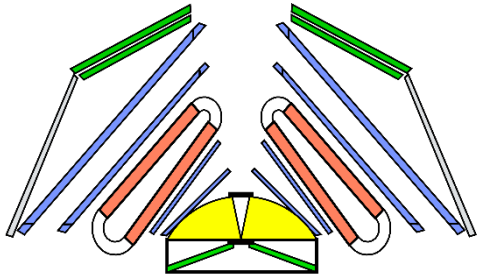


HADES

Analysis VIII

TECHNISCHE UNIVERSITÄT DARMSTADT

GLOBAL LAMBDA POLARIZATION ANALYSIS IN AU+AU COLLISIONS: CHASING STATISTICS

Feb24 & Apr25 beamtime @ $\sqrt{s_{NN}} = 2.25$ GeV

MOTIVATION

- Mean polarization is connected to vorticity by:

$$P = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow} \approx \frac{\omega}{2T} \qquad \text{(thermalized system)}$$

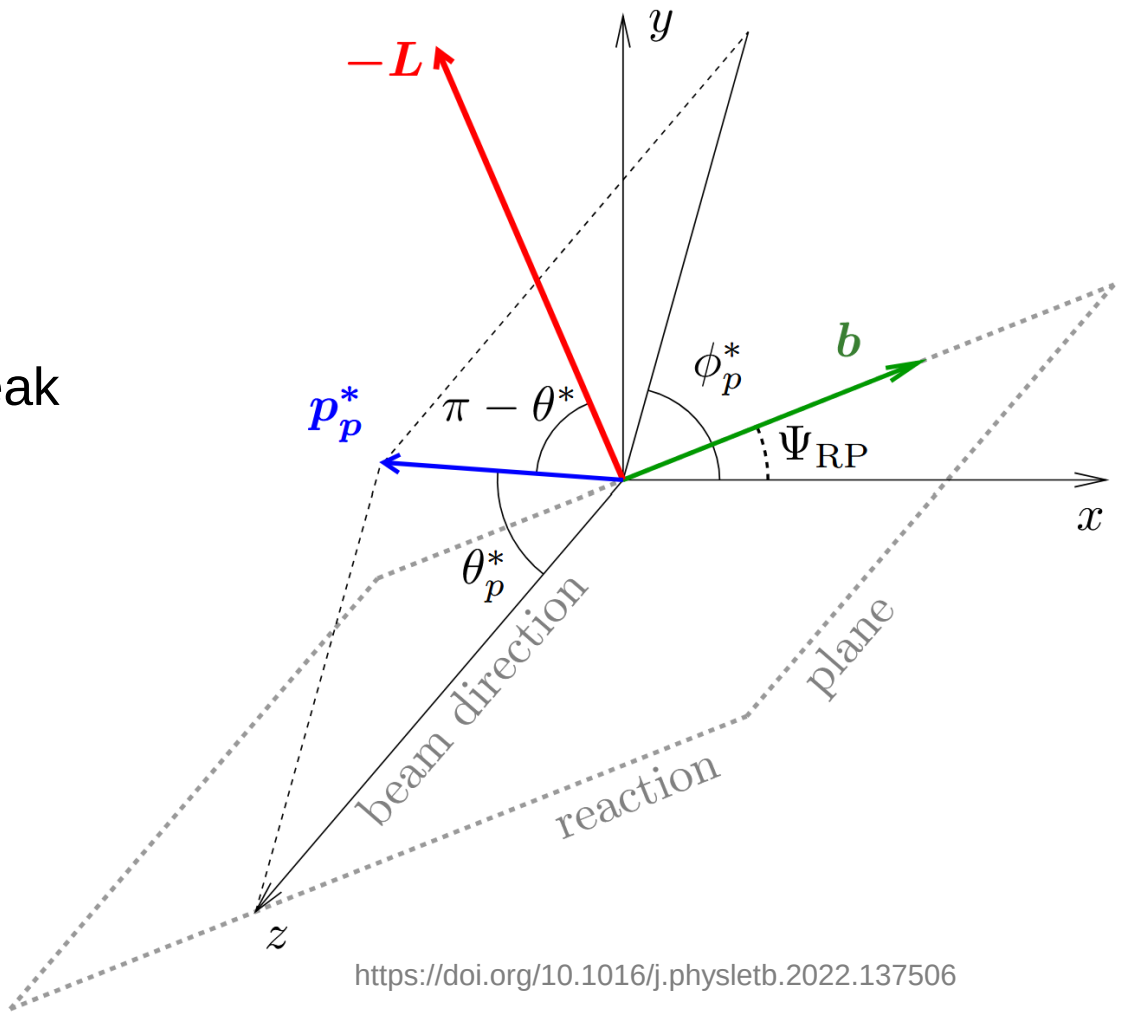
- Angular dependency due to parity violation of weak interaction decay:

$\Lambda \to p + \pi^-$ $(\approx 63.9\%)$
$\Lambda \to \pi^0 + n$ $(\approx 35.8\%)$

ϕ_p^*: rest frame of Λ

$$P_\Lambda = \frac{8}{\pi \alpha_\Lambda} \frac{\langle \sin(\psi_{RP} - \phi_p^*) \rangle}{R_{\mathrm{EP}}}$$

with[1] $\alpha_\Lambda = 0.749 \pm 0.008$



https://doi.org/10.1016/j.physletb.2022.137506

(1) S. Navas et al. (Particle Data Group), Phys. Rev. D 110, 030001 (2024)

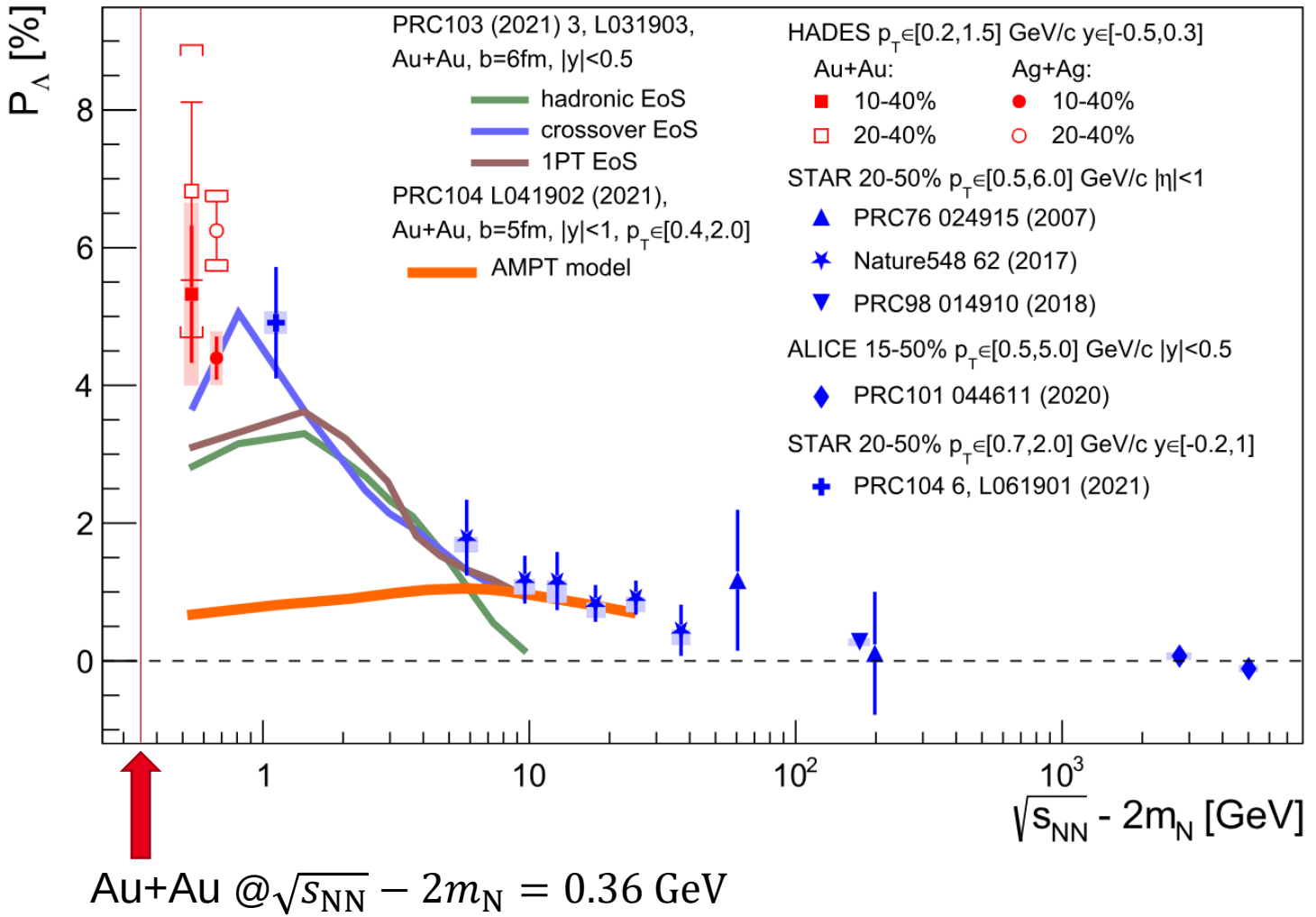
MOTIVATION

- $P_\Lambda \to 0$ for $\sqrt{s_{NN}} \to 0$
- Where is maximum of P_Λ?
- How does P_Λ changes if we go from QGP to hadronic degrees of freedom?

$\sqrt{s_{NN}} = 2.25$ GeV challenges:

- Lower energy → less Λ production
- More combinatorial background in Au+Au compared to lighter Ag+Ag system

https://doi.org/10.1016/j.physletb.2022.137506

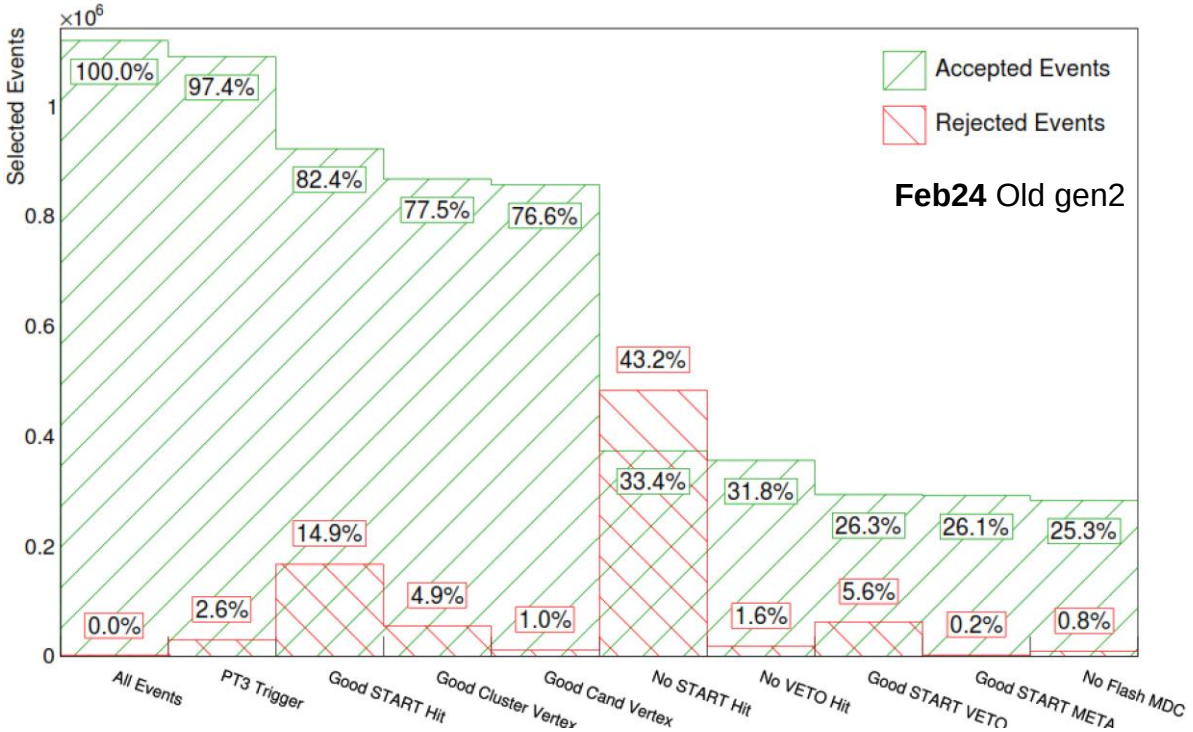


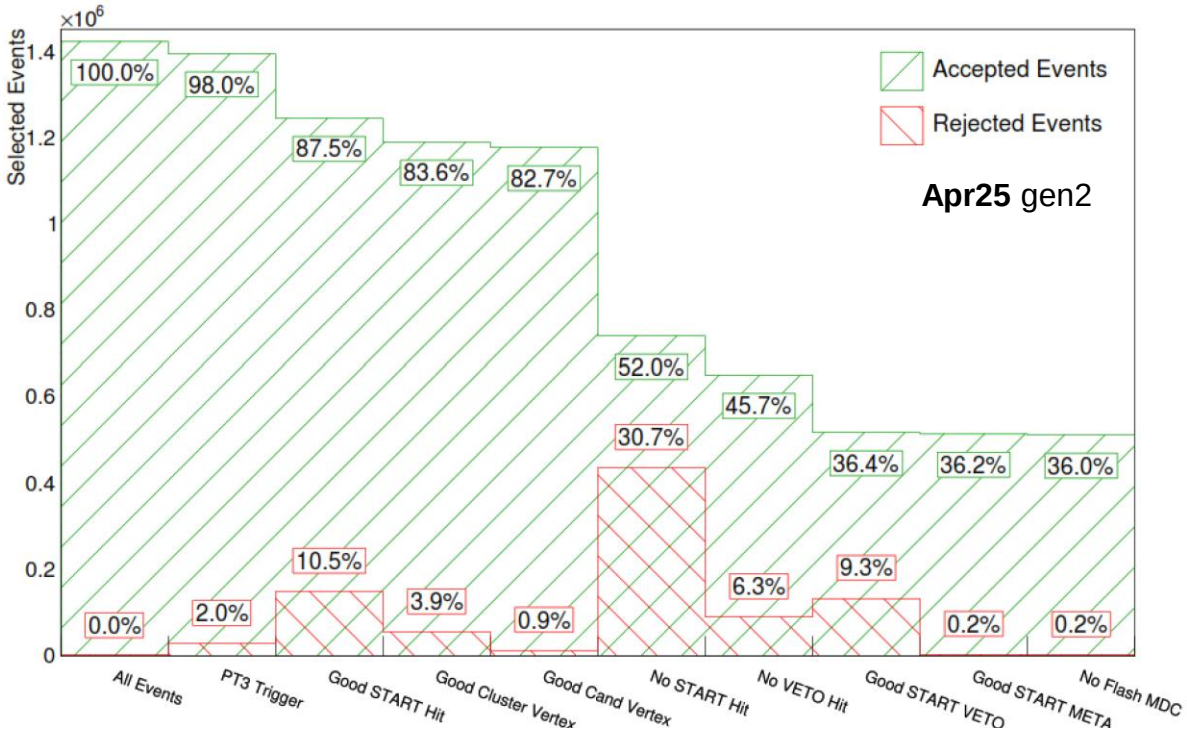
Au+Au @$\sqrt{s_{NN}} - 2m_N = 0.36$ GeV

STATISTICS IN FEB24 VS. APR25

- $N_{\Lambda,\,\mathrm{Feb24}} \approx 0.5\, N_{\Lambda,\,\mathrm{Apr25}}$ while $N_{\mathrm{All\ Evts,\,Feb24}} \approx N_{\mathrm{All\ Evts,\,Apr25}}$

  → Initial guess: look at "missmatch" caused by event selection



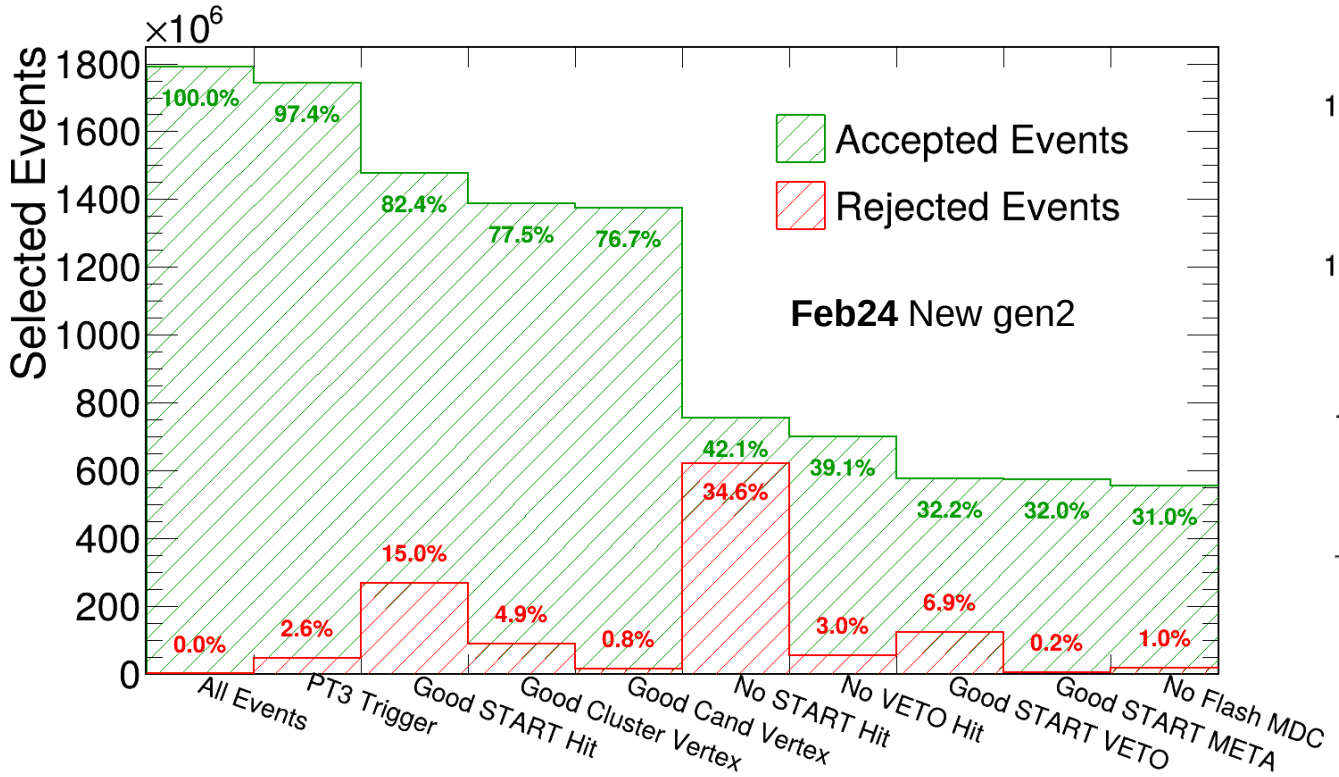


Figures: Simon Spies

STATISTICS IN FEB24 VS. APR25

TECHNISCHE UNIVERSITÄT DARMSTADT

- MDC offset found to cause issues in Feb24
  → Rerun of gen2 DSTs
  - ➢ Increase in particle yield



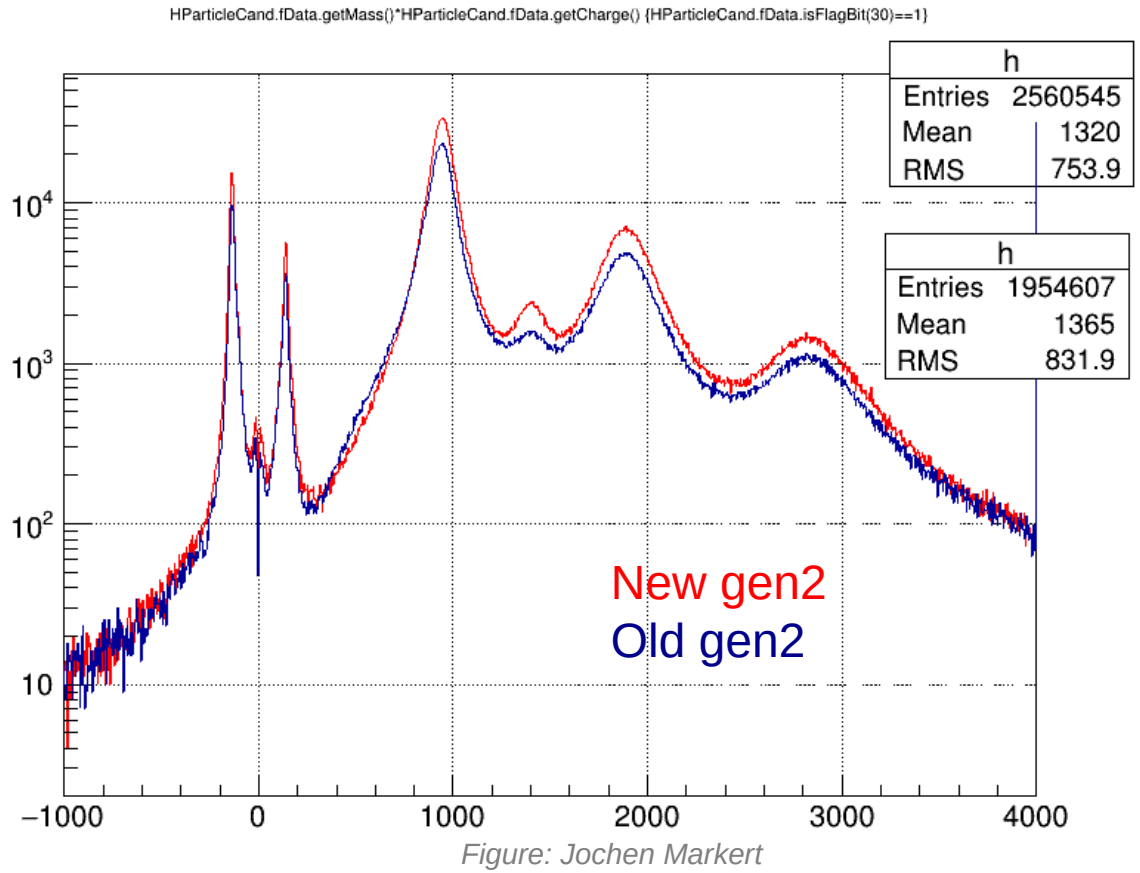
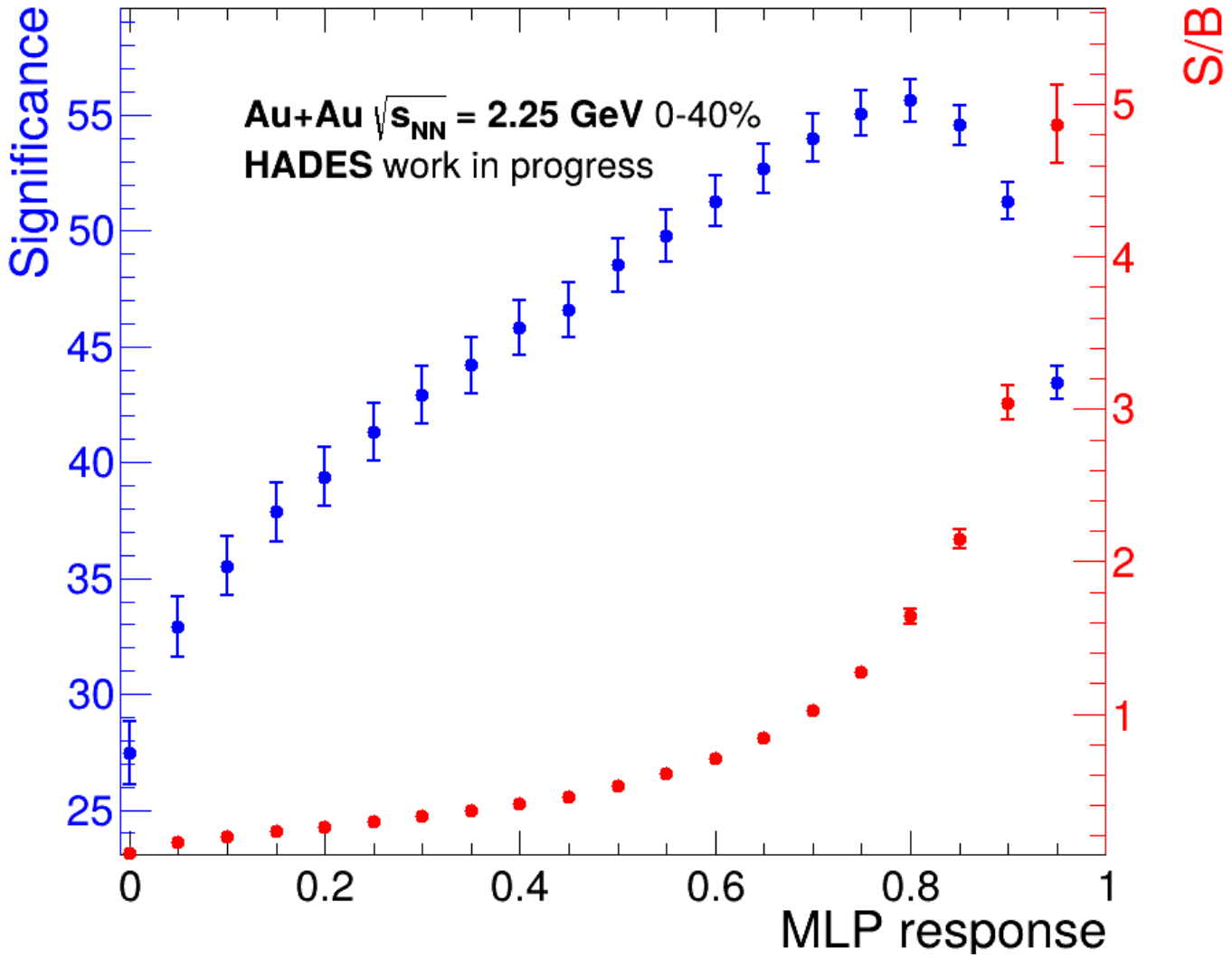


Figure: Jochen Markert

TMVA PERFORMANCE PLOTS



- Input samples for TMVA training based on decay topology:
  - **Signal**: emb. to real data PLUTO
  - **Background**: MEBG
- Choosing final cut value: statistics vs. purity
- Significance takes both into account:

$$SIG = \frac{S}{\sqrt{S+B}}$$

- For final analysis: $D > 0.8$

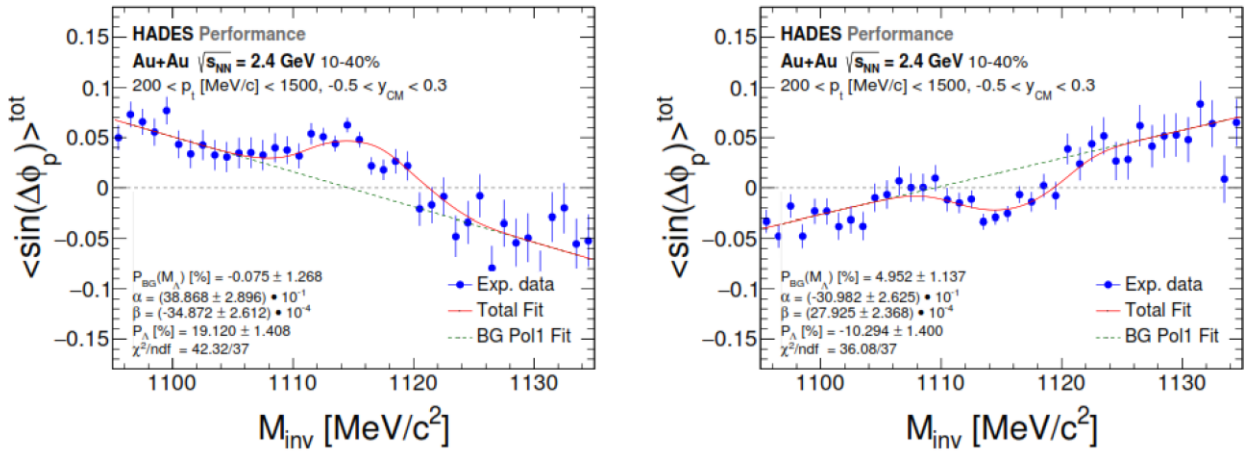
R CORRECTION

$$R(x_{vertex}, y_{vertex}) = y_{track} d_x - x_{track} d_y + x_{vertex} \sin(\phi) - y_{vertex} \cos(\phi)$$

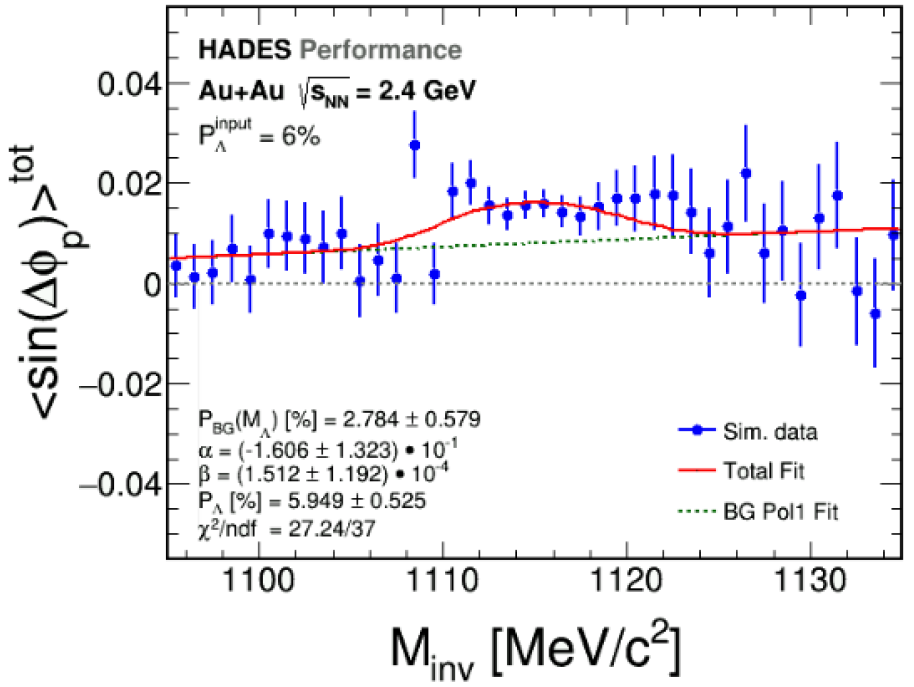
** minimum distance to any line parralel to z-axis, here EV**

- Non vanishing BG found even in simulation (including directed flow as shown in right figure)
- Strong correlation between P_Λ and R (see below)

doi: 10.26083/tuprints-00019763



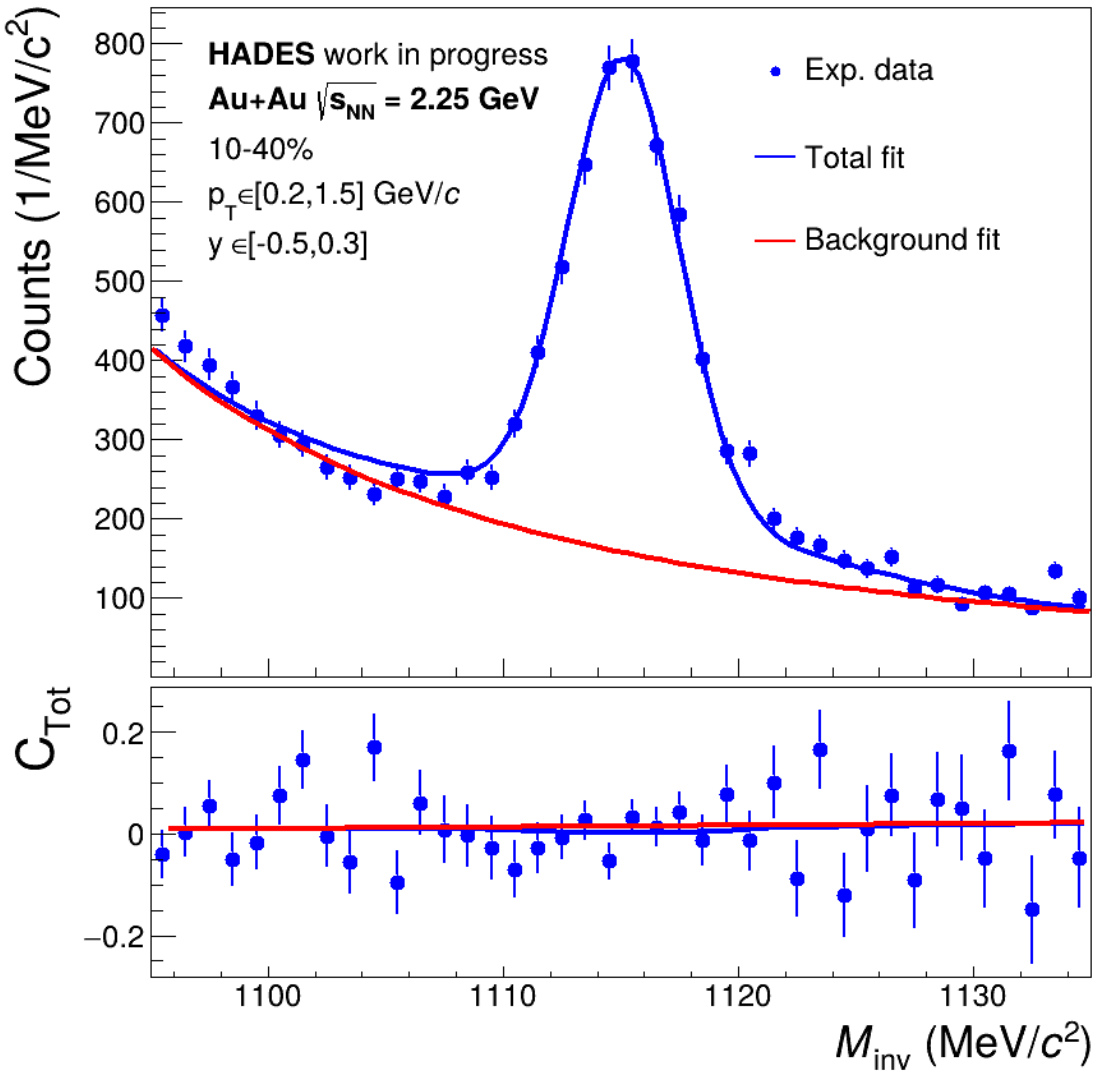
doi: 10.26083/tuprints-00019763



Should be symmetrical for aligned beam ➡ correction for this effect needed:

$$w_x = \frac{N^{Sig}_{R'<-6} + N^{Sig}_{R'>6}}{2N_x}$$

FEB24 + APR25 C_{tot}



$$P_\Lambda[\%] = -0.01 \pm 7.13$$

$$P_{BG}[\%] = 5.29 \pm 5.75$$

$$\beta = (0.33 \pm 1.13) * 10^{-3}$$

$$\alpha = -0.36 \pm 1.25$$

$$N_\Lambda(2\sigma) = 3788 \pm 83$$

Gain due to MDC offset calibration:

$\Delta N_\Lambda[\%] \sim 40\%$ (old: $N_\Lambda(2\sigma) = 2696 \pm 77$)
Reducing $\sim 20\%$ of the statistical error of P_Λ

$$C_{tot}(M_{inv}) = \langle \sin(\Delta\phi_p{}^*) \rangle_{Tot}(M_{inv})$$

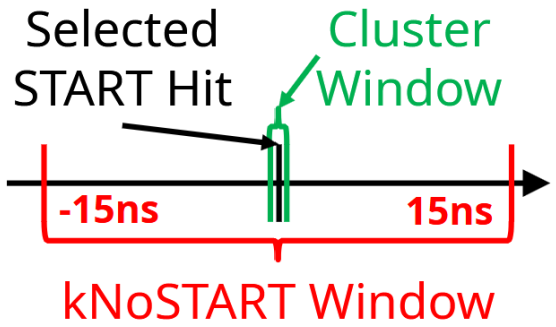
+ EP resolution
+ R-Correction
+ Efficiency

HADES EVENT SELECTION FLAGS

TECHNISCHE UNIVERSITÄT DARMSTADT

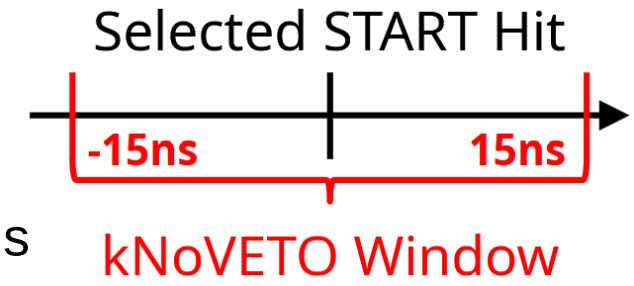
kNoSTART

- Requires no START hits in a time window of -15ns to 15ns around selected START hit
- Hits within cluster window of ±2ns around selected START hit are allowed



kNoVETO

- Requires no VETO hits in a time window of -15ns to 15ns around selected START hit



kGoodSTARTVETO

- Requires no START hit without a VETO hit between 15ns and 350ns
- Secondary START hit allowed if corresponding VETO hit within cluster time window of ±2ns
  → otherwise event will be discarded

EVENT SELECTION ANALYSIS

TECHNISCHE UNIVERSITÄT DARMSTADT

- Apply event selection flags:
  - *kGoodTRIGGER*
  - *kGoodSTART*
  - *kGoodVertexClust*
  - *kGoodVertexCand*
  - *kNoSTART*
  - *kNoVeto*
  - *kGoodSTARTVETO*
  - *kGoodSTARTMETA*
  - *kNoFlashMDC*

- For *kNoSTART*, *kNoVETO* & *kGoodSTARTVETO* distinguish 2 cases:

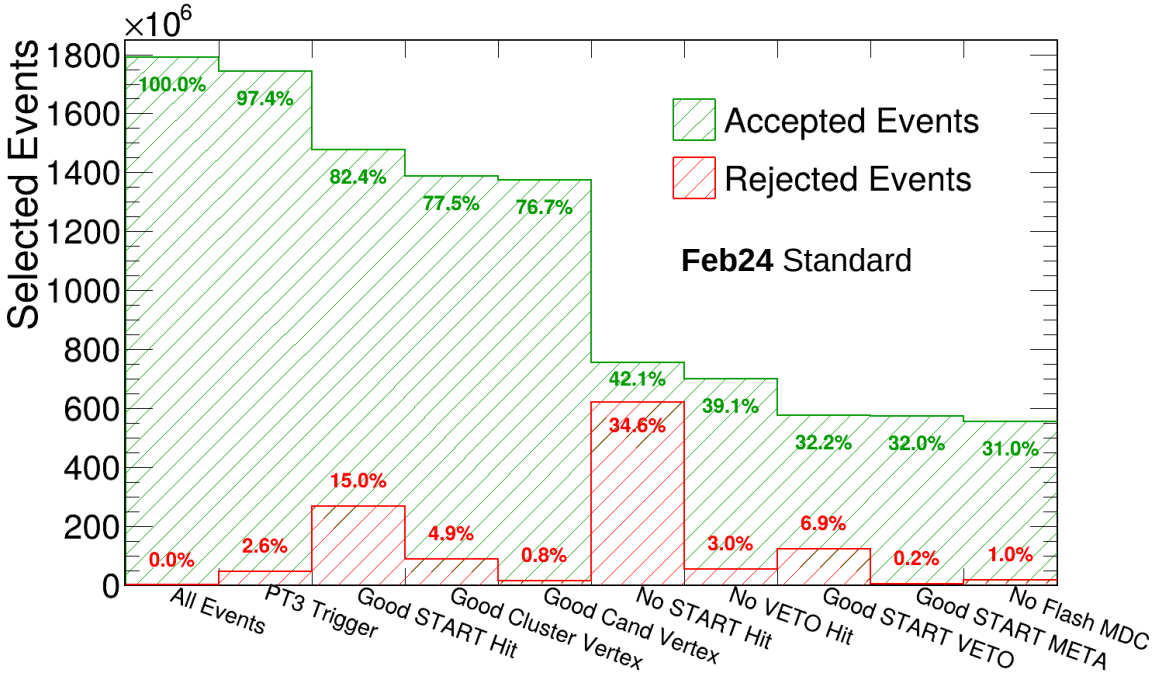
  1. Standard: keep the "original" HADES event selection flags unchanged

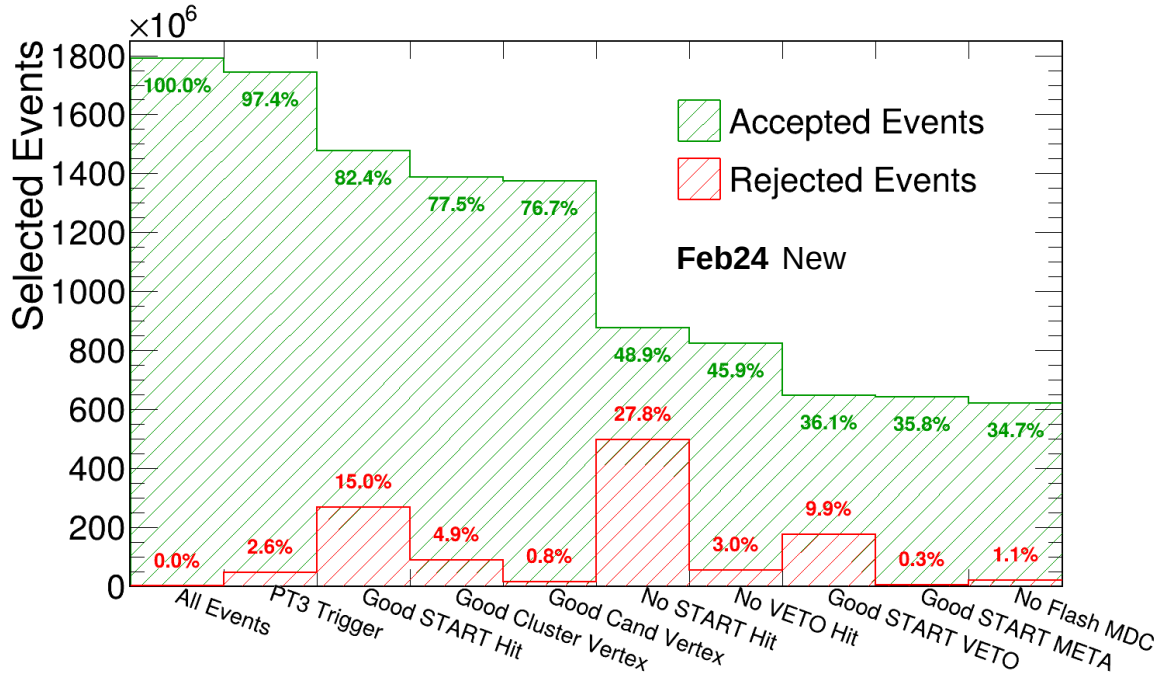
  2. New: change time windows in kNoSTART/ kNoVETO and kGoodSTARTVETO
     → kNoSTART/kNoVETO window: $[-5\text{ns}, 5\text{ns}]$ → flag gets less restrictive
     → kGoodSTARTVETO window: $[5\text{ns}, 350\text{ns}]$ → to cover gap $[5\text{ns}, 15\text{ns}]$

EVENT SELECTION IN FEB24

TECHNISCHE UNIVERSITÄT DARMSTADT

- Overall gain after all flags only 3.7%
- Reducing kNoSTART window by 67% only leads to gain of 7.8% in events

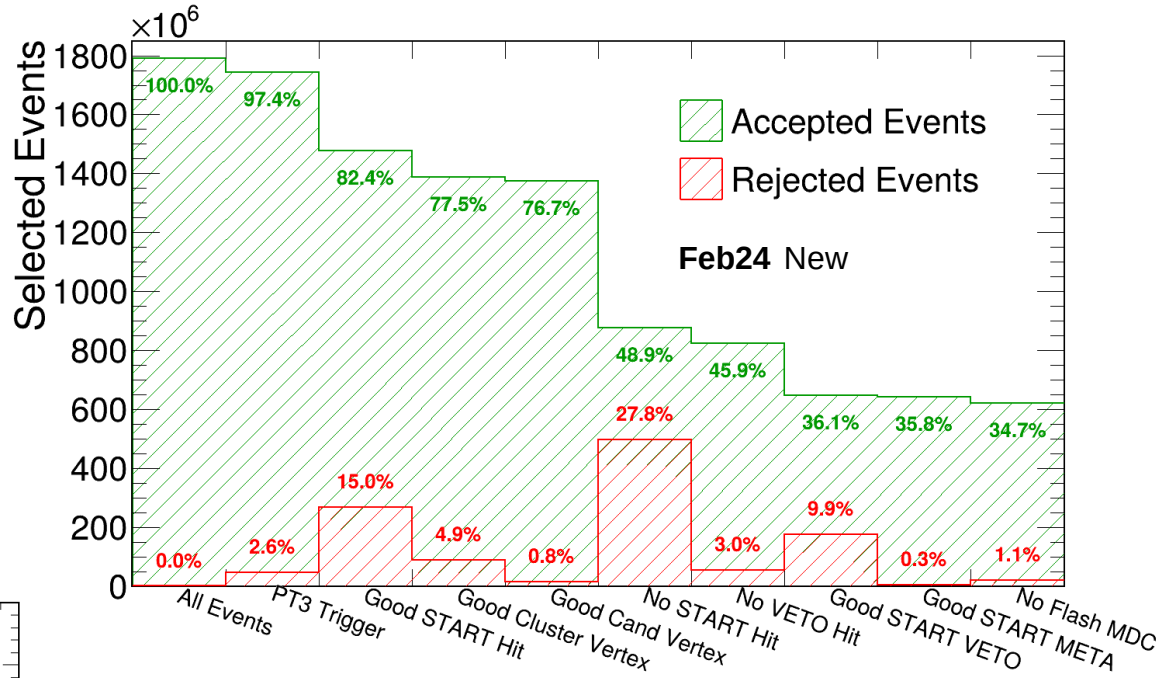


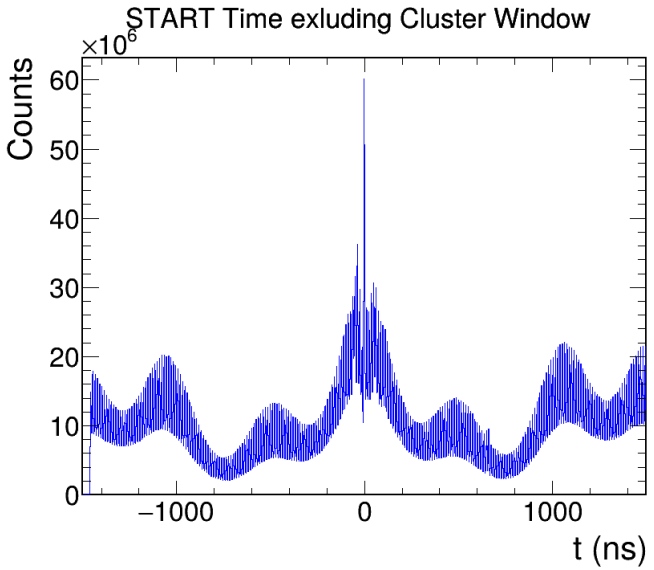


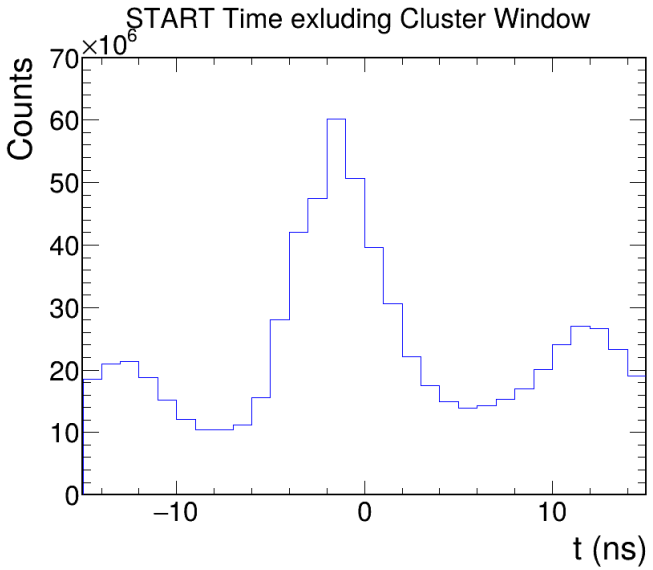
EVENT SELECTION IN FEB24

TECHNISCHE UNIVERSITÄT DARMSTADT

- Overall gain after all flags only 3.7%
- Reducing kNoSTART window by 67% only leads to gain of 7.8% in events
- Start time distribution shows higher multiplicity around selected start hit (not visible in e.g. Mar19)







- Discussion and further investigation needed and ongoing

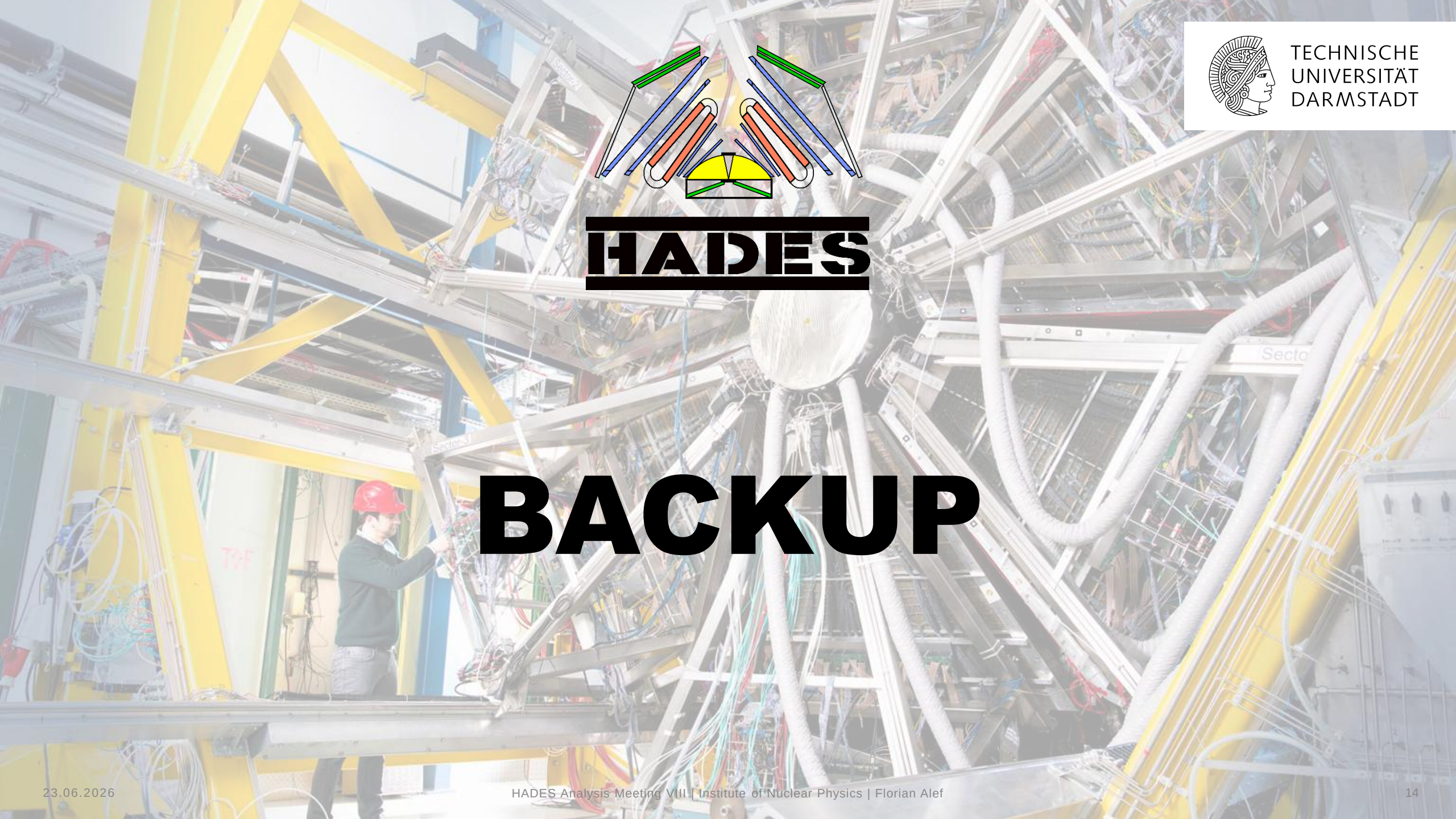
SUMMARY & OUTLOOK

Au+Au @ $\sqrt{s_{NN}} = 2.25$ GeV

- ✓ First results for P_Λ far below free NN Lambda production threshold
- ✓ Neural Network training for maximizing significance of the data sample
- ✓ 40% more Lambdas due to MDC offset
  → reduction of statistical error of about 20%
- – Extraction of P_Λ comes with high statistical errors due to larger collision system and subthreshold Λ production

- ➢ Study event selection effects further
- ➢ Extraction of systematic errors

Thank you for your attention!



BACKUP

MDC OFFSET

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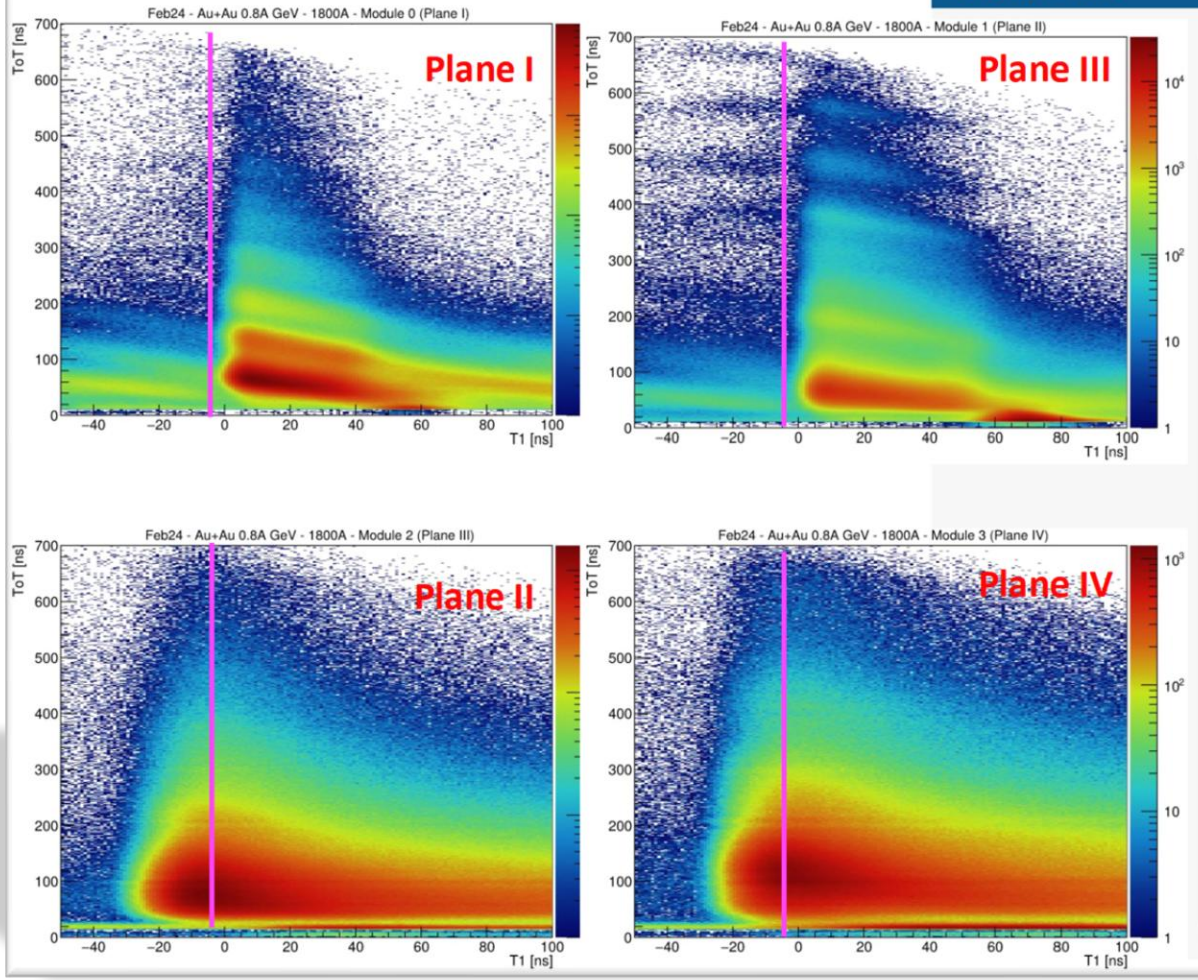
Au+Au : MDC : T1 vs. ToT



Parameter Container: MdcTimeCut
Version: 1140

Version Comments:

Original Context	Run Type	Run Id	Author	Description	
MdcTimeCutProduction	Beam	506192315	O.Pechenova	MdcTimeCut for Feb24	29-MA

sector	plane	cutT1L	cutT1R	cutT2L	cutT2R	cutLeft	cutRight	cutBumpT1L	cutBumpT1R	cut
1	1	-5	350	-1000	1000	10	700	0	0	
1	2	-5	350	-1000	1000	20	700	0	0	
1	3	-5	750	-1000	1000	25	800	0	0	
1	4	-5	750	-1000	1000	30	800	0	0	
2	1	-5	350	-1000	1000	10	700	0	0	
2	2	-5	350	-1000	1000	20	700	0	0	
2	3	-5	750	-1000	1000	25	800	0	0	
2	4	-5	750	-1000	1000	30	800	0	0	
3	1	-5	350	-1000	1000	10	700	0	0	
3	2	-5	350	-1000	1000	20	700	0	0	
3	3	-5	750	-1000	1000	25	800	0	0	
3	4	-5	750	-1000	1000	30	800	0	0	
4	1	-5	350	-1000	1000	10	700	0	0	
4	2	-5	350	-1000	1000	20	700	0	0	
4	3	-5	750	-1000	1000	25	800	0	0	
4	4	-5	750	-1000	1000	30	800	0	0	
5	1	-5	350	-1000	1000	10	700	0	0	
5	2	-5	350	-1000	1000	20	700	0	0	
5	3	-5	750	-1000	1000	25	800	0	0	
5	4	-5	750	-1000	1000	30	800	0	0	
6	1	-5	350	-1000	1000	10	700	0	0	
6	2	-5	350	-1000	1000	20	700	0	0	
6	3	-5	750	-1000	1000	25	800	0	0	
6	4	-5	750	-1000	1000	30	800	0	0	

Rows: 1 - 24

START EFFICIENCY PER DAY

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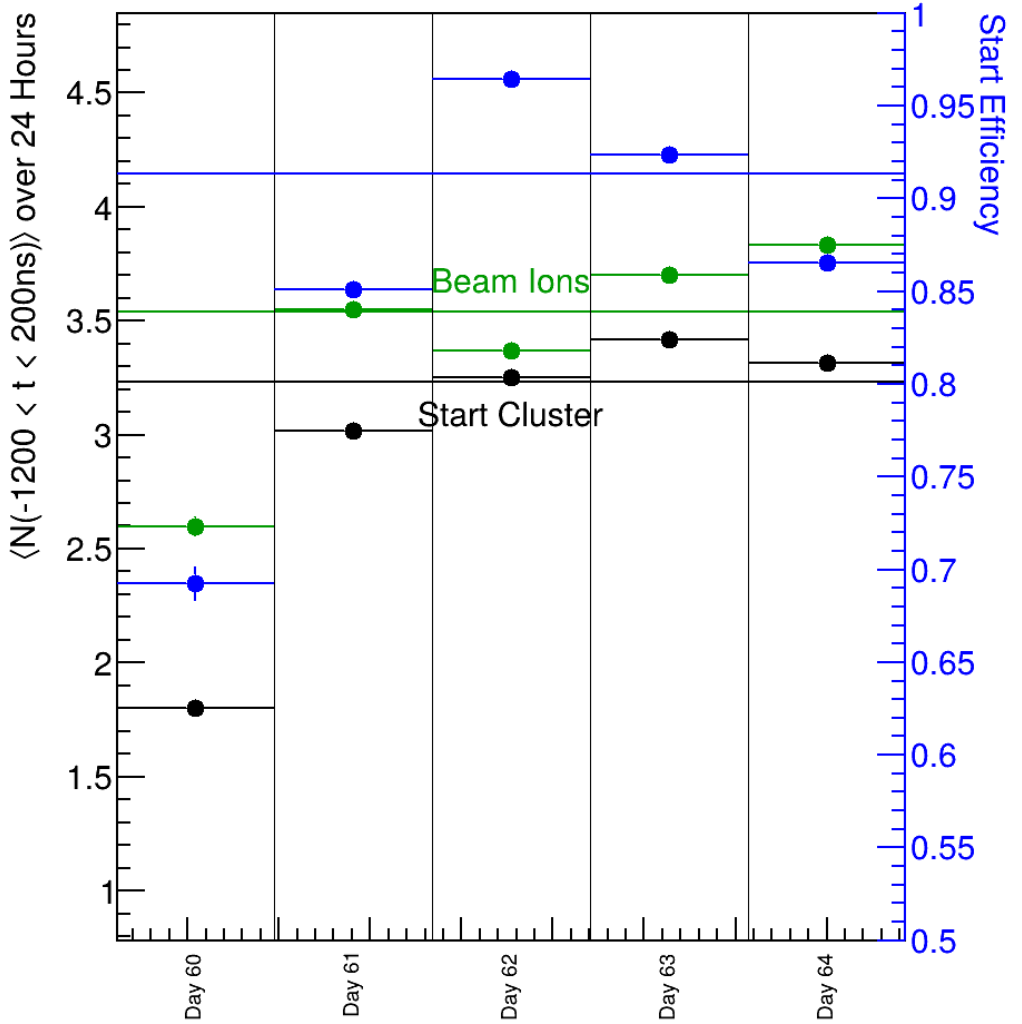
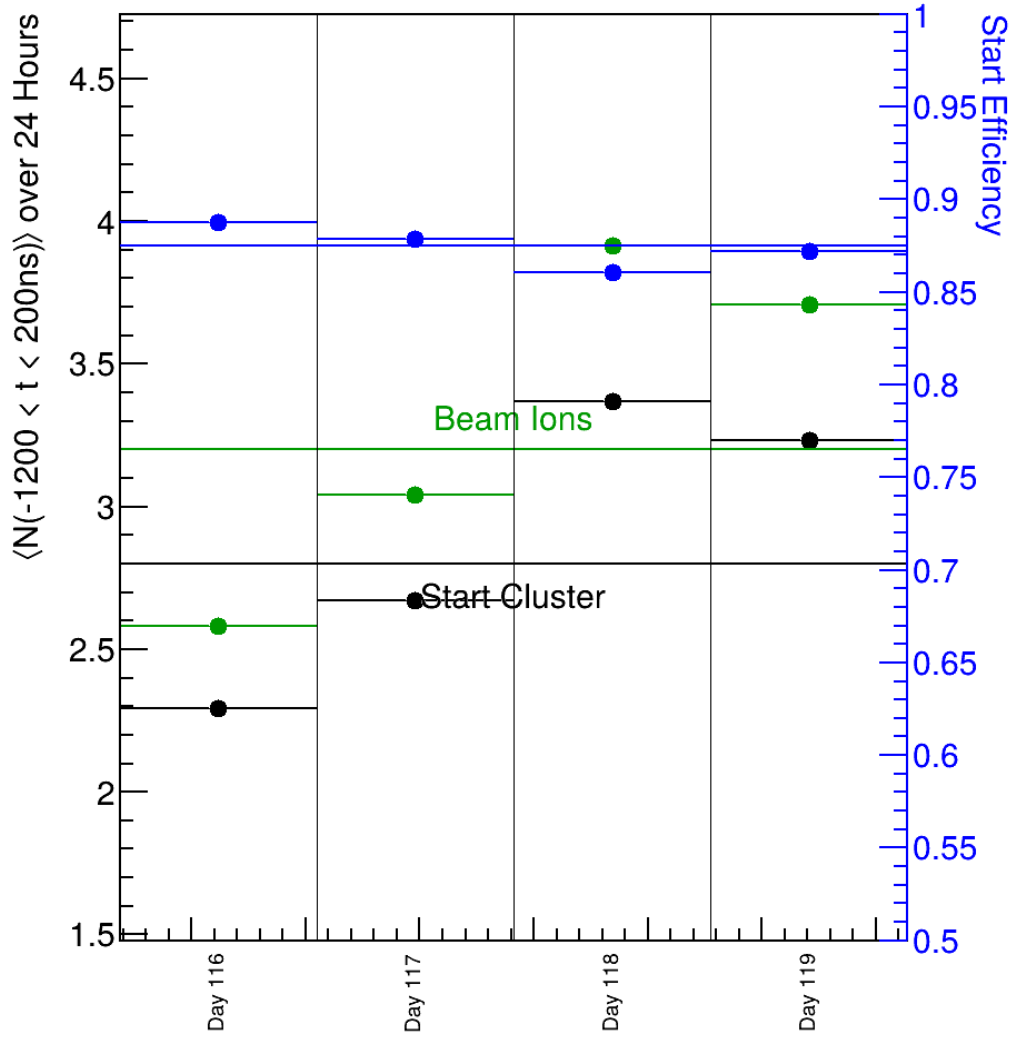
Feb24:



Apr25:



Figures: Simon Spies

PRESELECTION HARD CUTS

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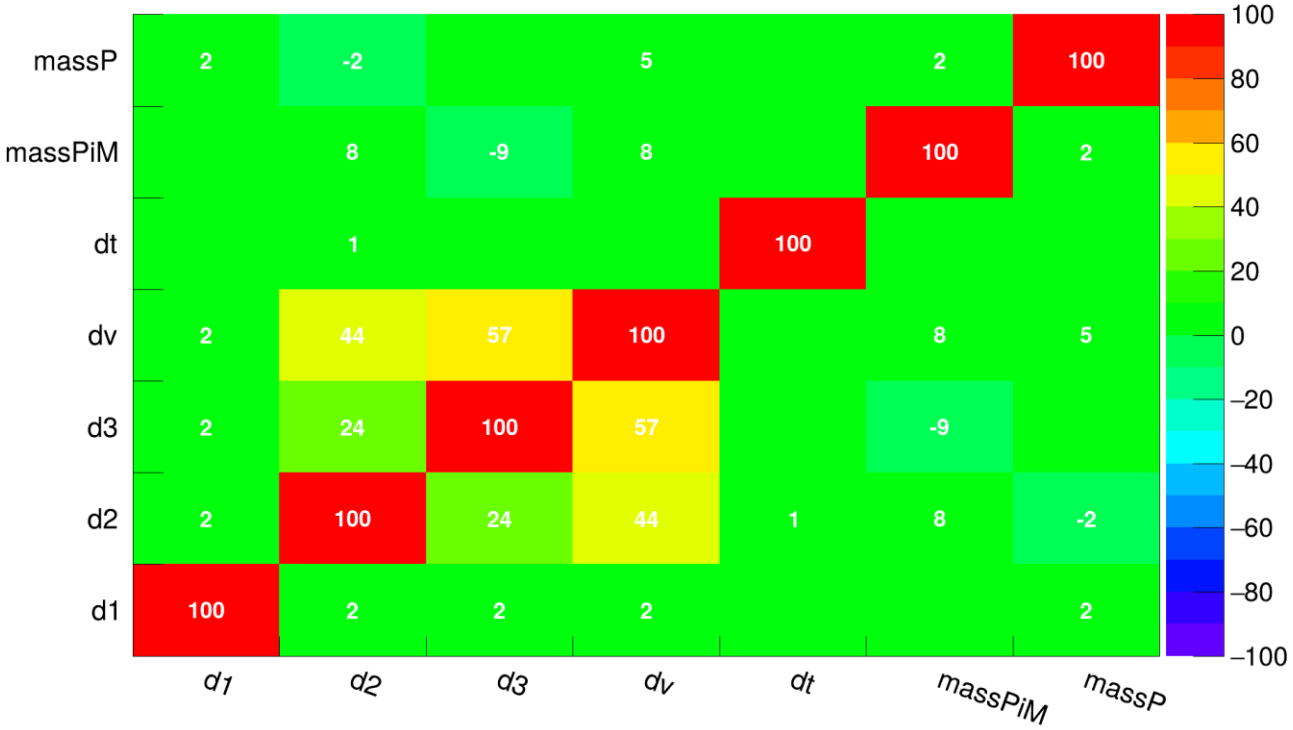
	AgAg @ $\sqrt{s_{NN}} = 2.55$	AuAu @ $\sqrt{s_{NN}} = 2.25$
d1	< 12 mm	< 8 mm
d2	> 5 mm	> 8 mm
d3	> 15 mm	> 26 mm
dv	> 50 mm	> 65 mm
dt	< 10 mm	< 10 mm
oa	>15°	>15°

TMVA PERFORMANCE PLOTS

Network architecture

- Sigmoid activation function
- 2 hidden layers: N+2, N neurons

Correlation Matrix (background)



Correlation Matrix (signal)

Training configuration

- Training epochs: 1500
- Loss function: Mean Square Error
- Test evaluation: every 10 cycles

Λ RECONSTRUCTION - TOPOLOGY

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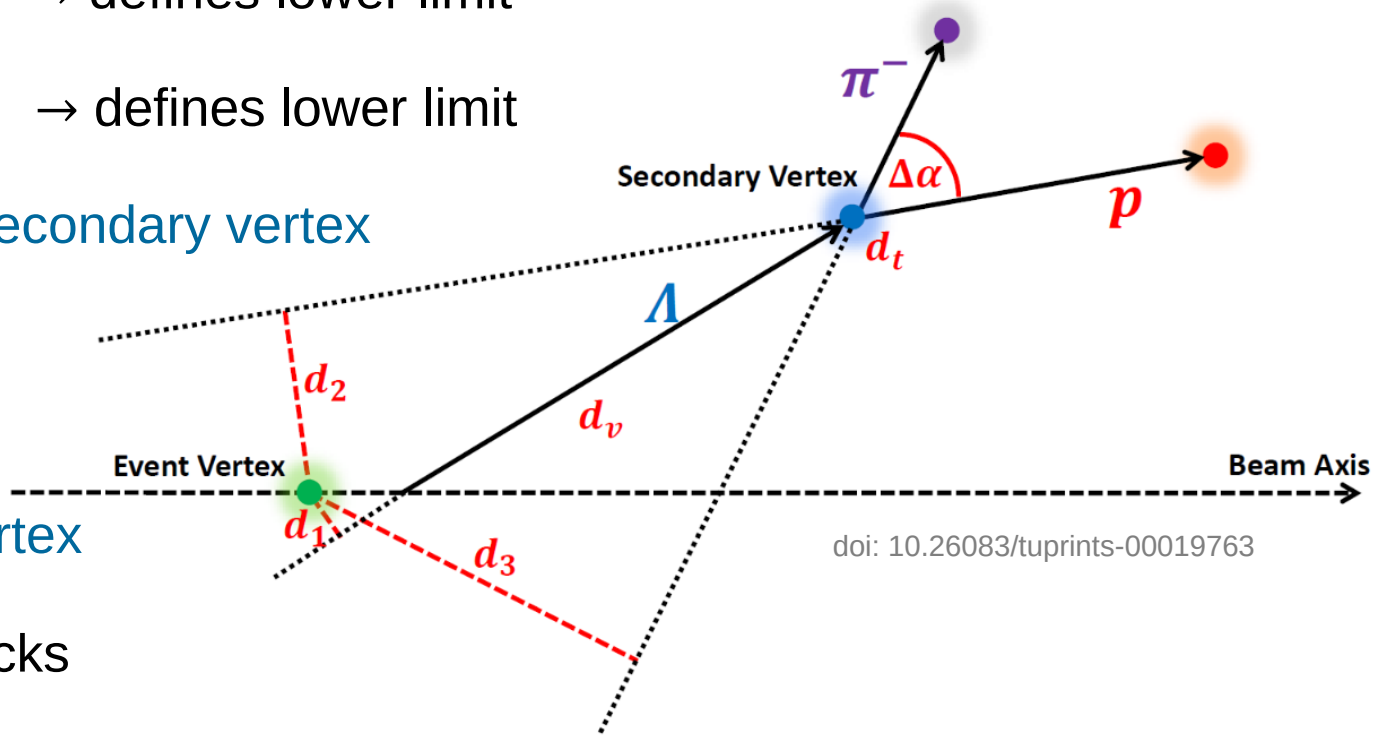
- d_1: DCA of mother track and event vertex → defines upper limit
- d_2: DCA of proton track and event vertex → defines lower limit
- d_3: DCA of pion track and event vertex → defines lower limit
- d_v: distance between event vertex and secondary vertex
  → defines lower limit
- d_t: DCA between daughter tracks
  → defines upper limit
  → middle point defines secondary vertex
- $\Delta\alpha$: opening angle between daughter tracks

➡ Neural network to optimize selection significance



doi: 10.26083/tuprints-00019763

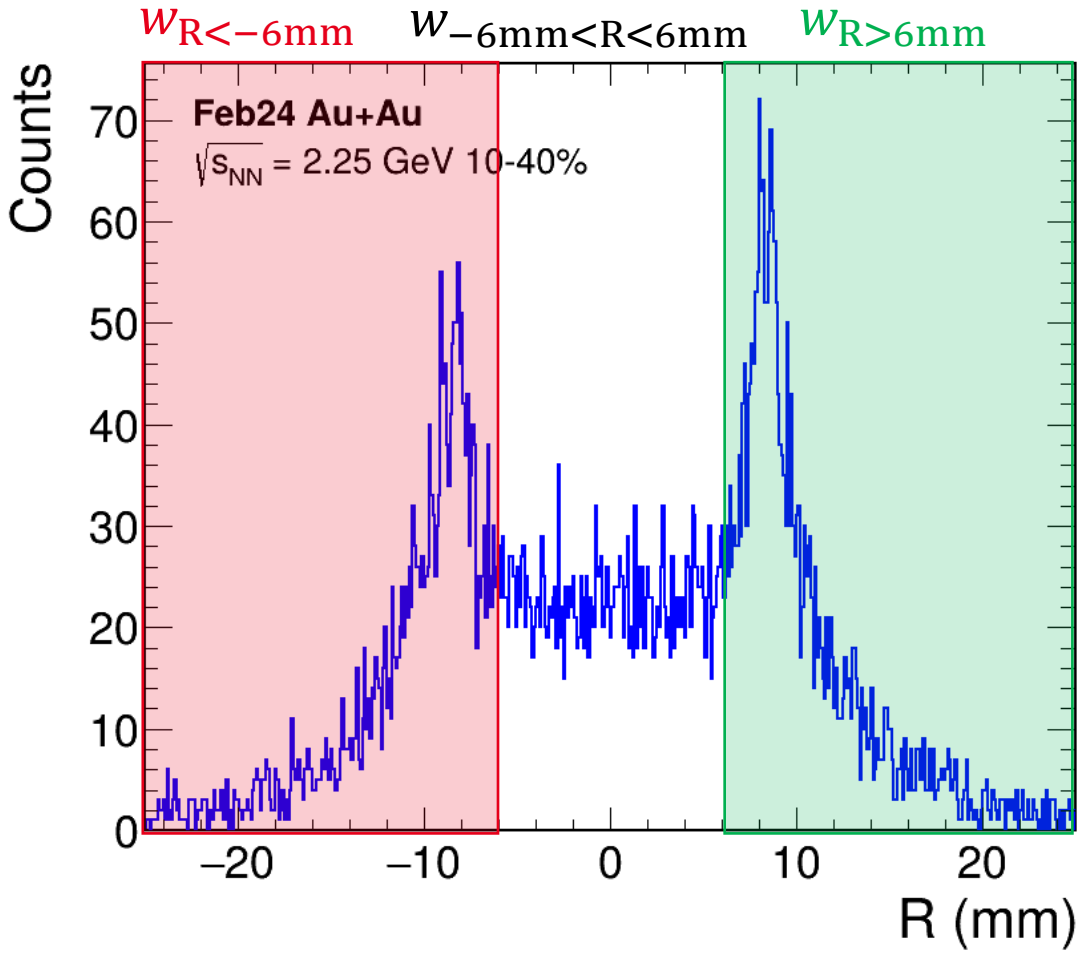
R CORRECTION

$$R(x_{vertex}, y_{vertex}) = y_{track} d_x - x_{track} d_y + x_{vertex} \sin(\phi) - y_{vertex} \cos(\phi)$$

Should be symmetrical for aligned beam

➡ correction for this effect needed:

$$w_x = \frac{N^{Sig}_{R'<-6} + N^{Sig}_{R'>6}}{2N_x}$$



- Correlated to d_2:
  cuts all tracks in sphere around EV with $r = 8$ mm
- Correction is very stable for varying R values