MUSE Update

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NSF

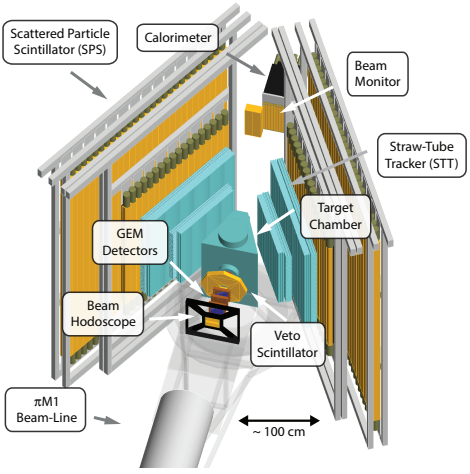
MUSE Current Status

- MUSE currently taking data
- Some difficulties with shift workers and live analysis
- PSI requires an annual review of all experiments at the lab
  - Process known as Benützerversammlung (BV), sometimes BVR
  - For MUSE, this is a 3 hour process where we explain the status of the experiment over the past year, and defend our request for beam time in the coming year
  - PSI also requires MUSE to submit an annual analysis report in advance of the review
  - In the past they would spread the review over two days and even give us homework...
- The current focus is on writing this report. The committee in particular is very confused and concerned about blinding.

BVR Charge

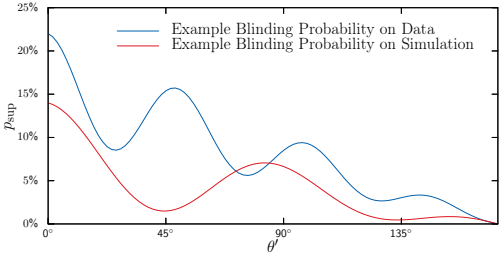
In the subcommittee meeting MUSE presented a blinding scheme that they have also submitted for publication. However the committee is concerned that MUSE has not adequately explained how the blinded data can be analyzed in such a way that they are confident that the unblinded data will yield a physically sensible result. The committee asks that MUSE prepare a detailed strategy describing how the blinded data (or some subset thereof) can be studied. This strategy should describe how such a 'pre-analysis' of the blinded data will provide an appropriate level of confidence such that, when the data is fully unblinded, it will provide physically reasonable results. The committee then requests that this strategy be applied to a suitable subset of data (for example the 2023 data) and the results presented in the form of a report to the committee in advance of BVR56. The committee also asks the collaboration to consider the benefit of having additional independent analyses as a crosscheck in order identify and eliminate analysis errors.

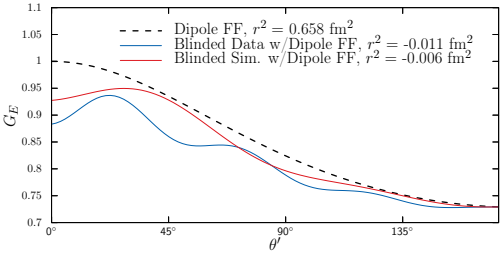
MUSE



- PiM1 Secondary beam line
- Measure incoming beam event by event
- Beam contains e's, μ's, and π's
- Can select positive or negative charge polarities
- Veto to reject beam halo, decay, and target background events
- Use RF signal for PID via TOF
- Beam species dependent trigger

Blinded Analysis



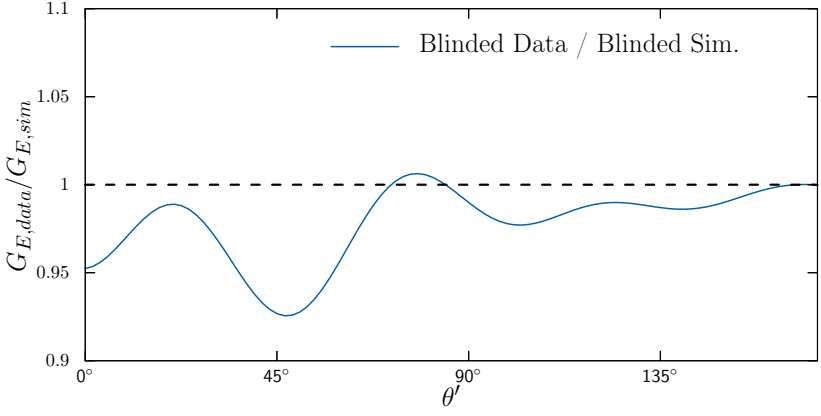


$A = [0.25..1], B = [3..10]$ are generated from fixed seed and are unique for charge, species, momentum, data vs. simulation

$$s = 0.2(A + 0.3\cos(B \times \theta')), P = s \times \frac{3 - \theta'}{3}$$

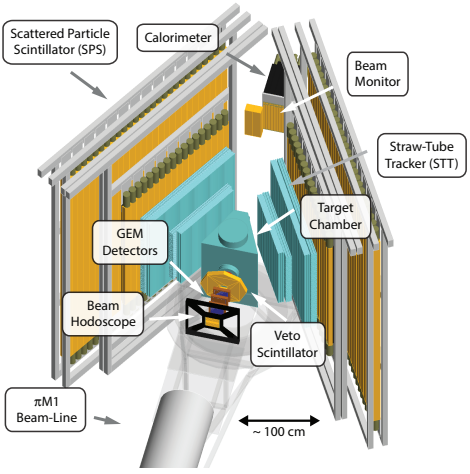
if $P \leq R$, where R is a uniformly distributed random number between 0 and 1, encrypt the track

Effect of Blinding on G_E



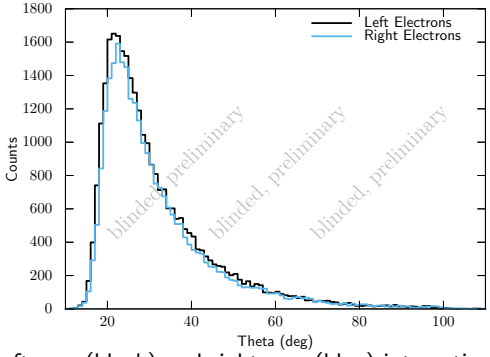
The ratio of data to simulation of the extracted form-factor, assuming a dipole shape.

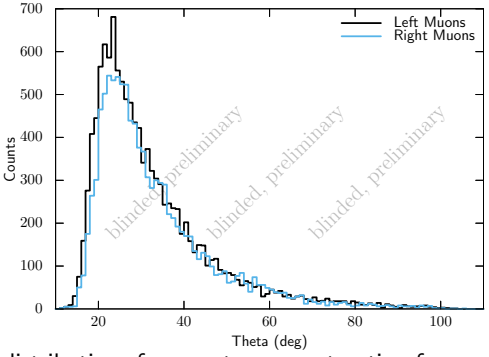
Analyzing Blinded Data



- How do we analyze blinded data for MUSE?
- Well beamline data is unblinded...
- For scattering data we do not blind Left v. Right!
- Comparisons of both sides of the detector allow for systematic comparisons, and detector quality checks
- We determine a scattering vertex, and then plot vertex quantities for left or right sides for each particle species

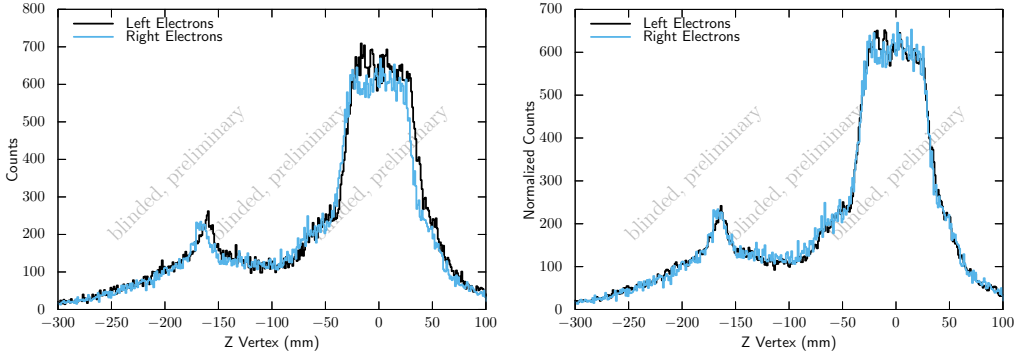
Left and Right θ Comparisons





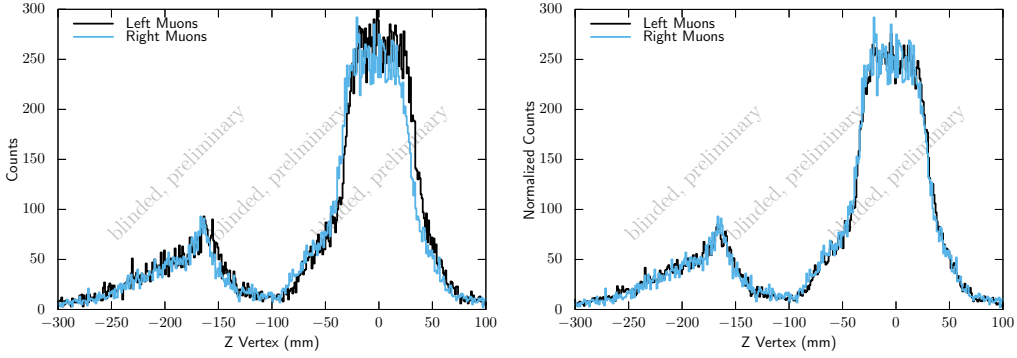
Left arm (black) and right arm (blue) interaction θ distributions from vertex reconstruction for electrons (left) and muons (right) after the listed cuts. Plots by Kyle.

Left and Right Z Vertex Comparisons



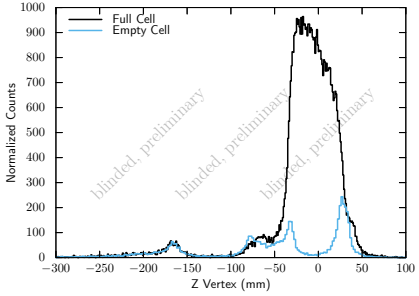
Left arm (black) and right arm (blue) Z vertex distributions for electrons with the listed cuts. The left figure shows raw data, the right is shifted and scaled. Plots by Kyle.

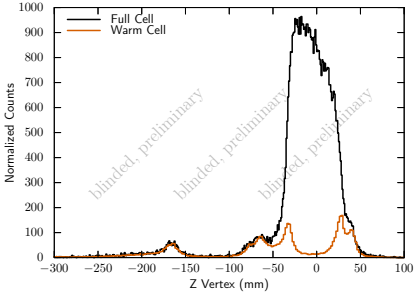
Left and Right Z Vertex Comparisons

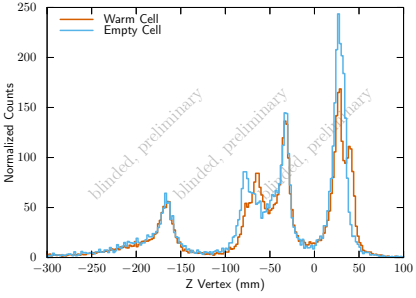


Left arm (black) and right arm (blue) Z vertex distributions for muons with the listed cuts. The left figure shows raw data, the right is shifted and scaled. Plots by Kyle.

Full, Warm, Empty, Z Vertex Comparisons







Unblinding Plan

- Unblinding is species, momentum, charge polarity specific
- Plan to blind run periods differently
- Unblind πp scattering first, less contentious
  - First 10 %
  - Remainder of data
- Depending on analysis status, either ep or μp
  - Similarly, first 10 %
  - Remainder of data
  - *Anticipate* TPE first, then e/μ universality, then radius

Current Status and Plans

Year	LH2 (events $\times 10^6$)	Empty (events $\times 10^6$)	Total (events $\times 10^6$)
2023	1,473.03	1,260.49	2,733.52
2024	2,259.24	1,556.74	3,815.98

In 2023, MUSE started production data taking for 12 beam months over 2 years.
MUSE aims for $\approx 12 \times 10^9$ events, 60/40 split between LH2/Empty Cell

Continuing data taking this year.
Aim to finish in 2025