

Blinding Precision Scattering Experiments

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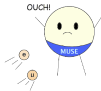
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NREC Workshop

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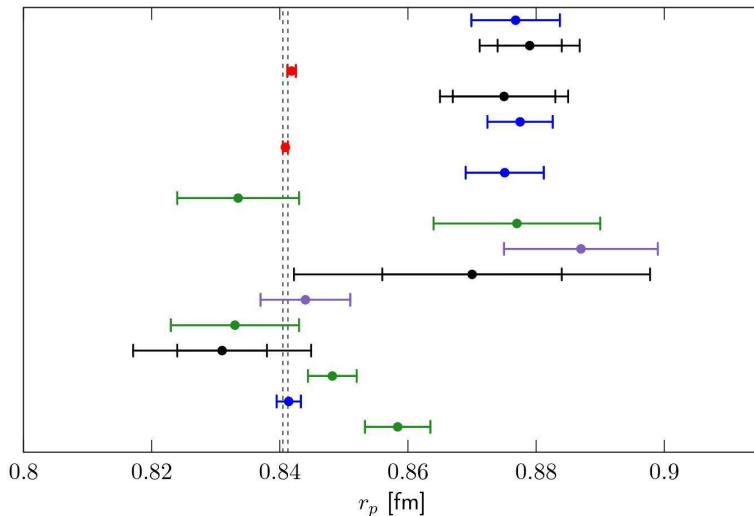
April 16, 2026



Blinding



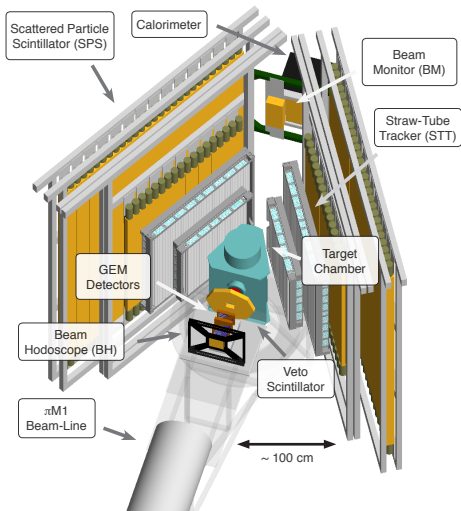
Proton Radius Results - Why Blind?



- CODATA'06 (2008)
- Bernauer (2010)
- Pohl (2010)
- Zhan (2011)
- CODATA'10 (2012)
- Antognini (2013)
- CODATA'14 (2015)
- Beyer (2017)
- Fleurbaey (2018)
- Sick (2018)
- Mihovilović (2019)
- Alarçon (2019)
- Bezginov (2019)
- Xiong (2019)
- Grinin (2020)
- CODATA'18 (2021)
- Brandt (2022)

Want to avoid bias! Either thinking a result is “right” or “good enough”

MUSE Sketch



What do we Blind?

What do we blind?

- Proton charge radius
- Cross sections
 - e^\pm , μ^\pm , and π^\pm
- Cross section ratios
 - Data and simulation

How do we blind?

- Protect CPU intensive parts of the analysis - tracking
- Encrypt scattered tracks with an angular dependence
- Encrypted tracks are secured by three public/private key pairs
 - Key pairs are taken from senior members of the collaboration
- Require two-of-three keys to decrypt
 - Requires collaboration approval
 - Attempt to reduce risk of lost key

How do we Blind?

- We bake the blinding algorithm into our analysis framework - the **cooker**. Used in
 - OLYMPUS
 - TREK
 - MUSE
 - DarkLight
- Wrapper around the CERN ROOT package
- Plugin based architecture
 - Read in ROOT branch, write out ROOT branch. Control over data format, and control over interface between plugins
- Force the blinding when using a scattered tracking plugin

Blinding Probability on Tracks

- Encrypt STT tracks with angular dependence
- A, B are generated from fixed seed and are unique for charge, species, momentum, data vs. simulation
- $A = [0.25..1]$, $B = [3..10]$

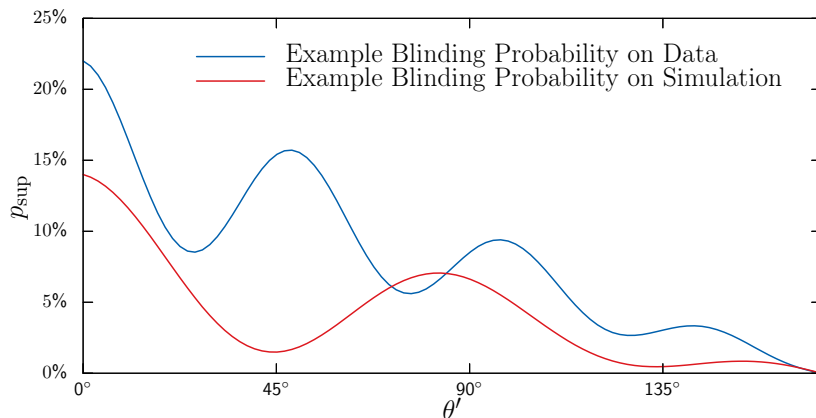
$$s = 0.2(A + 0.3 \cos(B \times \theta')) \quad (1)$$

$$P = s \times \frac{3 - \theta'}{3} \quad (2)$$

- if $P \leq R$, where R is a uniformly distributed random number between 0 and 1, encrypt the track
- Can blind up to 25 % of tracks at any given angle

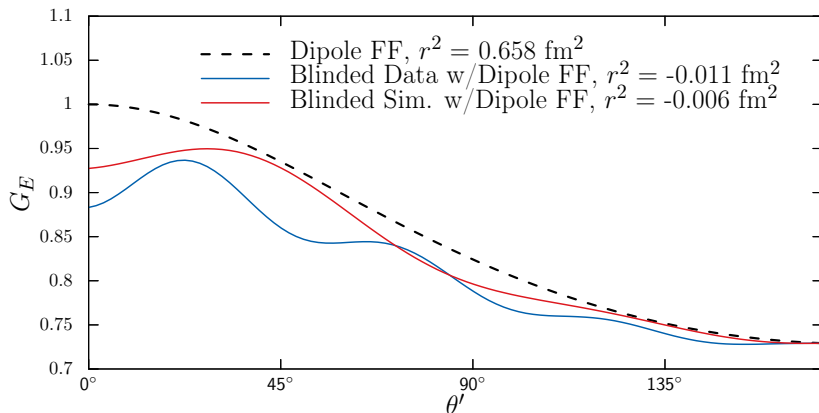
Detailed scheme presented in: J. C. Bernauer, EWC, *et al.*, [arxiv:2310.11469](https://arxiv.org/abs/2310.11469), submitted to PRC

Example Blinding Curve



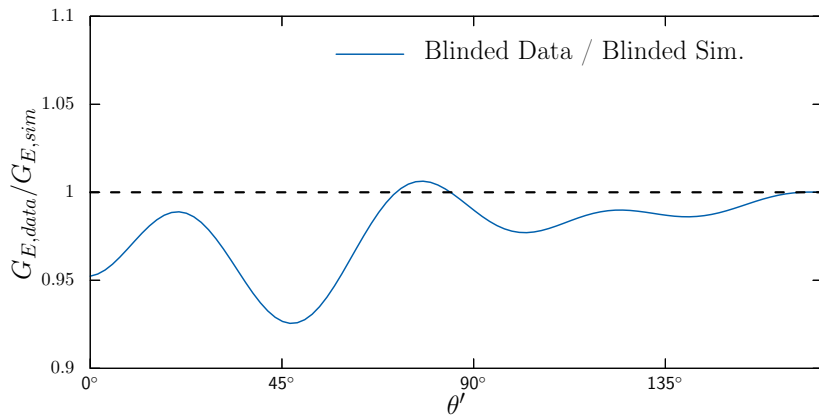
Two example distributions for blinding simulation or data as a function of θ' . For simulation (data) the values of $A = 0.4$ (0.8) and $B = 4.1$ (7.2) are used.

Effect of Blinding on G_E



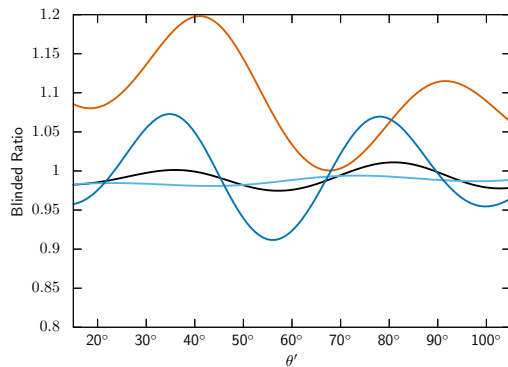
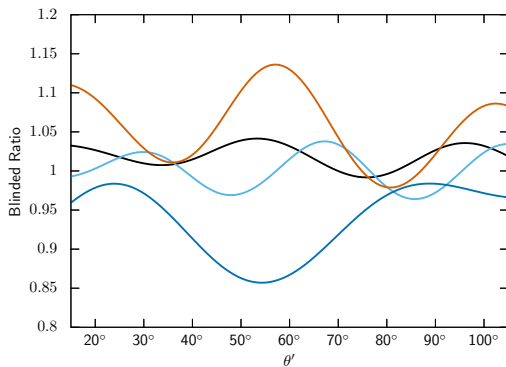
The r^2 denotes the proton charge radius from the associated form factors. Note that the blinding directly changes the extracted radius from the true radius.

Effect of Blinding on G_E



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

Blinding Multiple Ratios



Example of eight blinded ratios. True ratio assumed to be 1.

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

Summary

- Blinding is crucial to prevent experimenter bias, especially for contentious results
- MUSE has robust scheme to blind physics quantities in experiment
- Blinding is species, momentum, charge polarity specific, and unique for simulation and data
- Can unblind analysis in steps

Backup