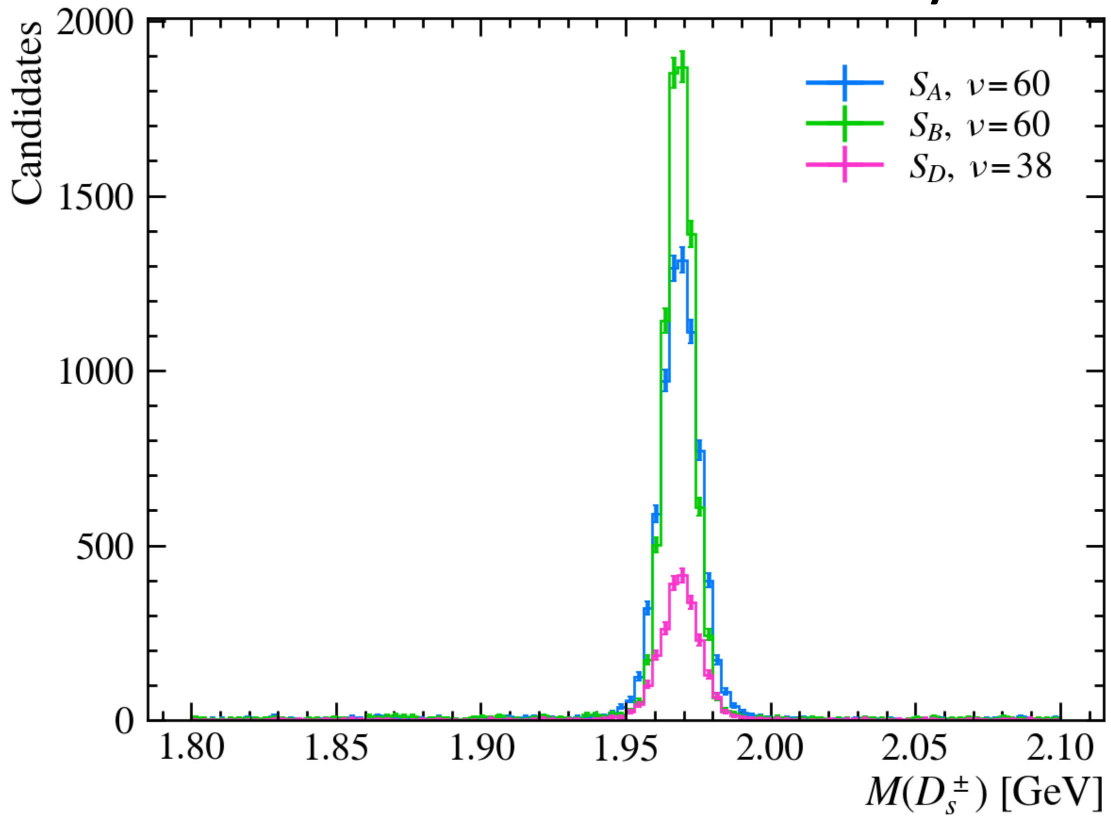
Selection Purity, p_T^{min}

- Fix **Sample Purity to 95%** by cutting on **p_T^{min} of $D_s^{\pm}$ children**
- Compare $\epsilon_{\text{Signal}} = N_{\text{Selec}}/N_{\text{Gen}}$

Results ↓ Scenario →	S_A	S_B	S_D
p_T^{min} Cut (Purity = 95%)	796 MeV	741 MeV	1176 MeV
Signal Efficiency **(Purity = 95%)**	**14.8 ± 0.2 %**	**16.2 ± 0.2 %**	**4.53 ± 0.09 %**
p_T^{min} Cut (Purity = 90%)	576 MeV	531 MeV	891 MeV
Signal Efficiency (**Purity = 90%**)	21.1 ± 0.2 %	21.7 ± 0.2 %	7.0 ± 0.1 %

- **Comparison between scenarios important**, absolute numbers less so
- Lose significantly more signal candidates with S_D to achieve same purity
- Plans to repeat this for other cut strategies (IP_t, $IP\chi^2_{4D}$)
- **Can be evolved into a tool for a trigger rate study**

Purity = 95%



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Geometric Acceptance

Properties ↓ Scenario →	S_A	S_B	S_D
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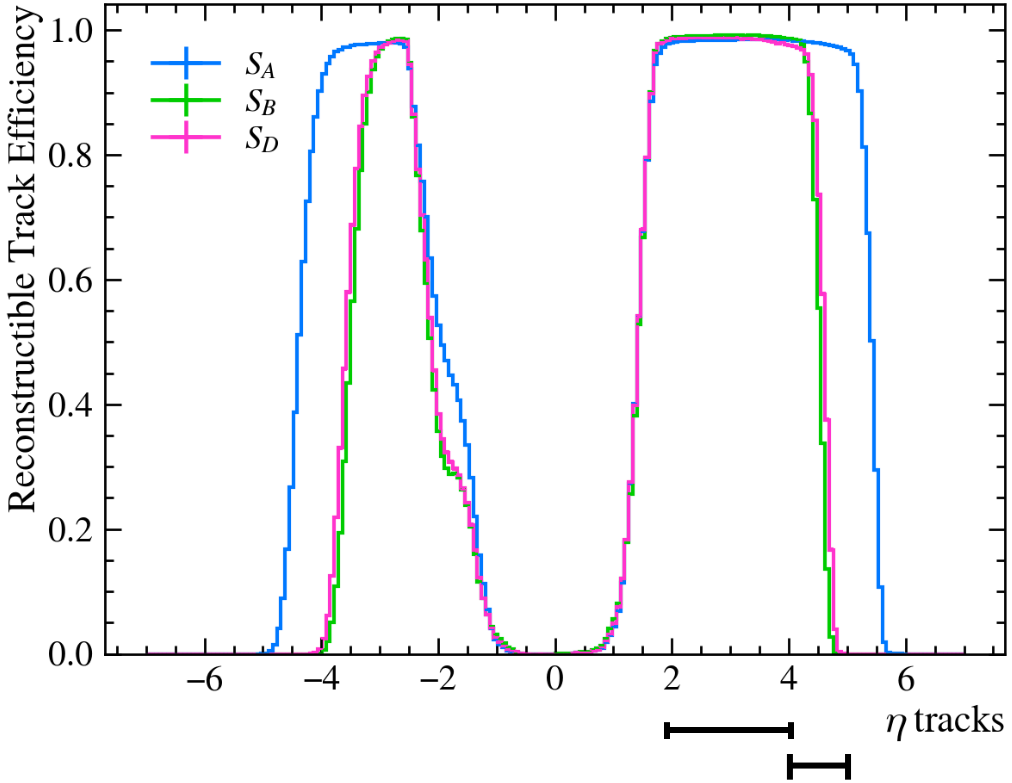
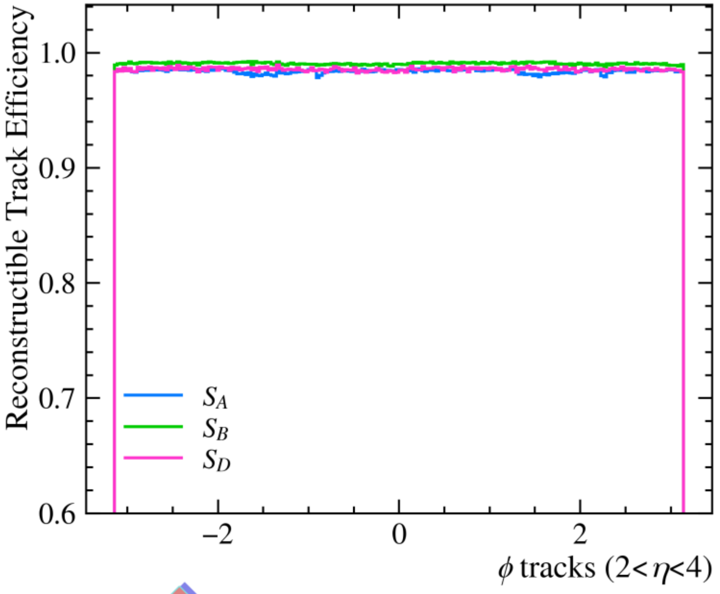
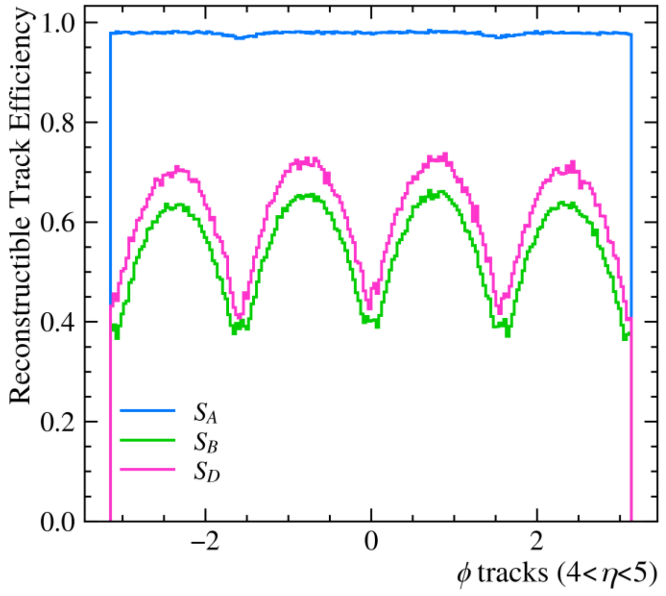
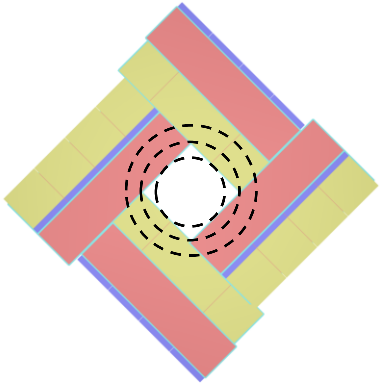
- Increased radius in S_B & S_D reduces acceptance at high η as expected





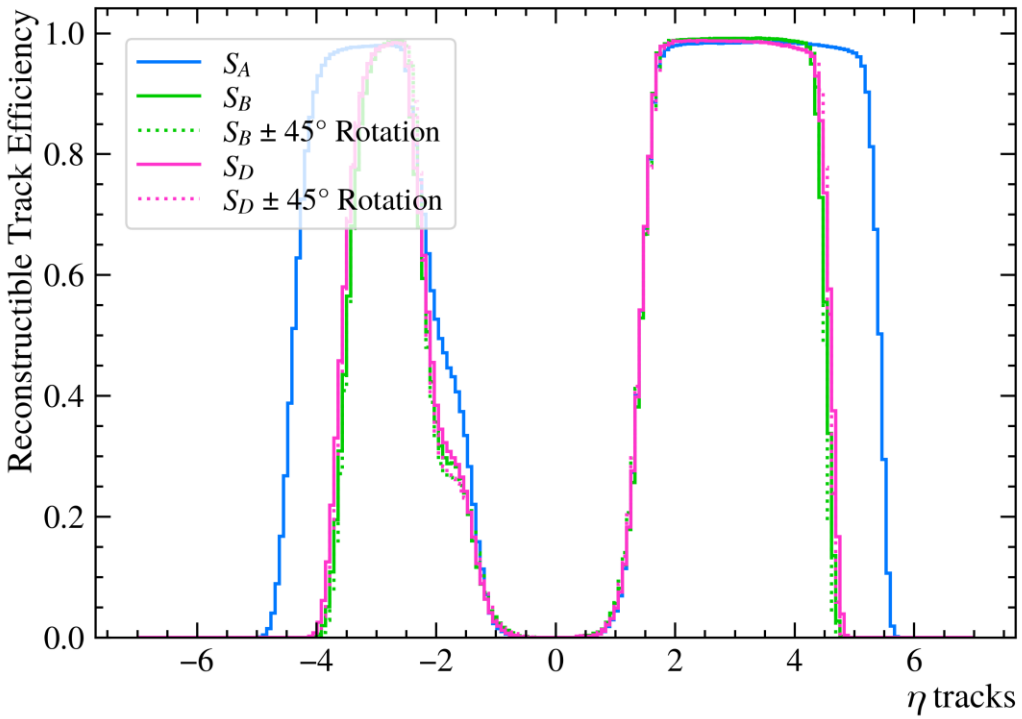


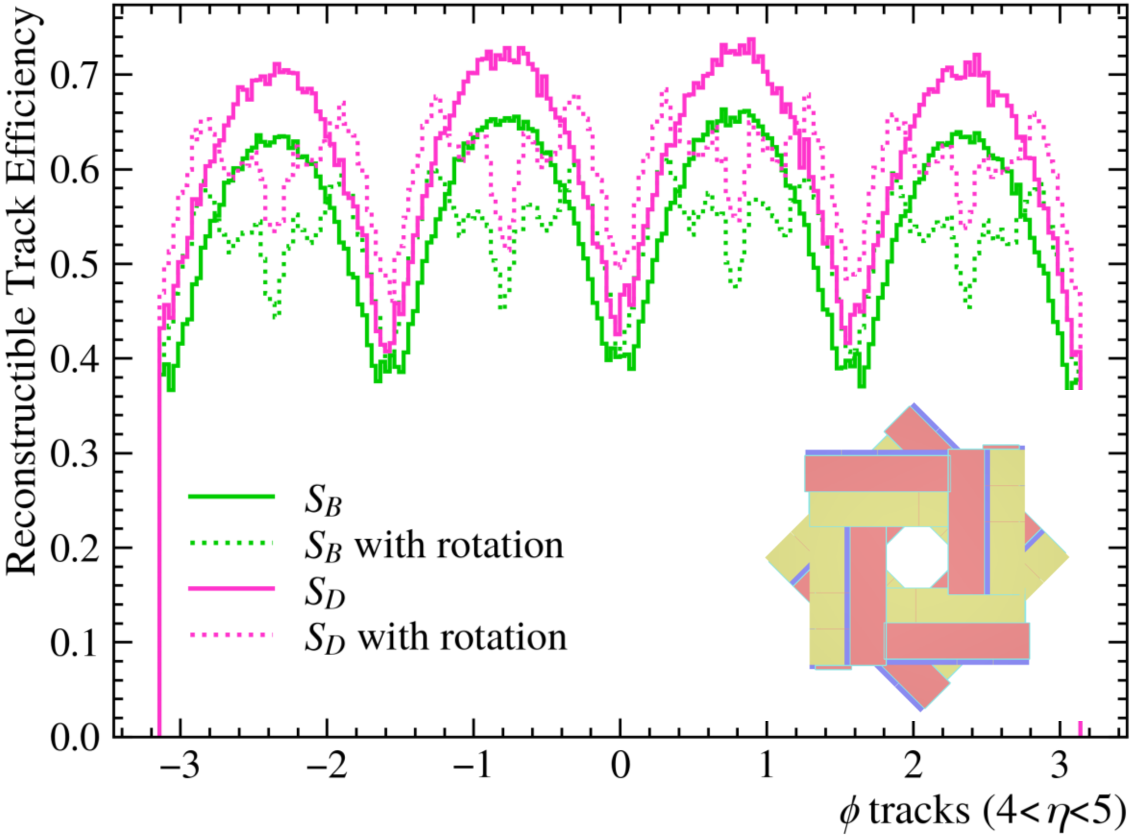


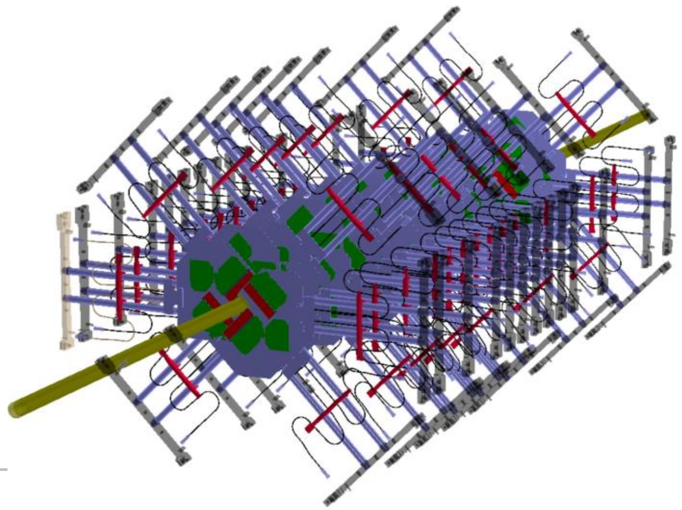
- ϕ dependence at high η for S_B/S_D due to **square cut-out**
- Framework allows physics loss to be evaluated and alternative cut-outs to be tested

Adding Rotation

- Expect to recover some acceptance by **rotation of modules and optimisation of z positions**
- Individual sensors rotated by altering “VP:StationNNDeltaRot”



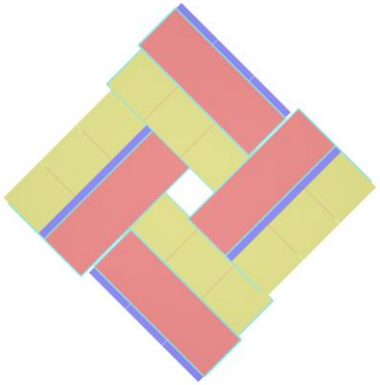




- More detailed studies in progress, z optimisation to be implemented soon, expect to be able to recover some acceptance

Looking Ahead : VELO

- Framework allows flexible and systematic approach to detector development
- Examples shown are changing sensor/foil configuration but material budget of ASICs and Support are major factors in performance:
    - DD4HEP and quick production of results will enable component optimisation in parallel with R&D efforts
    - New ideas can be tested and compared without significant extra work
- Plan to move forward by splitting work within VELO UII Simulation group



Looking Ahead : Global Optimisation

- Plan to transfer the stack to a **nightly slot and run periodic tests through LHCbPR**
    - Producing an array of plots and results like shown, simplifying comparison between scenarios
- Currently running with VELO stand-alone but aiming **to involve other sub-detectors** where possible:
    - Both through full integration of prototype geometry / reconstruction algorithms
    - And through more **flexible collaboration** like VELO+CALO
    - Enables study of other key physics channels which require specific sub-detectors