

MC simulation study for future experiment

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Contents

- Introduction
 - Requirement, reaction points, momentum dispersion
- Simulation study of PCS-HKS-HES option (different from Okuyama study)
 - Method, condition
 - Performance of HKS and HES as horizontal-bending and vertical-bending spectrometers
- Summary

Because we cannot use HRS at Hall A, we will use HES at Hall C instead
In order to conduct the experiment at Hall C, I simulated PCS-HKS-HES and evaluated the performance with one spectrometer vertical-bending.

Introduction

Requirement

- **Setup: PCS - HKS - HES**
- **Require sub-MeV missing mass resolution for solid and cryo-gas targets**

E05-115 exp.

Momentum resolution: 2×10^{-4}

Solid angle: 8 msr

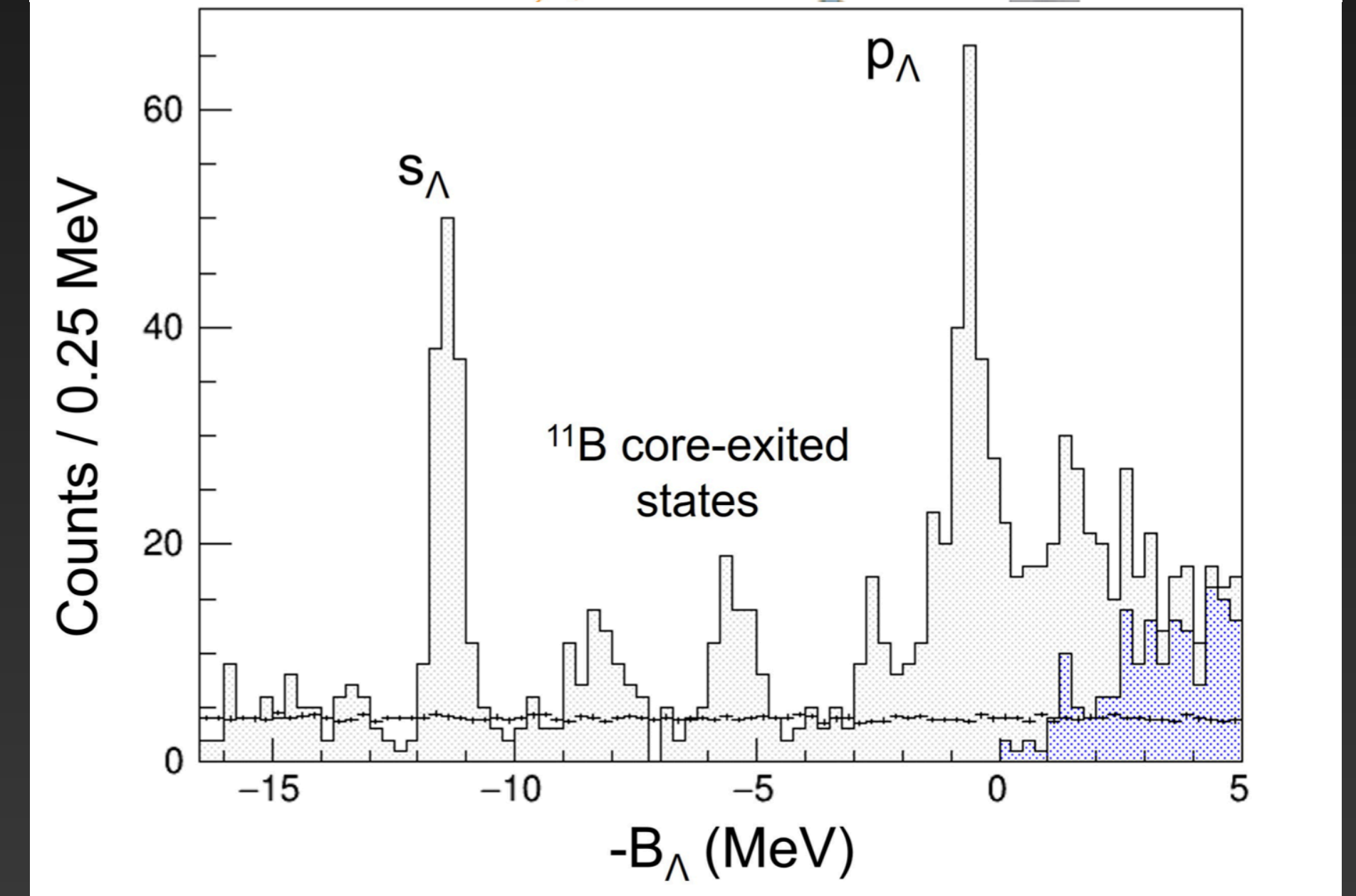
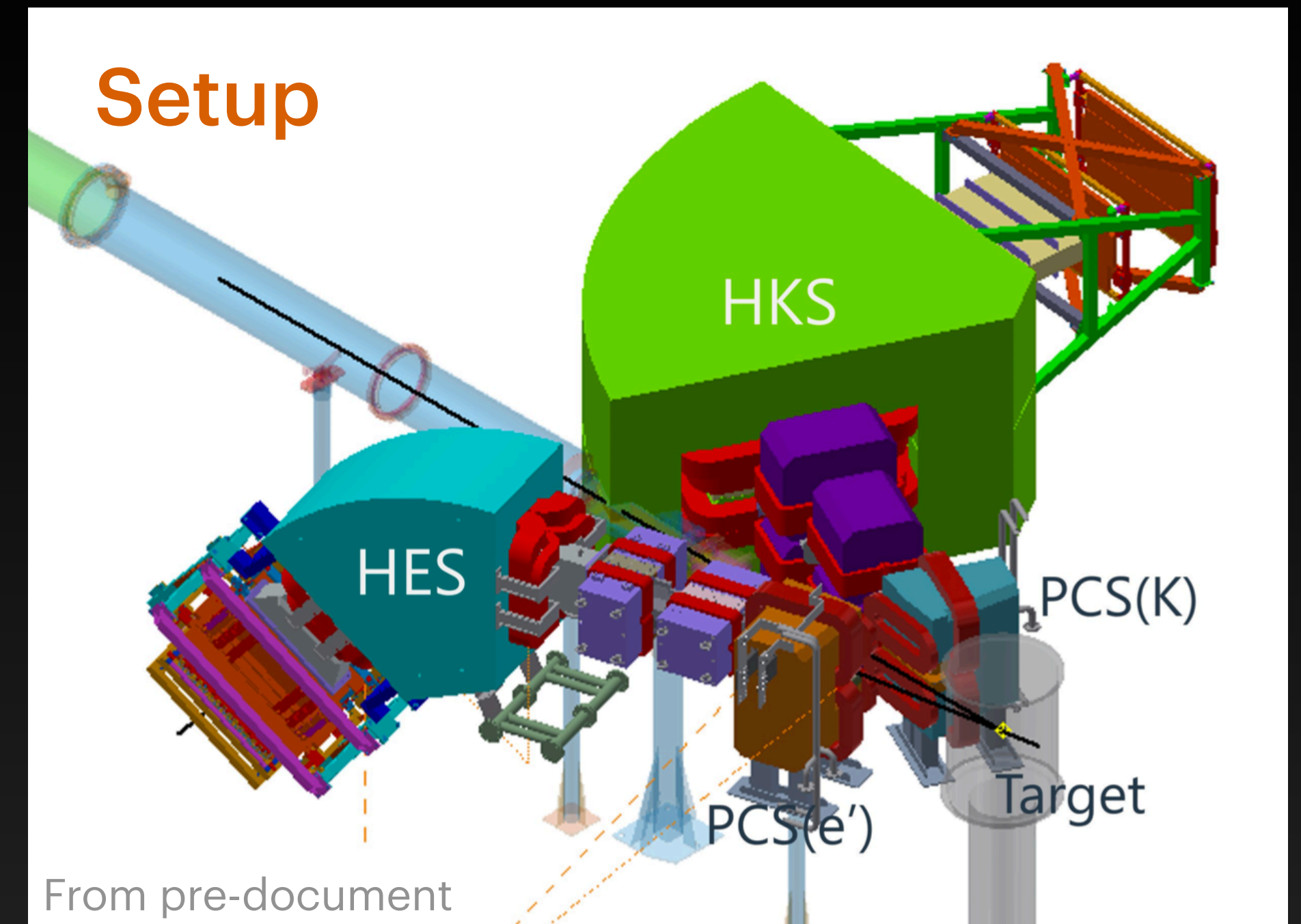
missing mass resolution: 500 keV

Minimum requirement for HKS & HES

Momentum resolution $\Delta p/p$: several $\times 10^{-4}$ (FWHM)

Solid angle: ~several msr

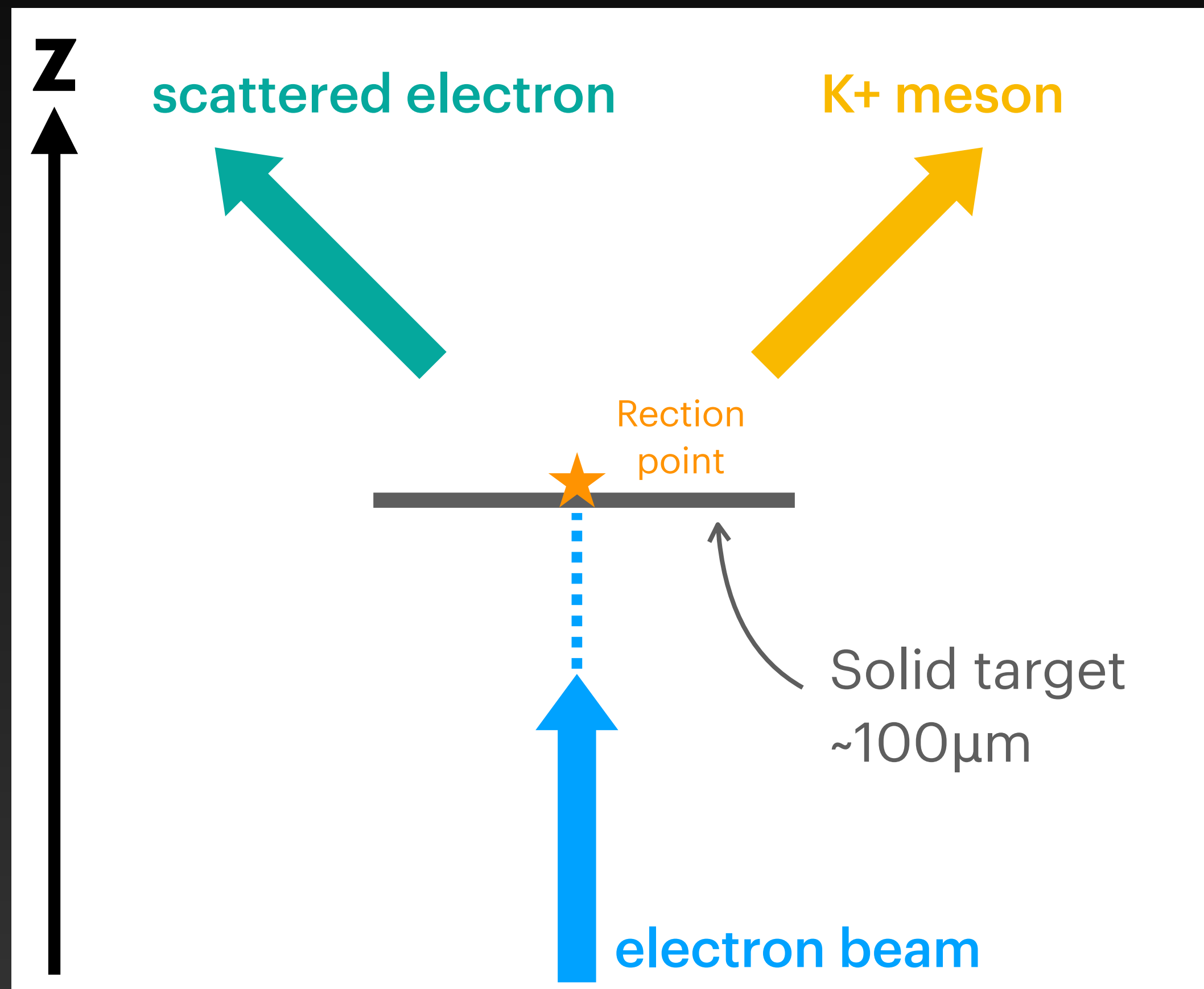
Then we can obtain several hundreds keV resolution at least



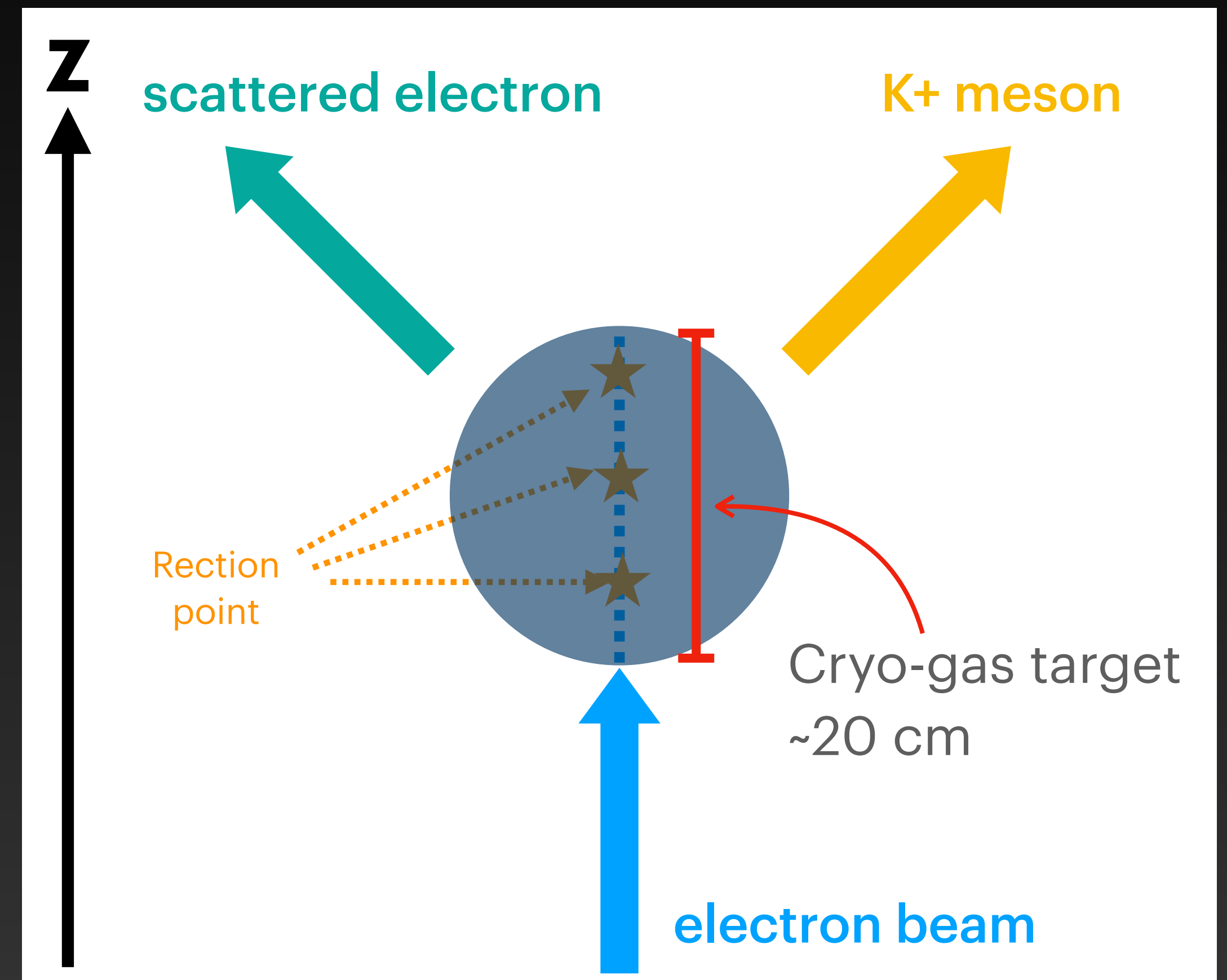
Estimated missing mass spectrum of ${}^{12}_{\Lambda}\text{B}$ from pre-document

Resolution and Reaction points

Solid Target



Cryo-gas Target

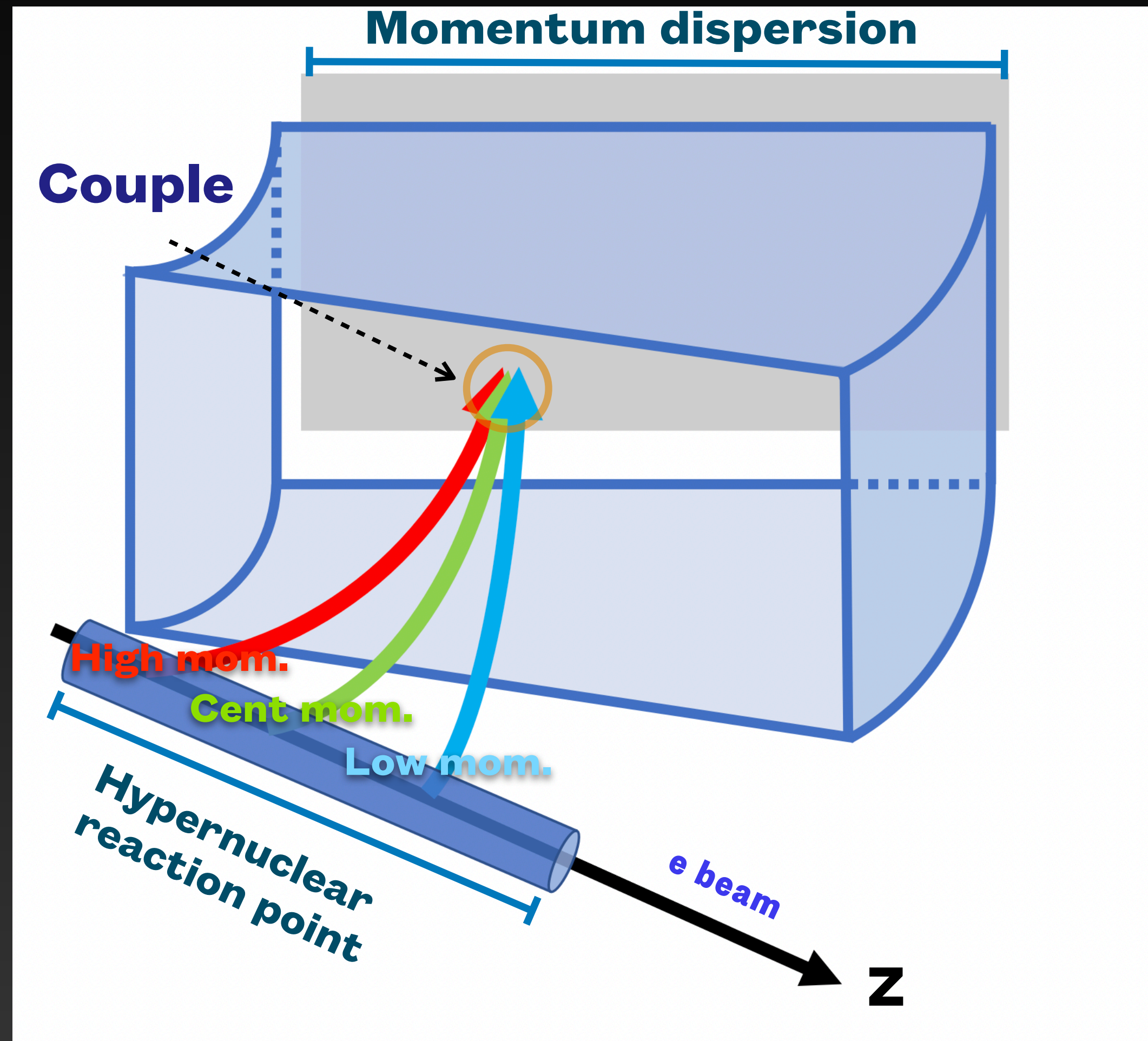


Momentum resolution keeps its quality

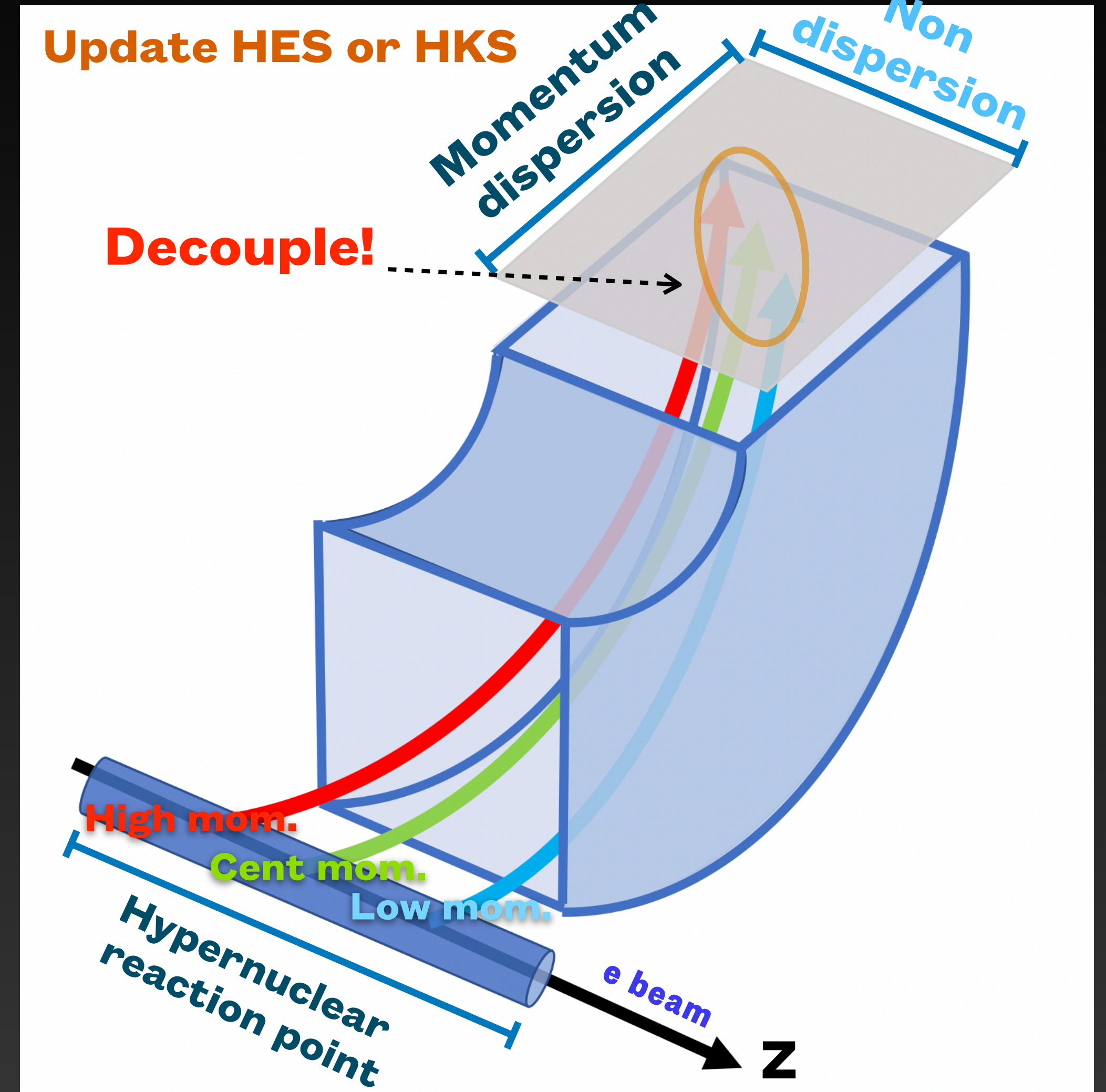
Momentum resolution gets worse

Momentum dispersion and Bending direction

Horizontal



Vertical



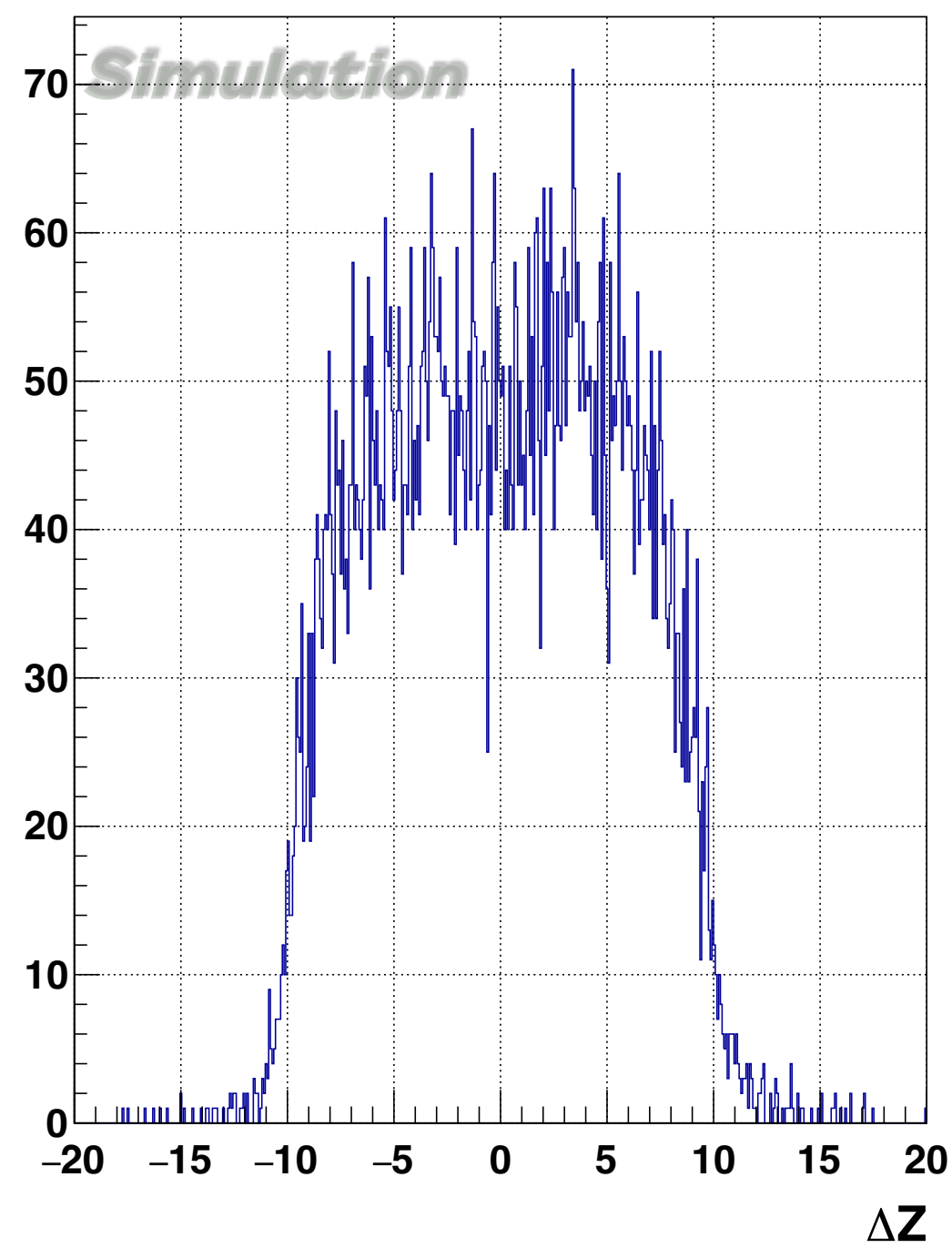
Momentum dispersion and Bending direction

Horizontal

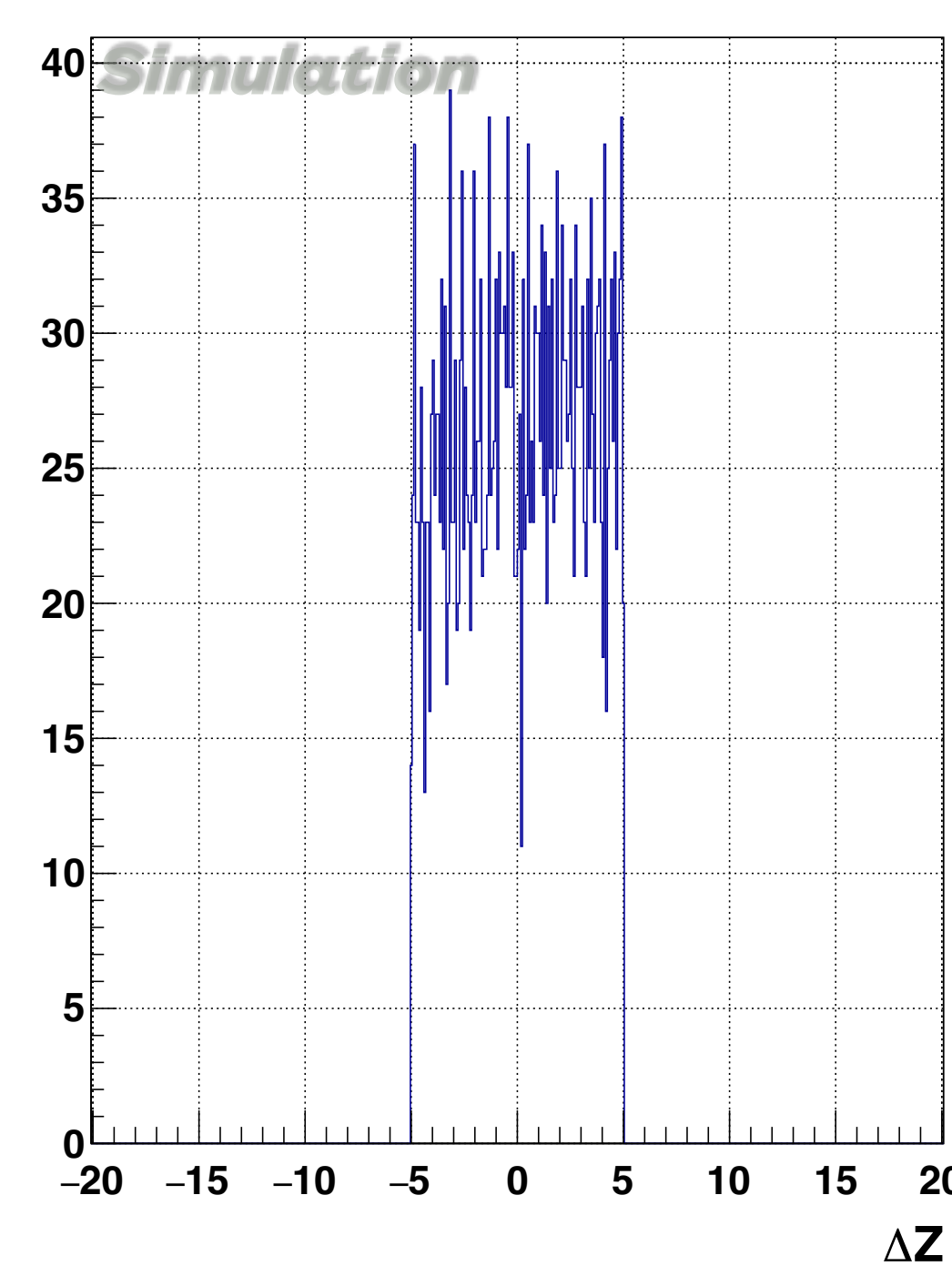
Vertical

Momentum dispersion

Z-vertex resolution, HKS



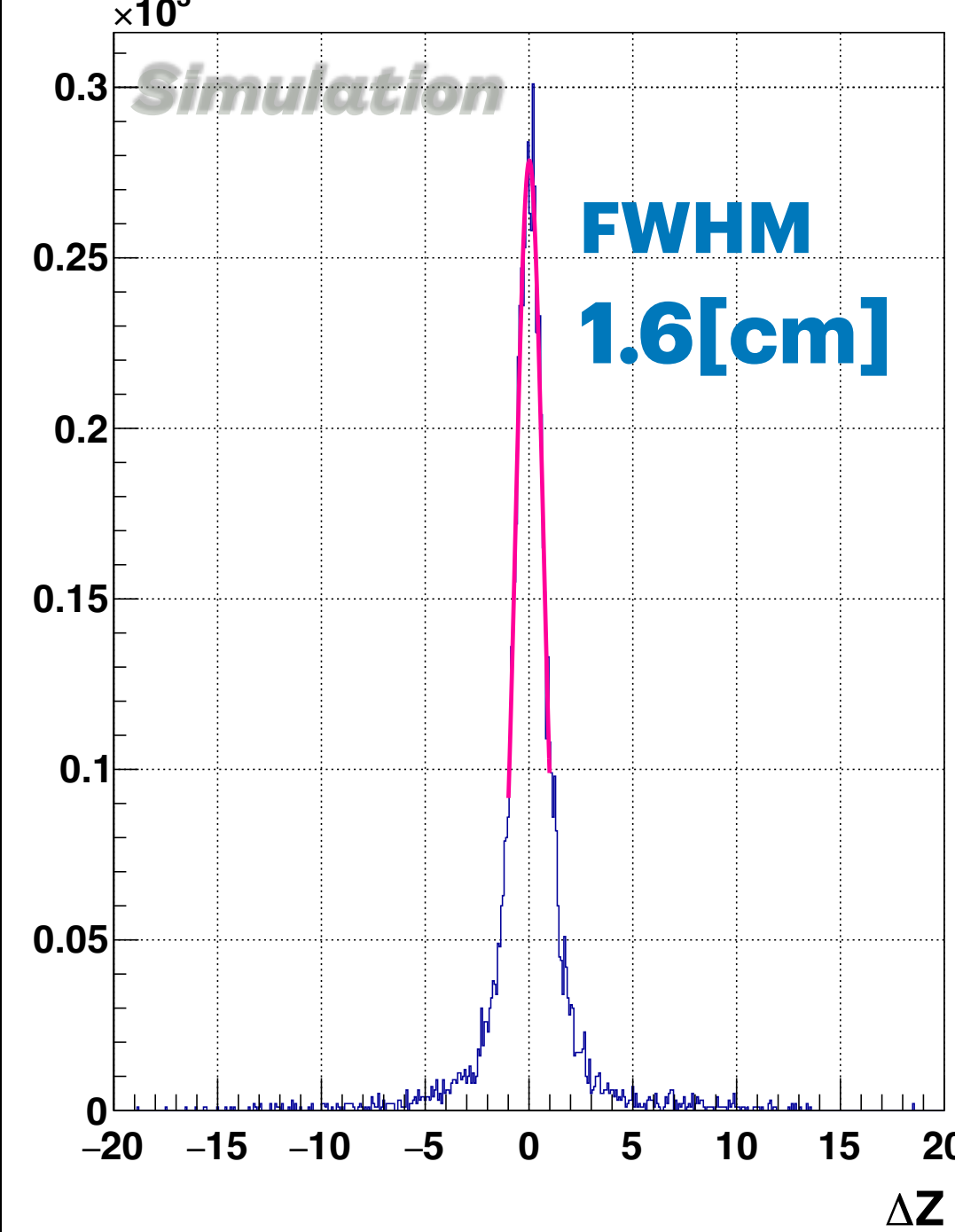
Z-vertex resolution, HES



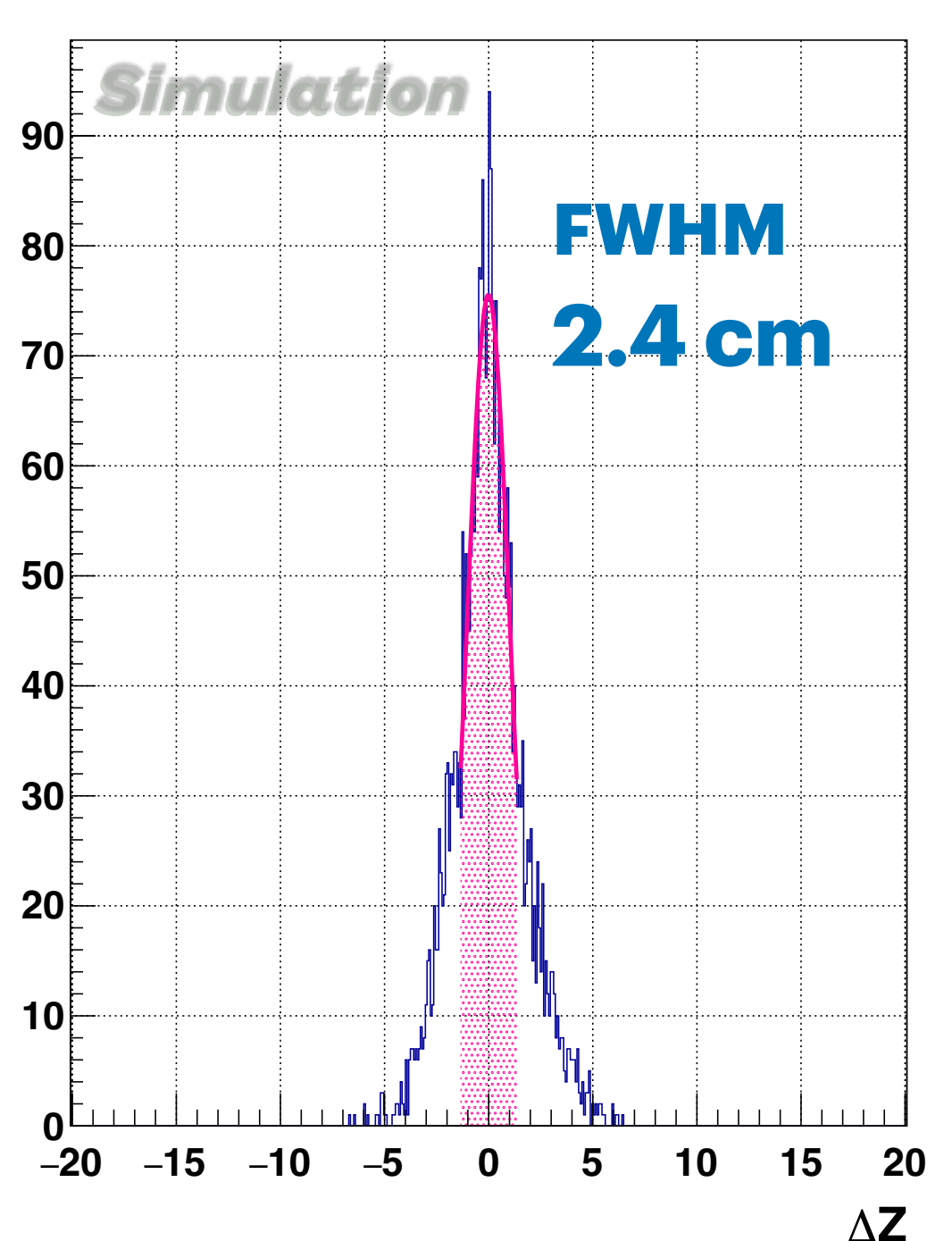
Cannot reconstruct Z

Update HES or HKS

Z-vertex resolution, HKS



Z-vertex resolution, HES



Gas target 20cm

$\geq 10\%$ precision determination

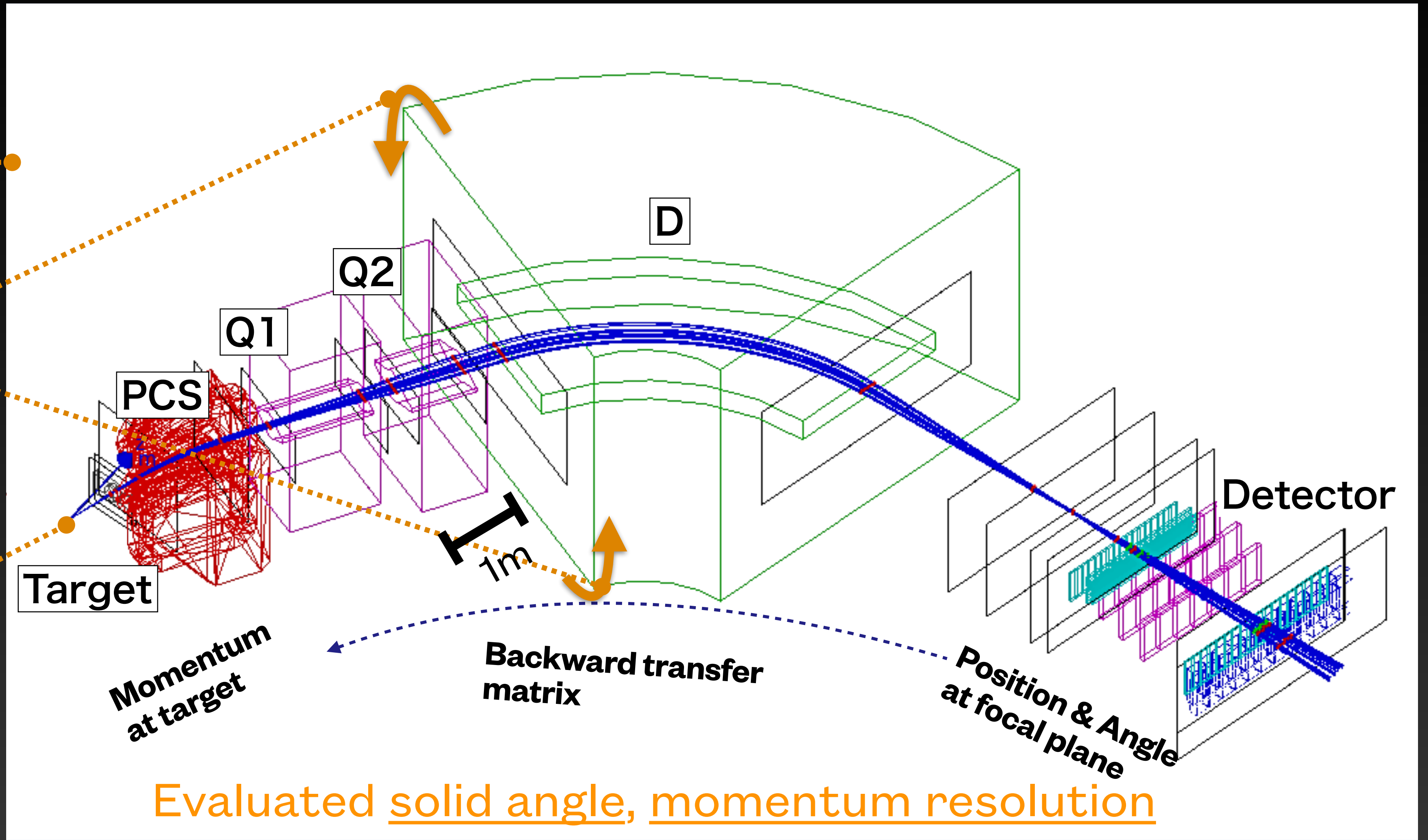
➔ Momentum resolution of the gas target gets better when vertical-bending, so we have to choose one spectrometer vertical-bending

Simulation Method

Geant4 Simulation

Condition

- ① HKS or HES
- ② Horizontal or Vertical
- ③ Solid target ($Z=0$) or cryo-gas target ($-10 \leq Z \leq 10$),



The purpose is to decide which option is the best of all HKS-HES bending patterns

How to Estimate

Momentum resolution

$$p_t = a_1 x_{FP} + a_2 y_{FP} + a_3 x'_{FP} + a_4 y'_{FP} + a_5 x_{FP} y_{FP} + \dots$$

$$= \sum_{a+b+c+d \leq m} C(a, b, c, d) (x_{FP})^a (y_{FP})^b (x'_{FP})^c (y'_{FP})^d$$

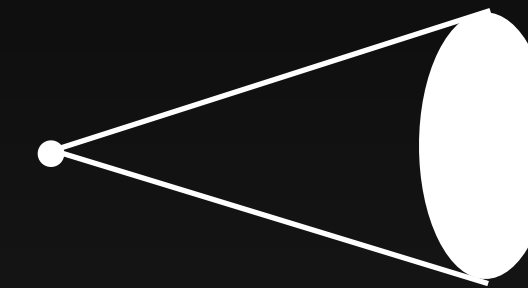
Determine coefficients $a_i (i = 0 \dots l)$ by solving coefficient vector from

Number of possible combination of (a, b, c, d)

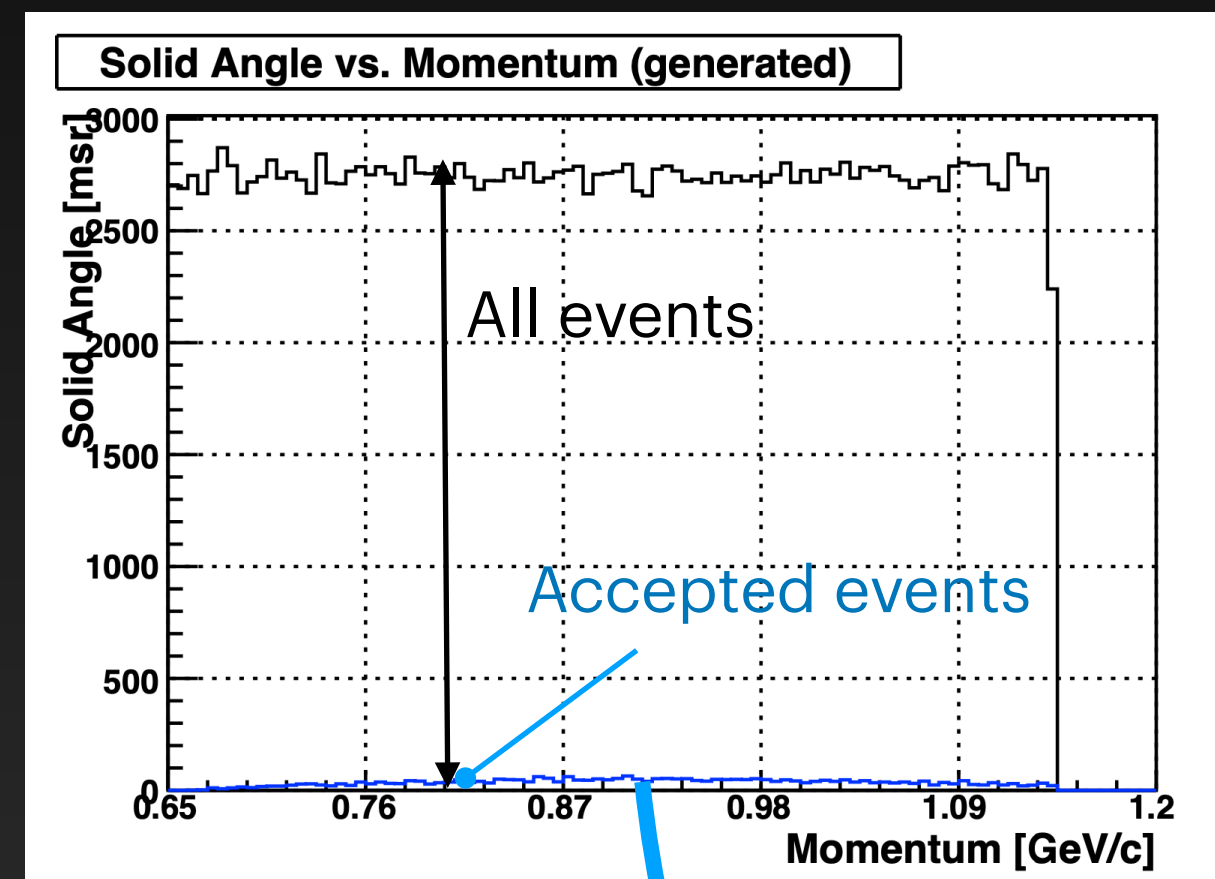
$$\begin{matrix} \text{Number of event} \\ \downarrow \end{matrix} \begin{pmatrix} p_t^{(1)} \\ p_t^{(2)} \\ \vdots \\ p_t^{(n)} \end{pmatrix} = \begin{pmatrix} x_{FP}^{(1)} & y_{FP}^{(1)} & \dots & (y'_{FP}^{(1)})^6 \\ x_{FP}^{(2)} & y_{FP}^{(2)} & \dots & (y'_{FP}^{(2)})^6 \\ \vdots & \vdots & \ddots & \vdots \\ x_{FP}^{(n)} & y_{FP}^{(n)} & \dots & (y'_{FP}^{(n)})^6 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ \vdots \\ a_m \end{pmatrix}$$

$$\frac{\text{Actual value } p_t^{true} - \text{Value calculated above } p_t^{calc}}{p_t^{true}} = \Delta p/p$$

Solid angle

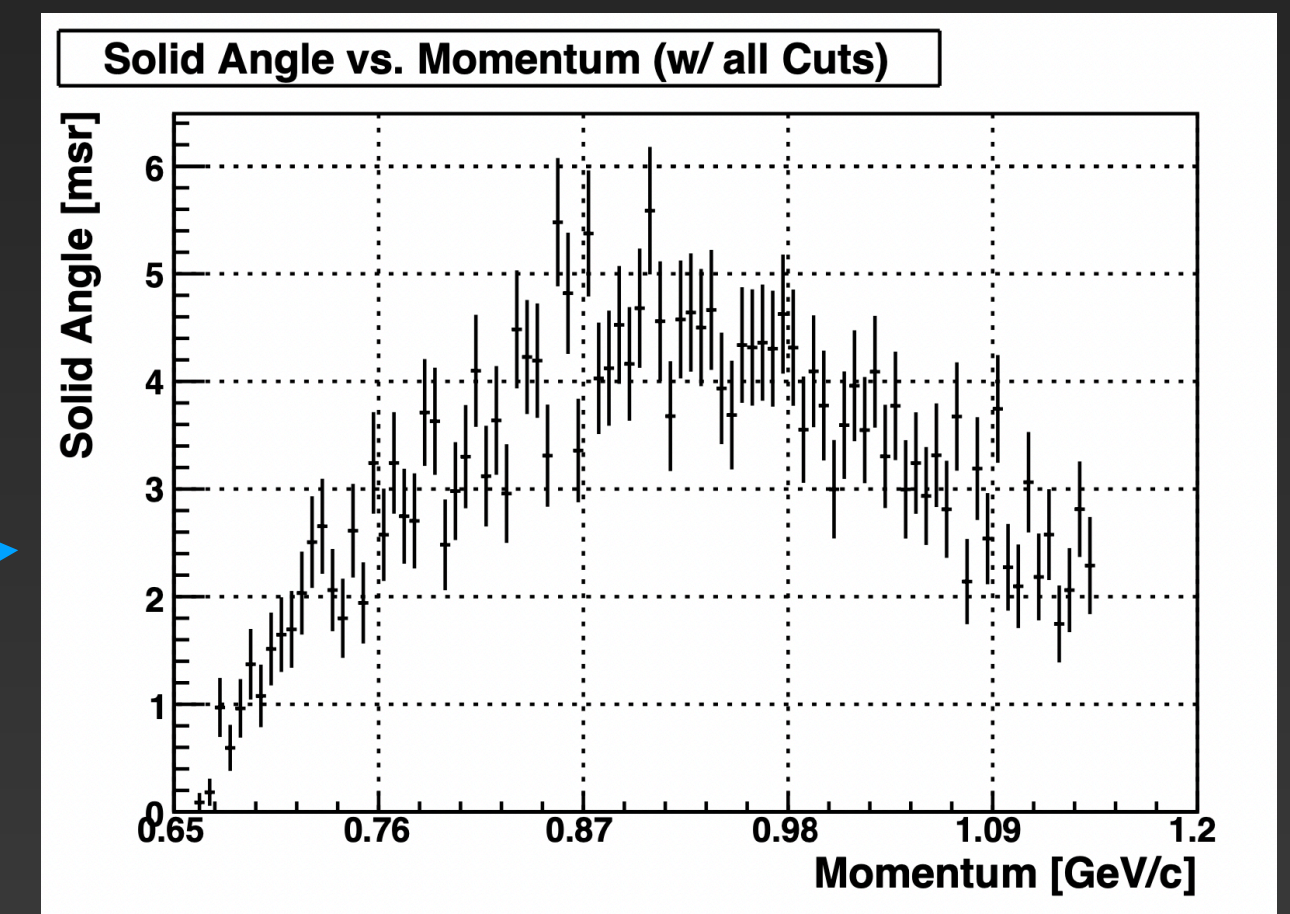


Cone range of emitted particles distributed uniformly in angle range $\Delta\theta, \Delta\phi$



In every momentum bin,

$$\sin \theta \Delta\theta \Delta\phi \times \frac{\text{accepted events}}{\text{all events}}$$

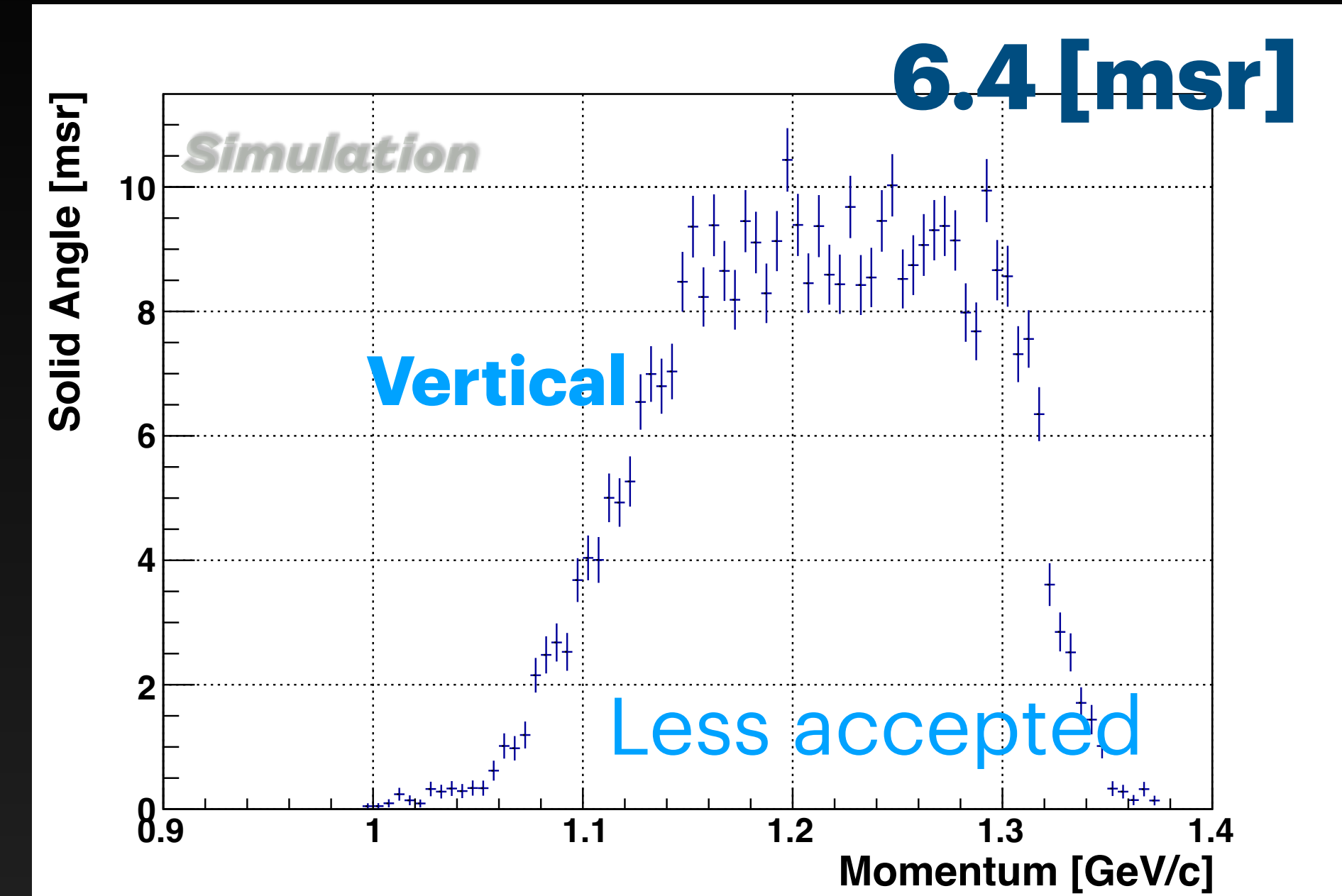
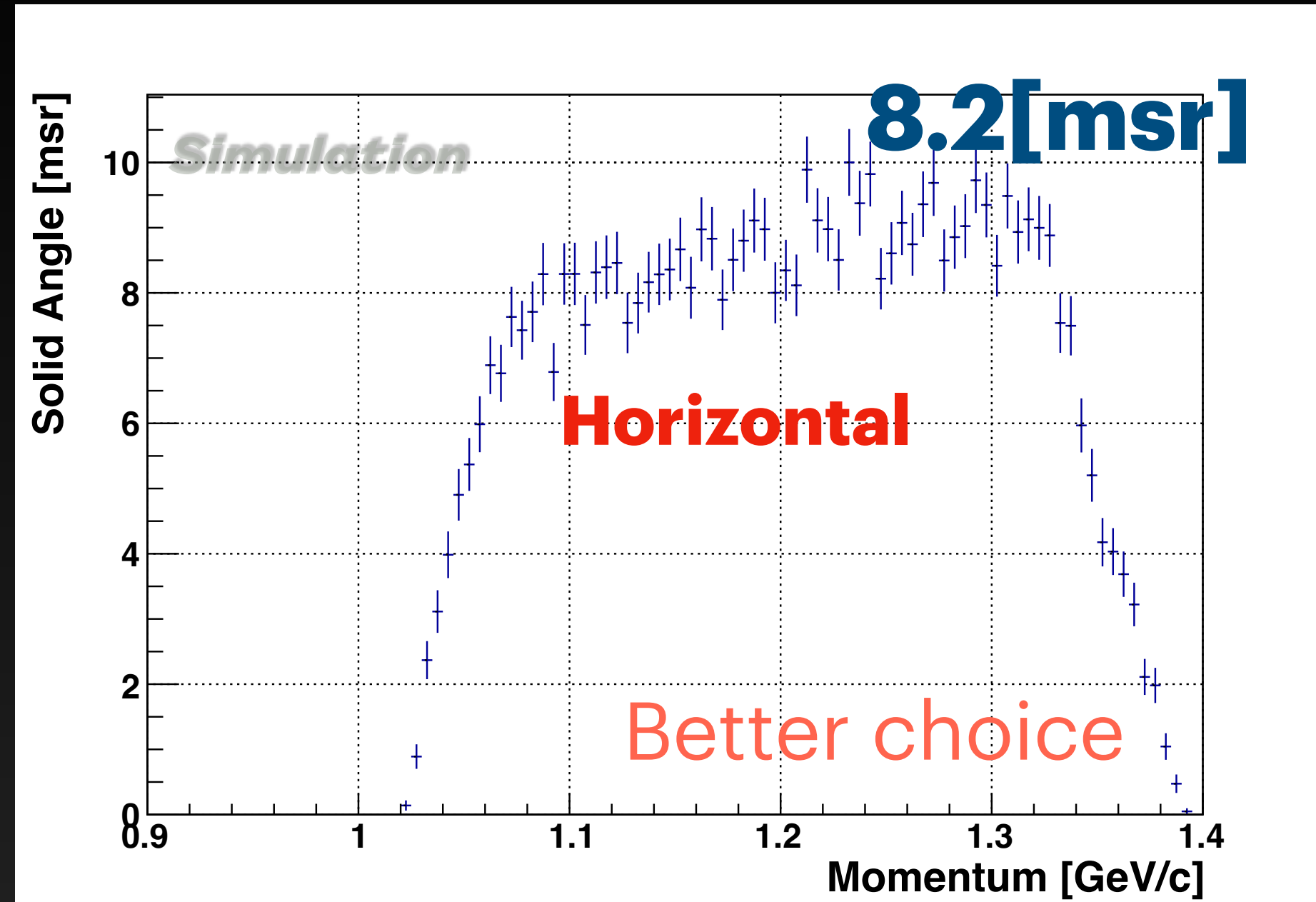


HKS Simulation Result

Solid Angle

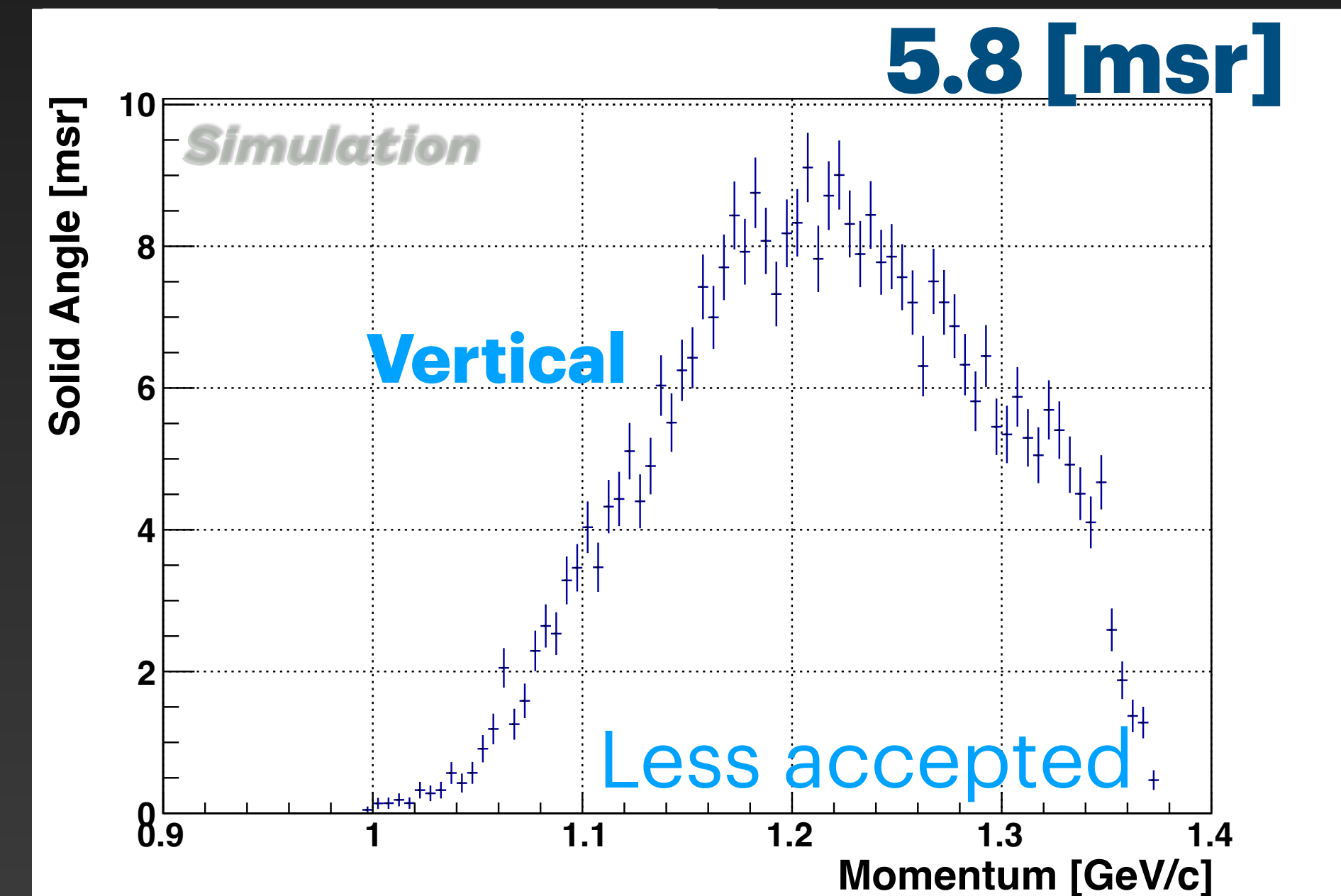
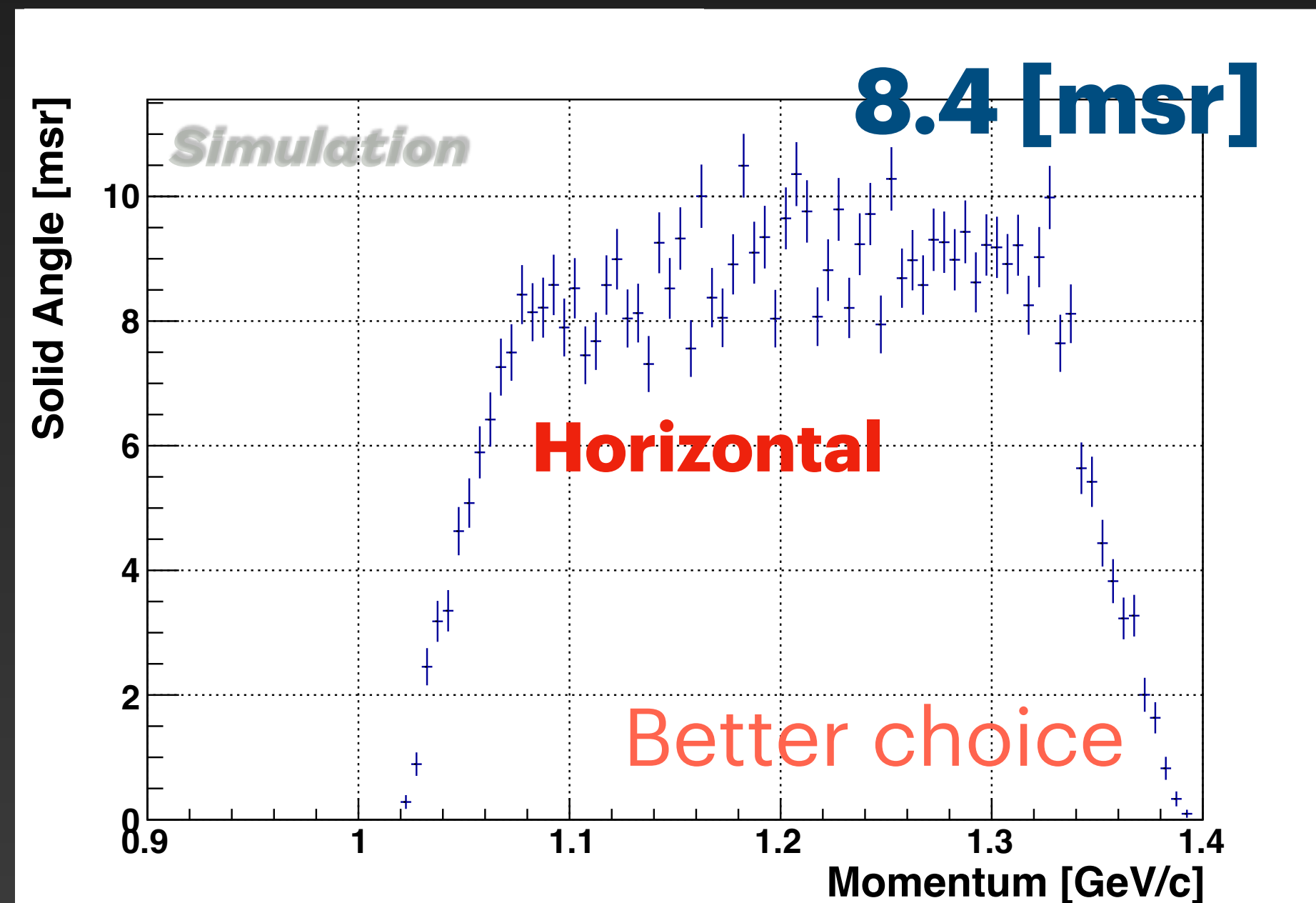
Solid target

Vertical-bending HKS doesn't work due to 20% decreasing of solid angle



Gas target

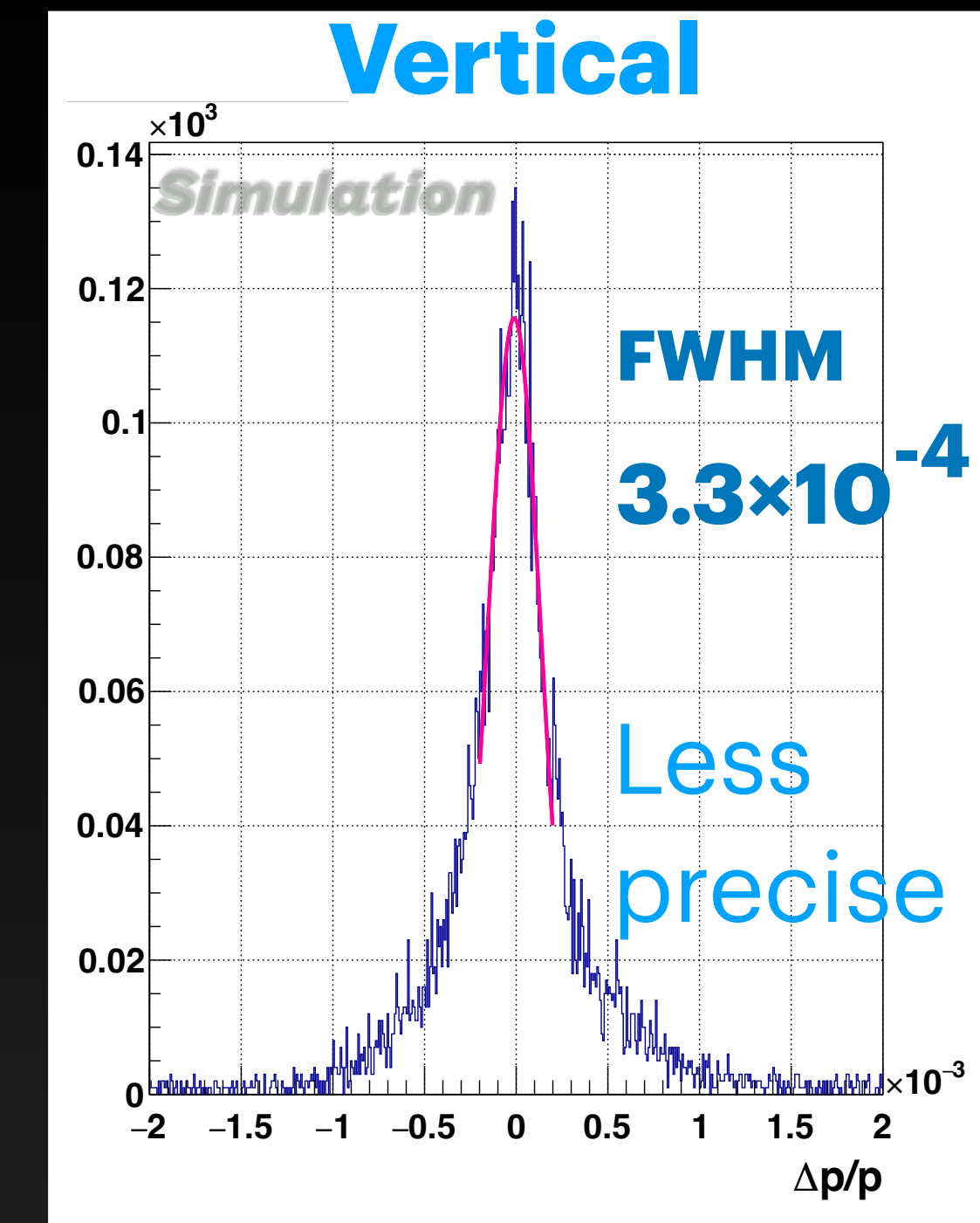
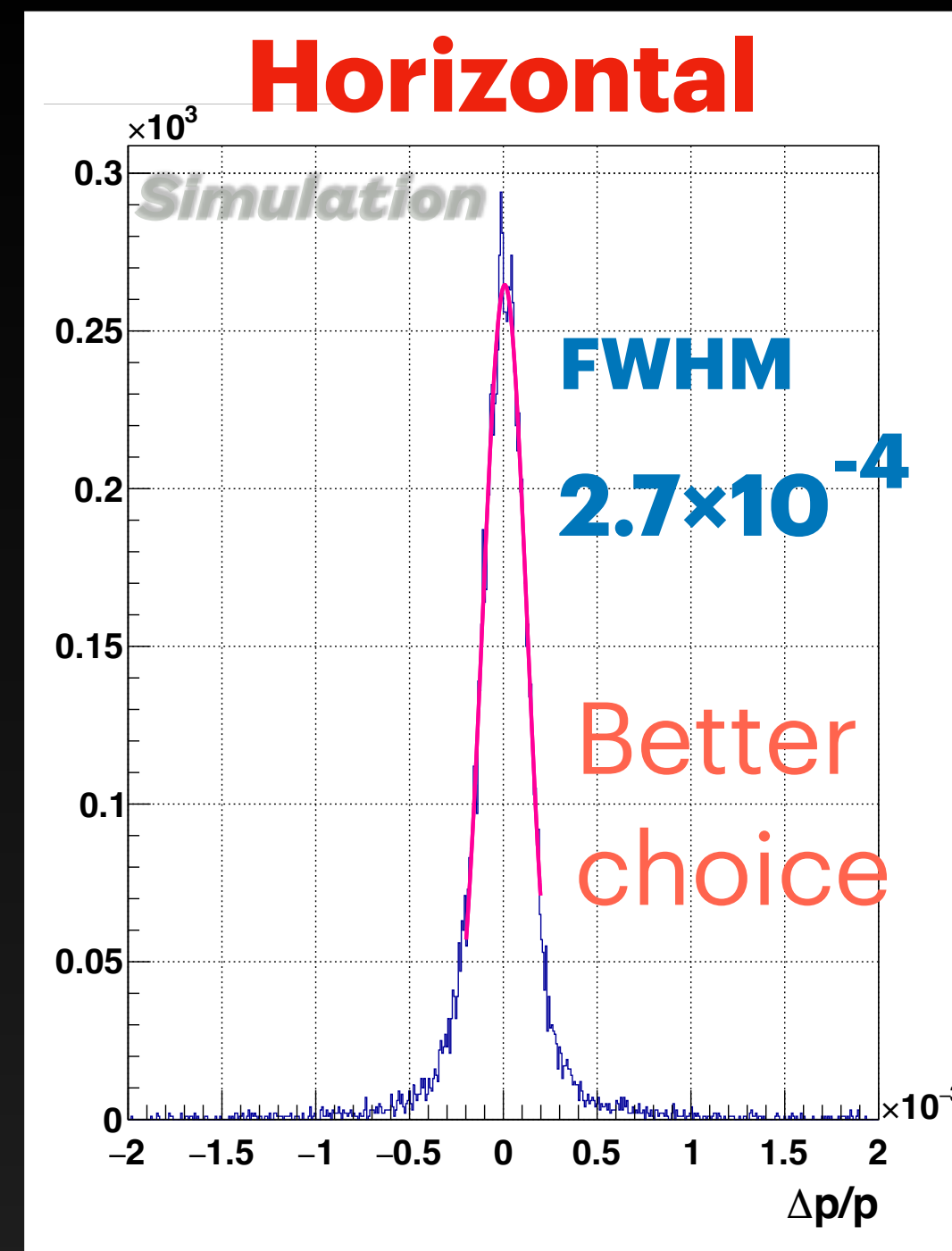
Vertical-bending HKS doesn't work due to 30% decreasing of solid angle



Momentum Resolution

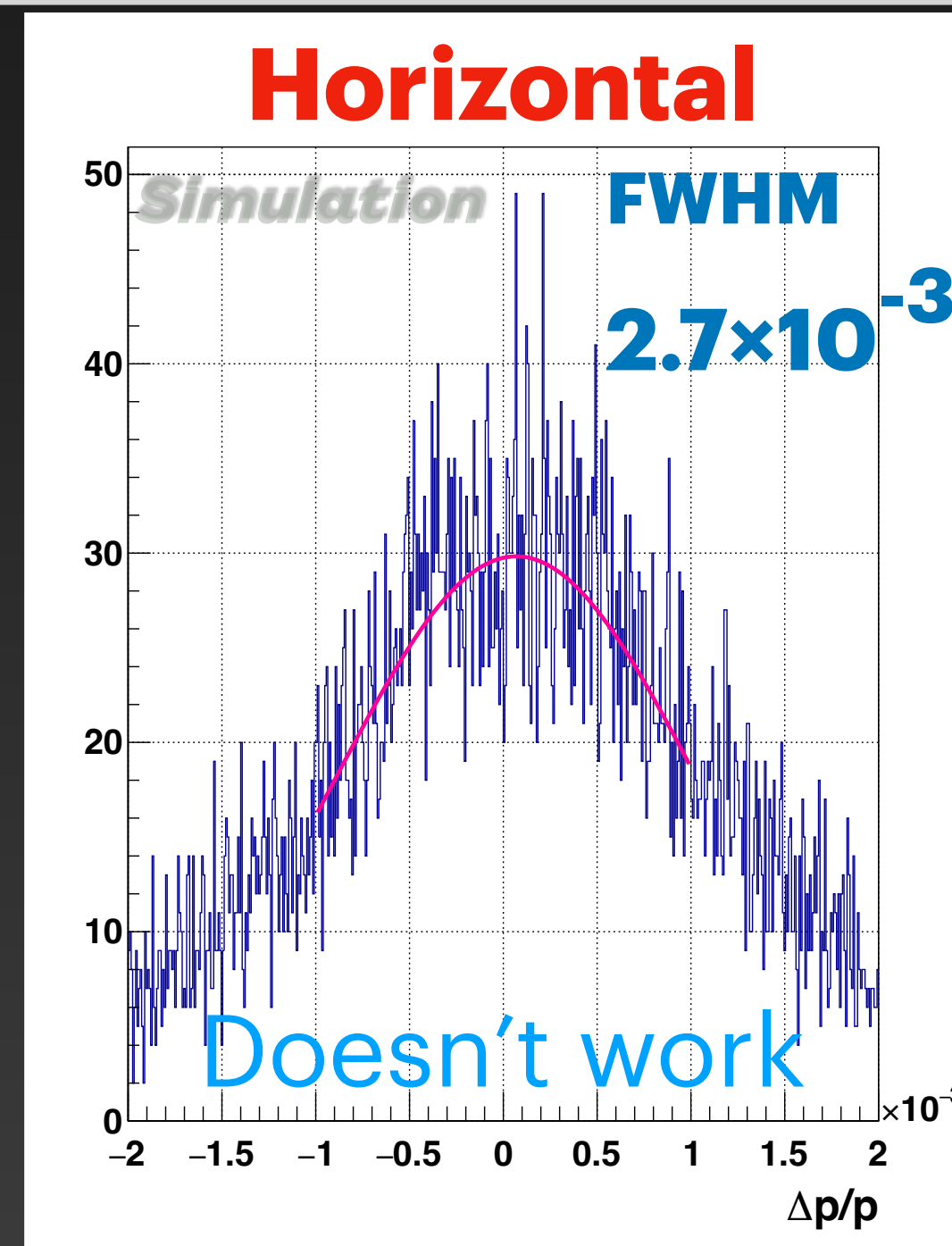
Solid target

Vertical-bending HKS should not be chosen due to 20% worse resolution

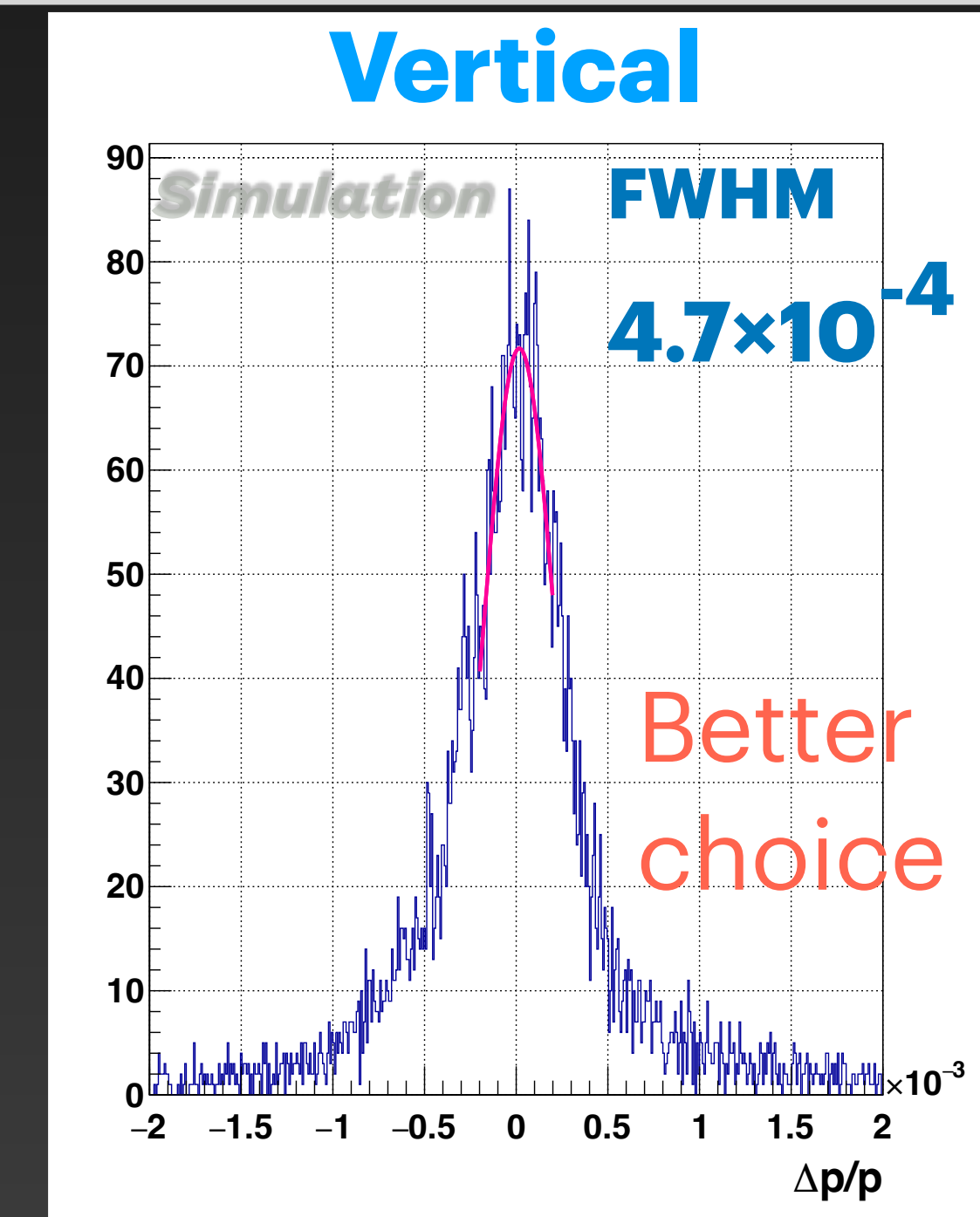
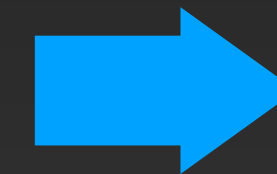


Gas target

Vertical-bending HKS is the better choice due to reviving its performance



Reviving its performance!

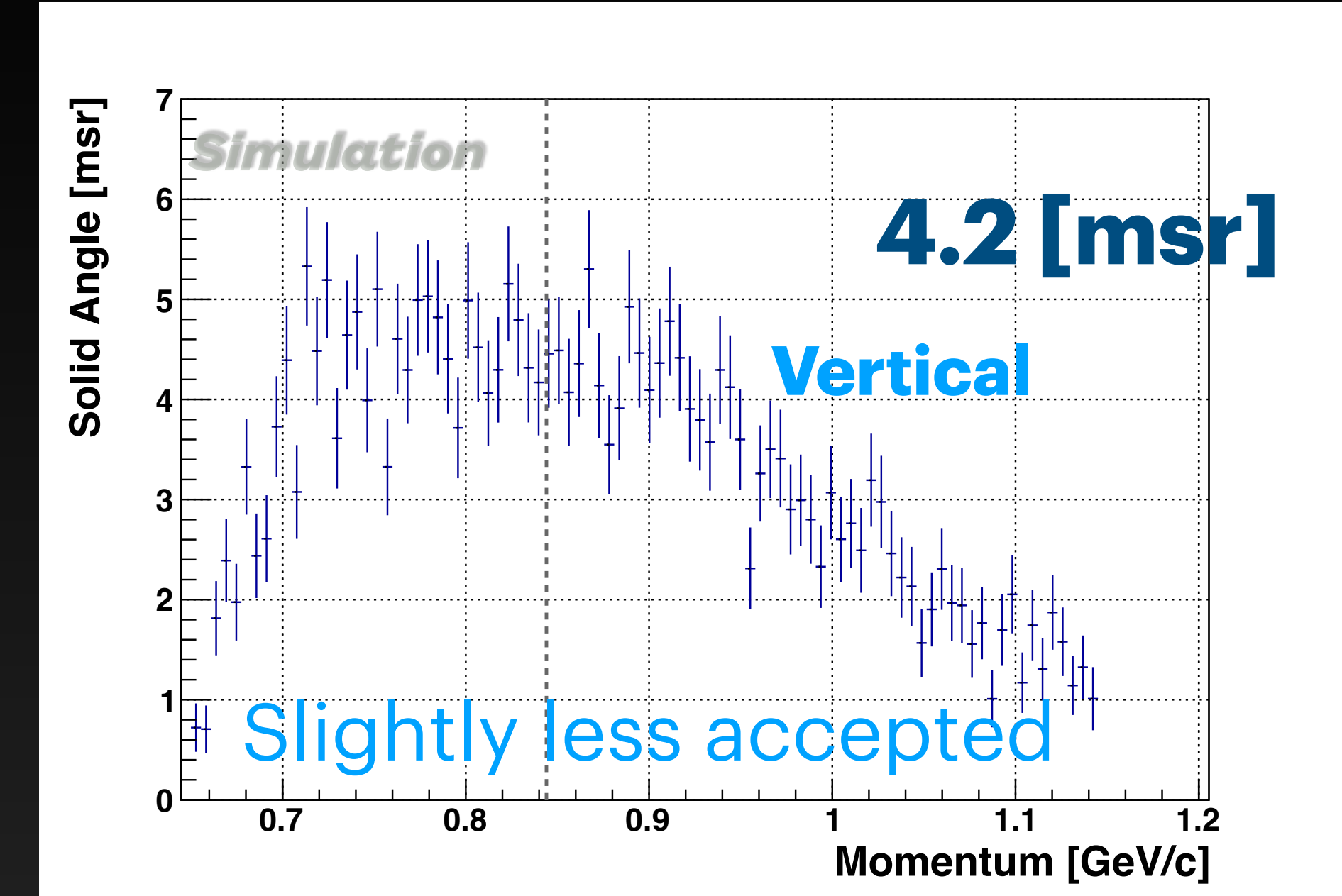
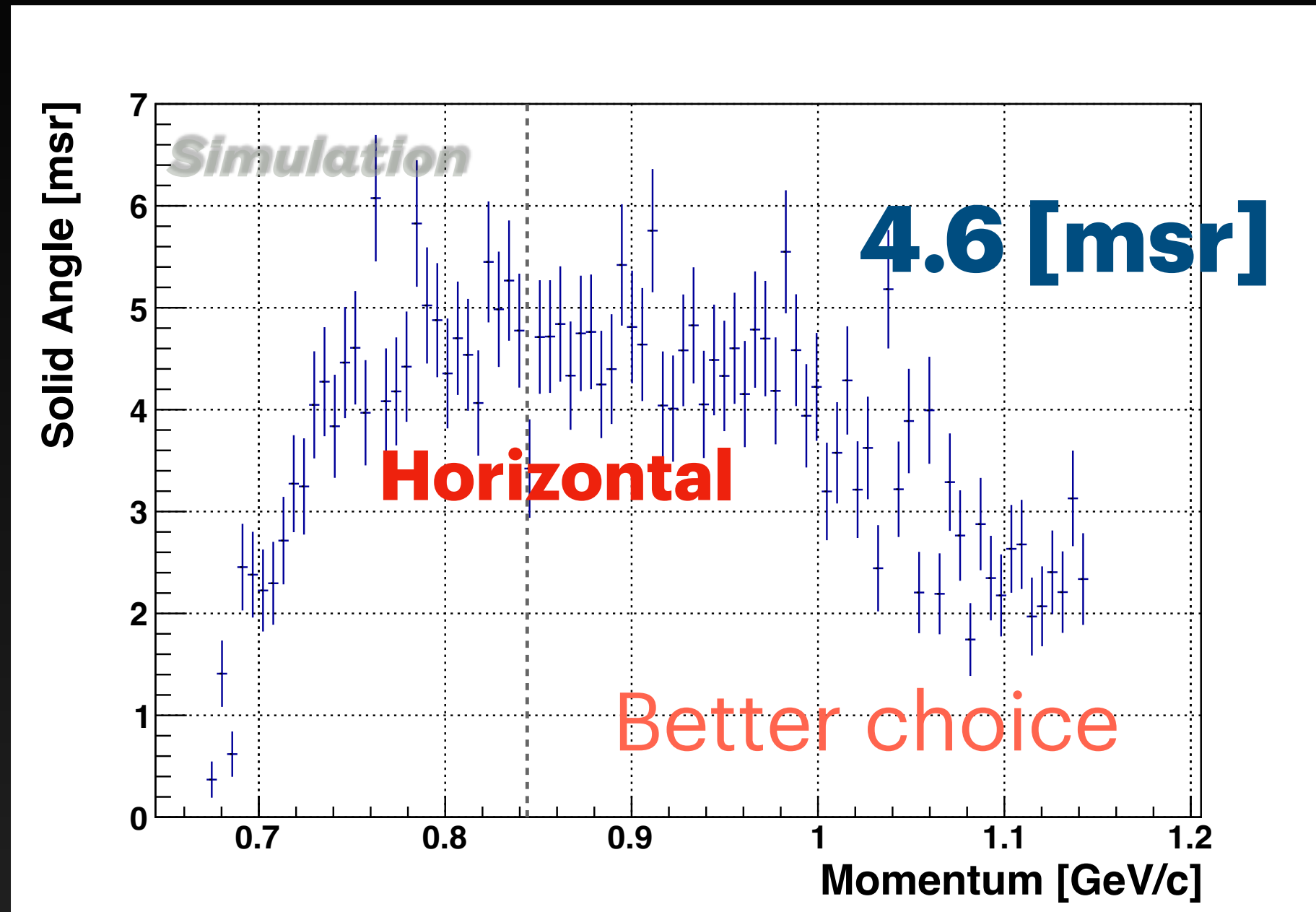


HES Simulation Result

Solid Angle

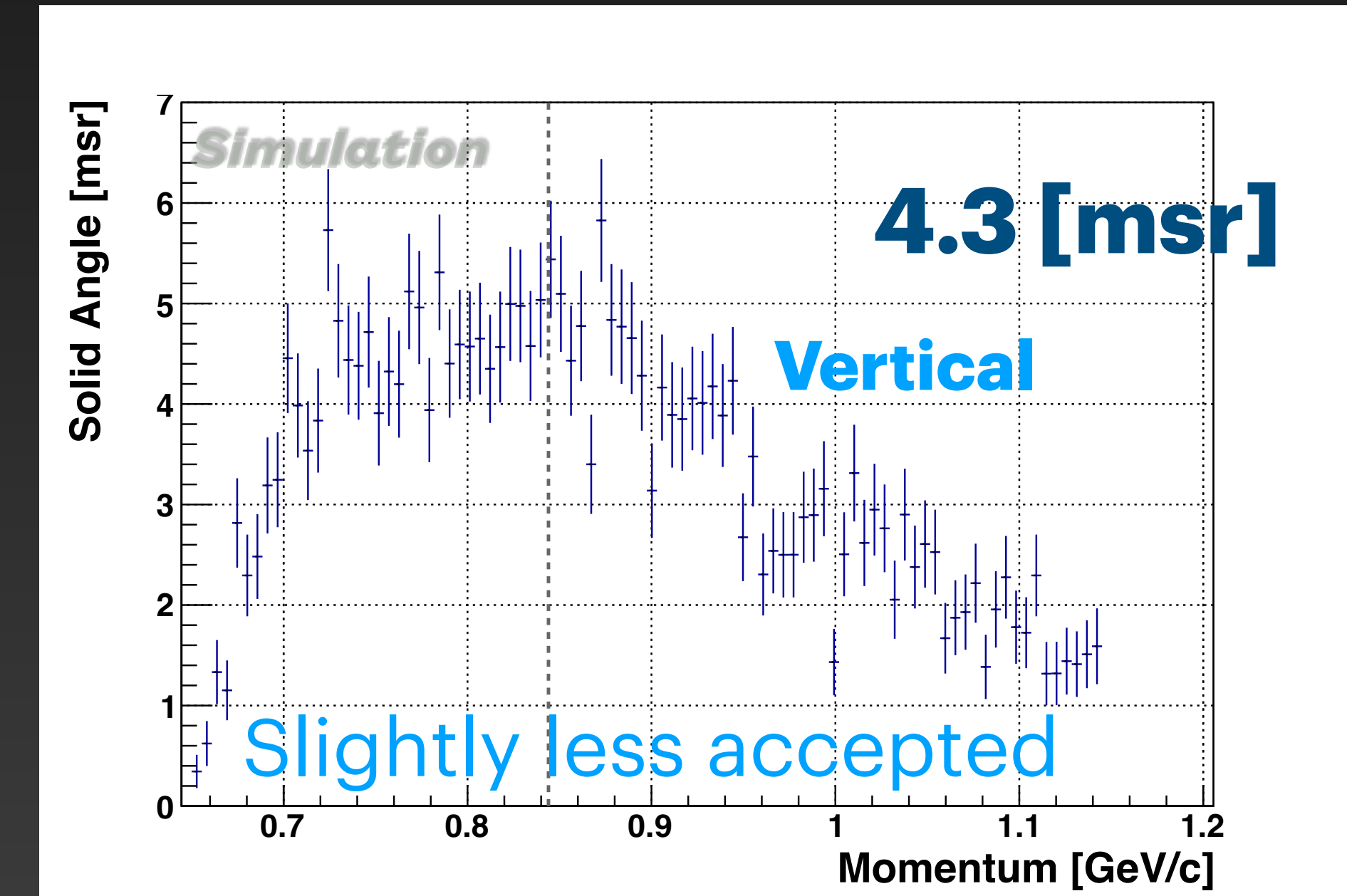
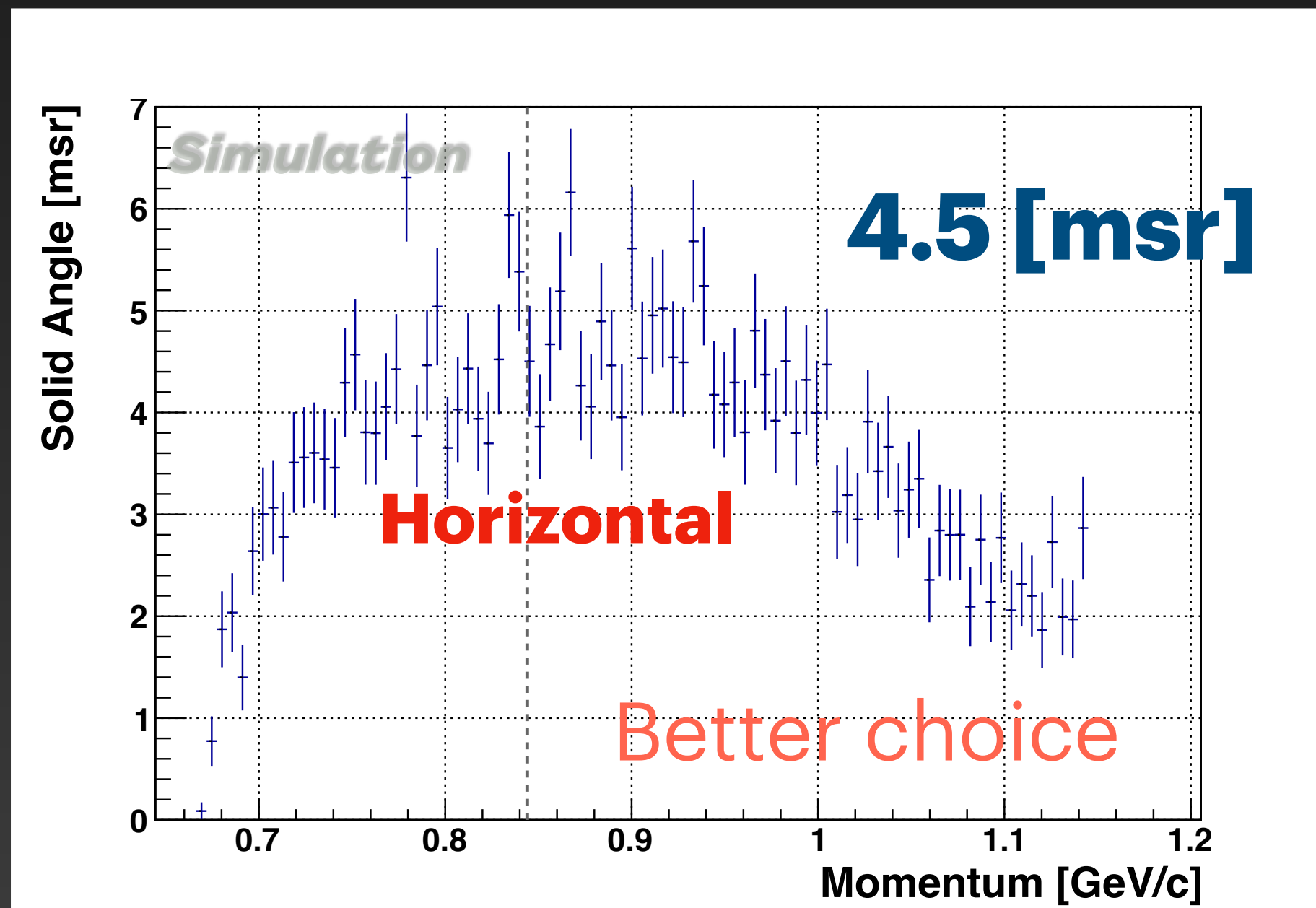
Solid target

Horizontal-bending HES is still be better choice but vertical-bending HES can be adapted due to suppressing decreasing under 10%



Gas target

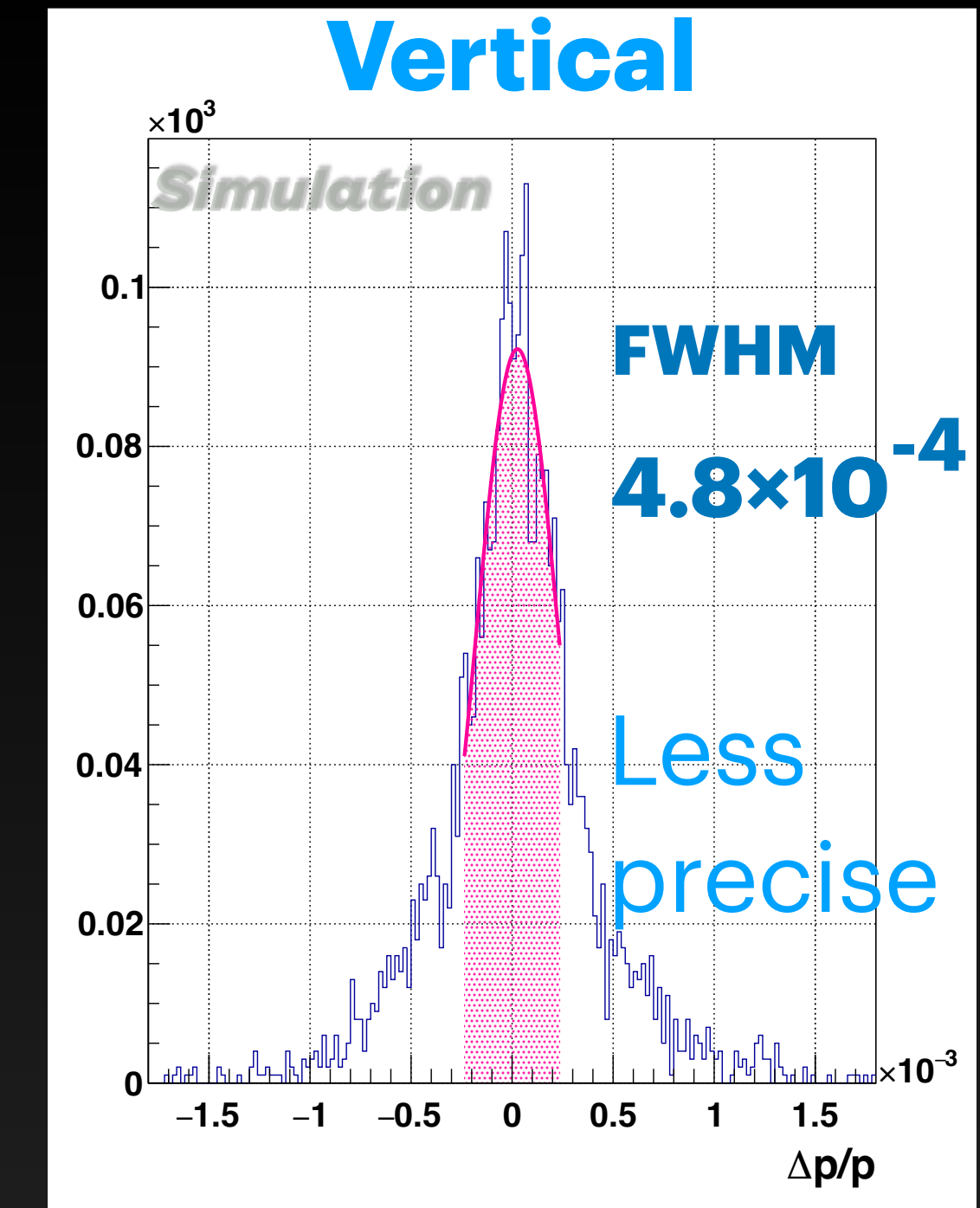
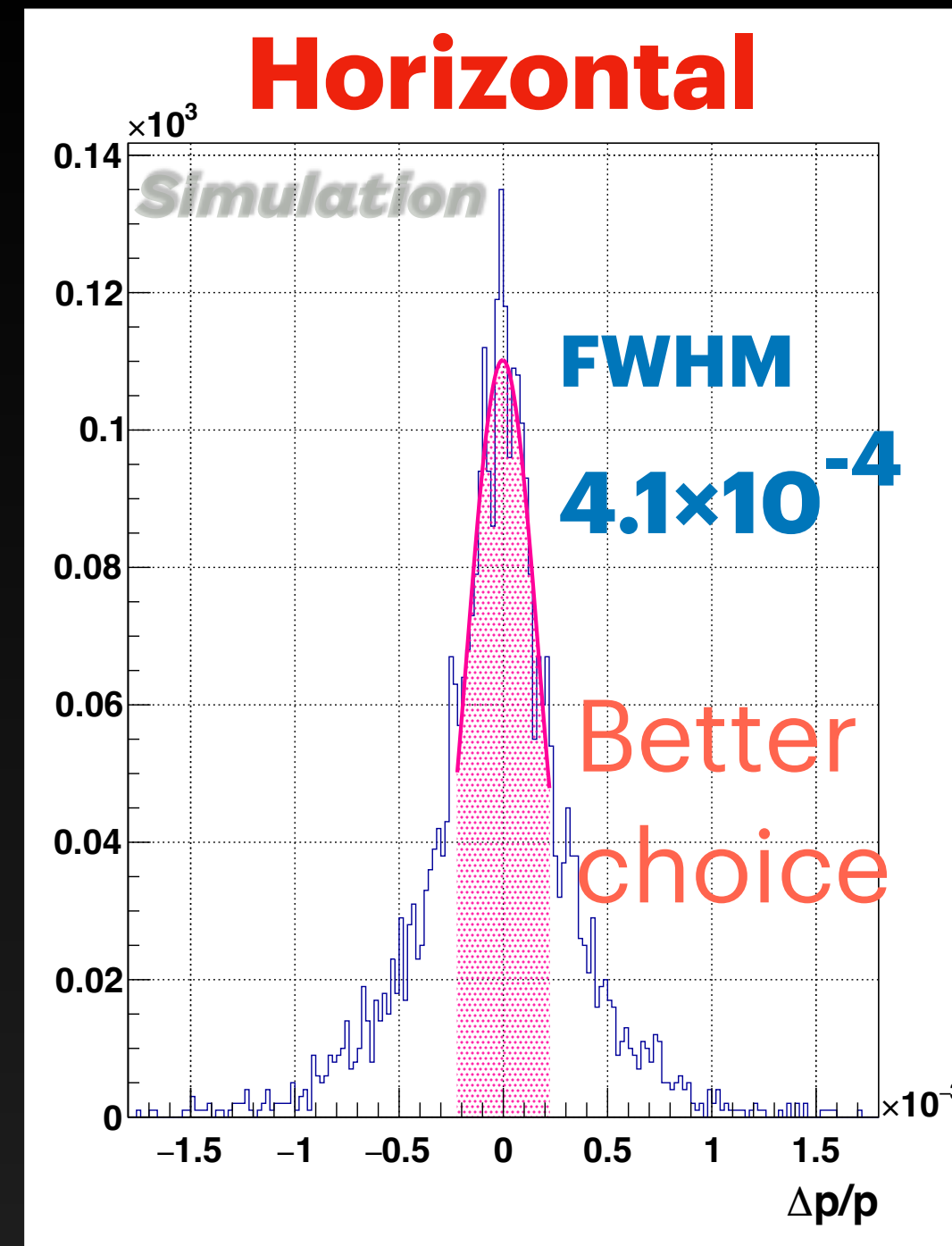
Horizontal-bending HES is still be better choice but vertical-bending HES can be adapted due to suppressing decreasing under 10%



Momentum Resolution

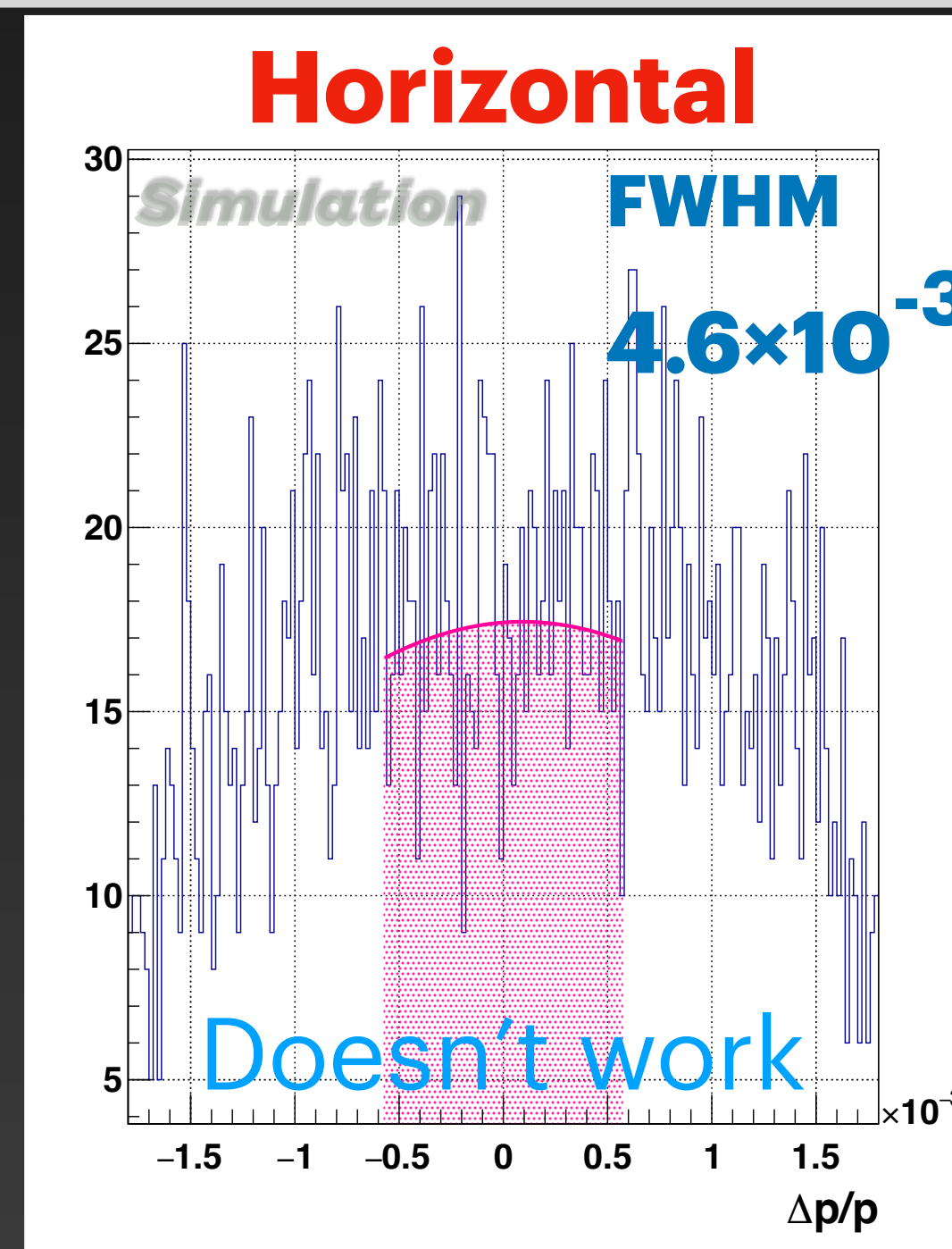
Solid target

Vertical-bending HES should not be chosen due to 15% worse resolution

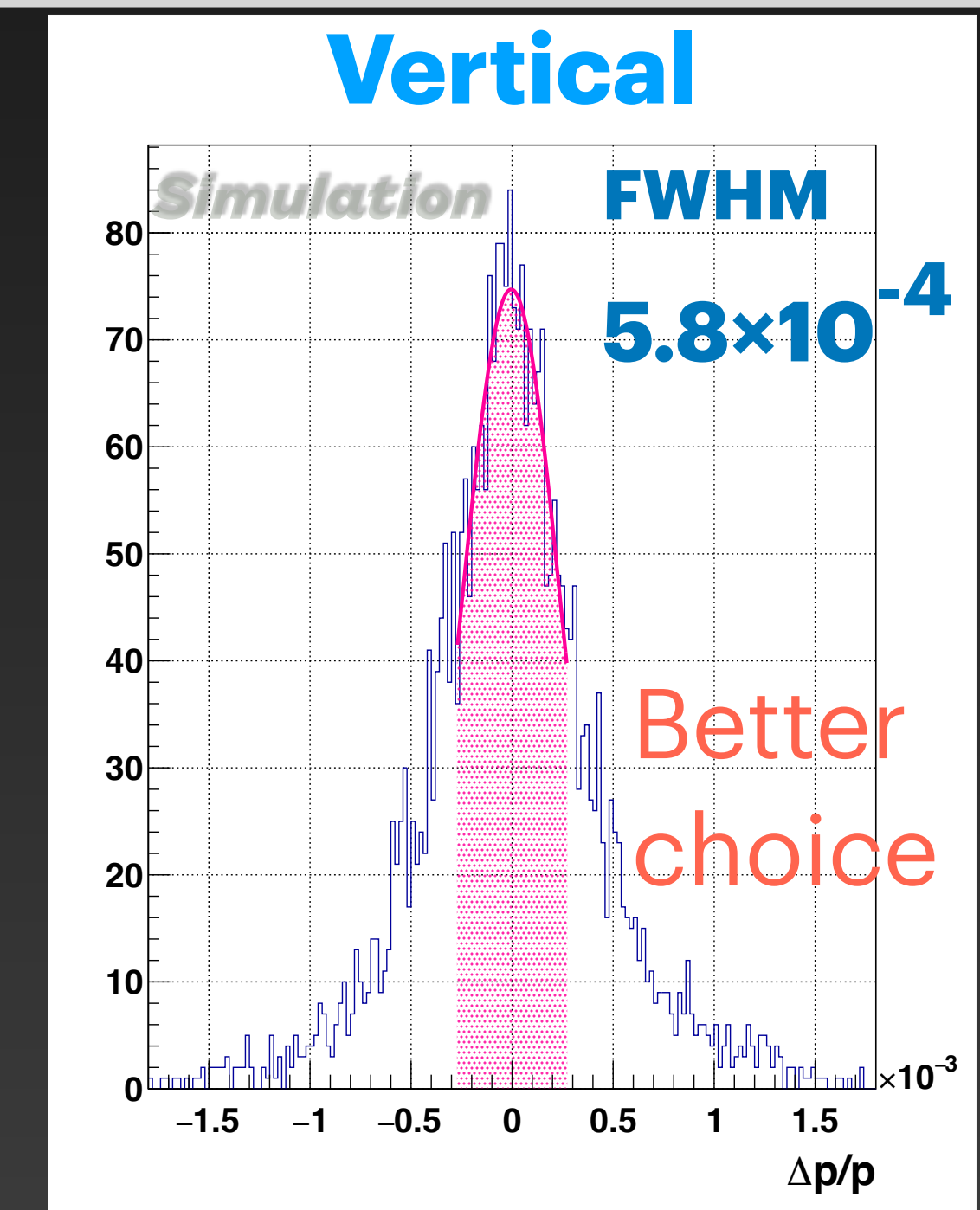
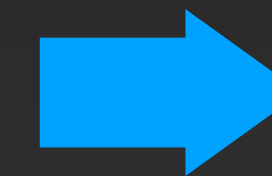


Gas target

Vertical-bending is the better choice due to reviving its performance



Reviving its performance!



Simulation Summary

Solid Target

Option	Solid angle [msr]	Momentum resolution
Horizontal-bending HKS	8.2	2.7×10^{-4}
Vertical-bending HKS	6.3	3.3×10^{-4}
Horizontal-bending HES	4.6	4.1×10^{-4}
Vertical-bending HES	4.2	4.8×10^{-4}

Best choice of all for solid target

Cryo-gas Target

Option	Solid angle [msr]	Momentum resolution
Horizontal-bending HKS	8.4	2.7×10^{-3}
Vertical-bending HKS	5.7	4.7×10^{-4}
Horizontal-bending HES	4.5	4.6×10^{-3}
Vertical-bending HES	4.3	5.8×10^{-4}

6 times better

8 times better
Better choice for gas target

Horizontal-bending HKS and vertical-bending HES is the best and satisfies minimum requirement

Summary

Summary

- Simulation study of PCS-HKS-HES
 - One side of spectrometer should be vertical-bending because of the gas target
- Minimum requirement for several hundreds keV missing mass resolution
 - HKS & HES
 - **Momentum resolution $\Delta p/p$: several $\times 10^{-4}$ (FWHM)**
 - **Solid angle : several msr**
- Result
 - For solid target, HKS should be horizontal-bending because of best momentum resolution
 - For gas target, HES should be vertical-bending because of better recovery of momentum resolution
 - **Horizontal-bending HKS - Vertical-bending HES is so far the best option**
 - Horizontal-bending HKS \rightarrow Momentum resolution: 2.7×10^{-4} , Solid angle: 8.2 [msr]
 - Vertical-bending HES \rightarrow Momentum resolution: 5.8×10^{-4} , Solid angle: 4.3 [msr]