future measurements of neutron skins

Michaela Thiel

on behalf of the A1 and P2 collaborations

Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

Precision Tests with Neutral-Current Coherent Interactions with Nuclei
MITP Topical Workshop
May 23 – 27, 2022
JGU Mainz

future measurements of neutron skins…

Parity-Violating Electron Scattering off Nuclei (Krishna Kumar)

Nuclear Weak Charges and Neutron Skins in Current and Future PVES Experiments (Nicola Cargioli)

Neutron Skins across PVES, Neutron Stars and Gravitational waves (Chuck Horowitz)

Parity-Violating Program at MESA (Frank Maas)

future measurements of neutron skins…

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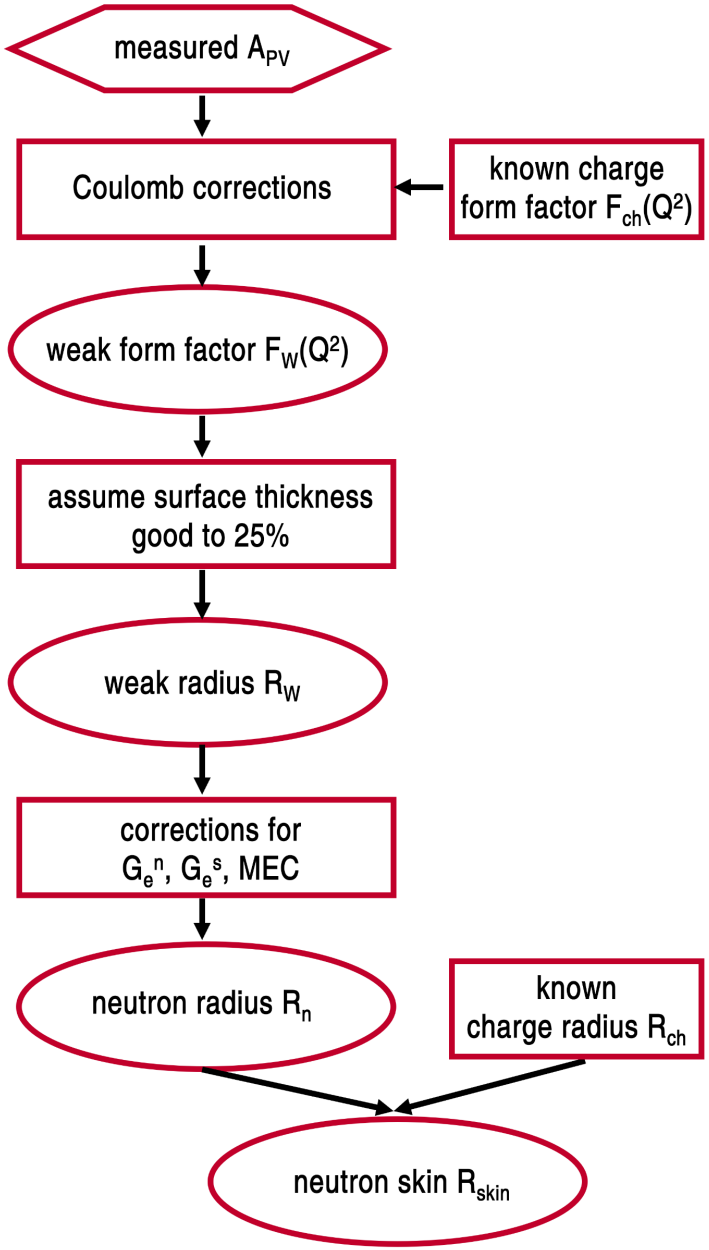
…what else to tell?

a story about challenges, problems, expectations, prospects, and more problems

PVES: extraction of neutron skin



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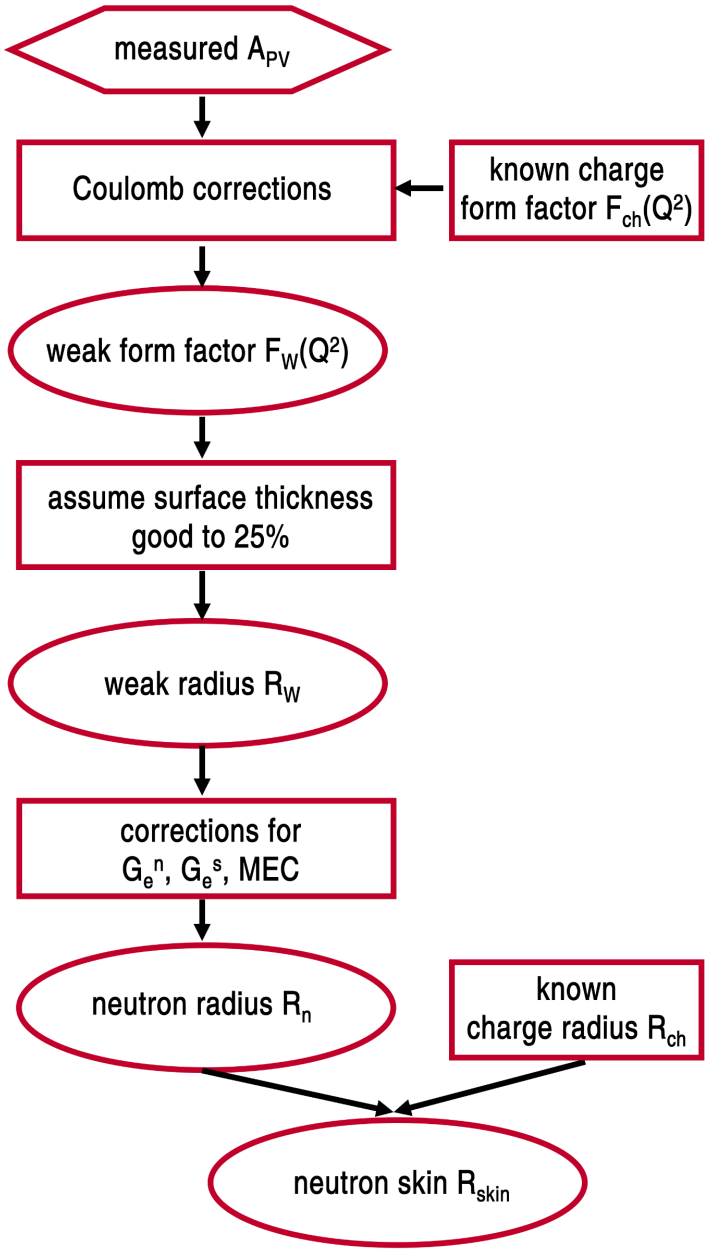
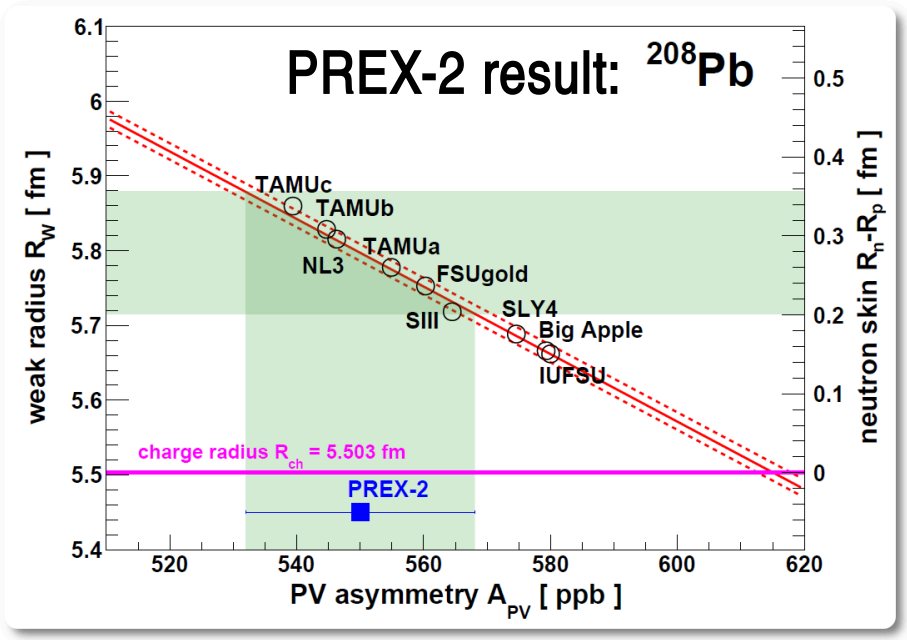


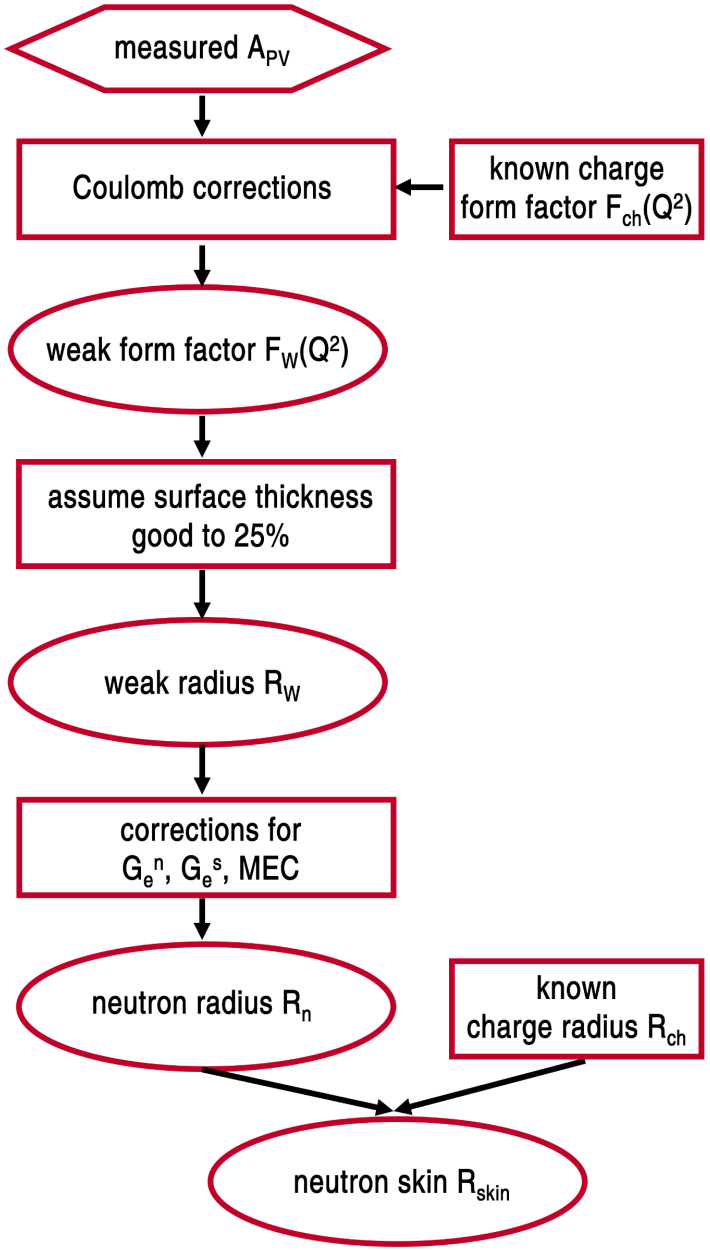


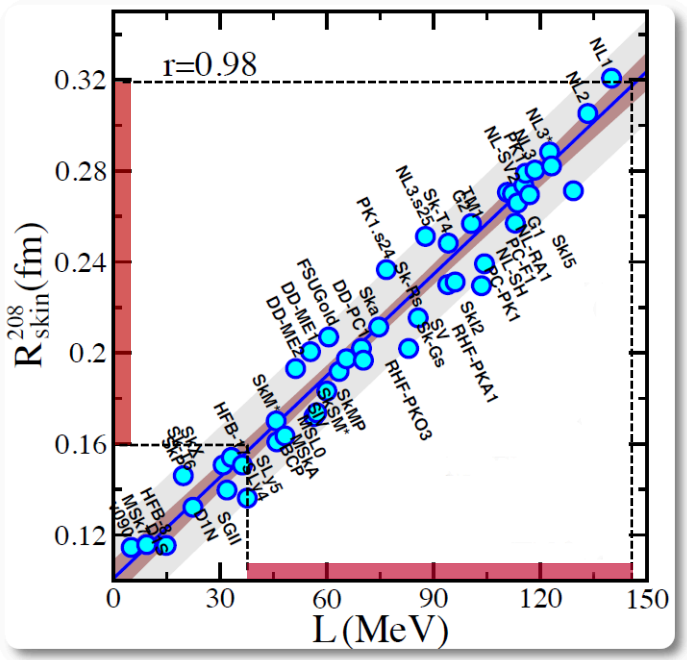
D. Adhikari et al., PRL 126 (2021) 172502

A_{PV} = 550 ± 16 (stat) ± 8 (sys) ppb

R_{skin} = 0.278 ± 0.078 fm

PVES: extraction of neutron skin





J. Piekarewicz, F.J. Fattoyev, Physics Today 72, 7, 30 (2019)

A_{PV} = 550 ± 16 (stat) ± 8 (sys) ppb

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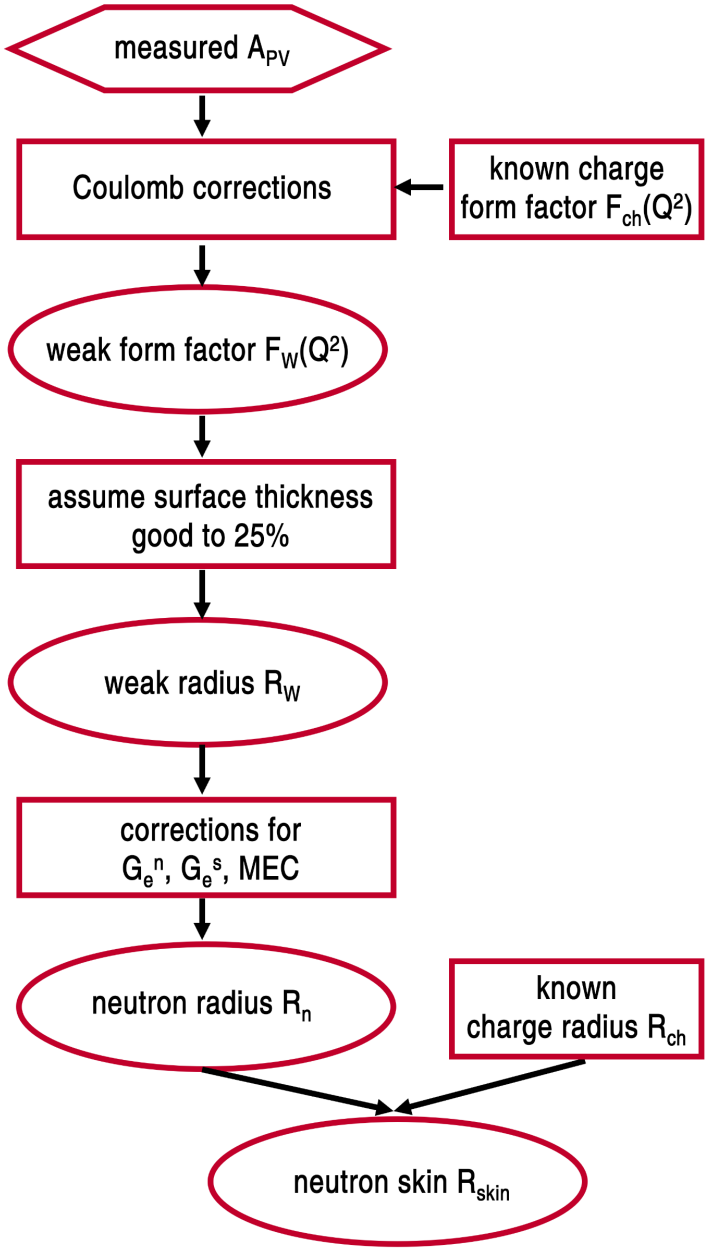
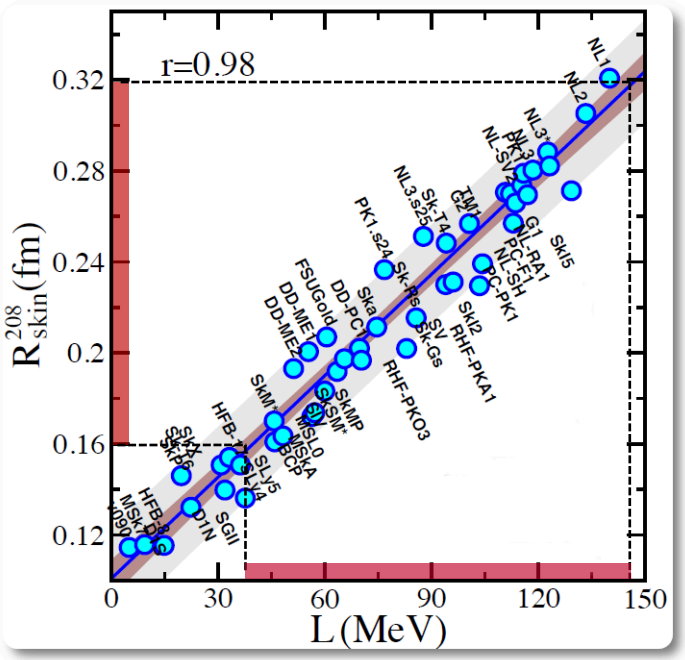
→ L = ± 50 MeV

PVES: extraction of neutron skin





J. Piekarewicz, F.J. Fattoyev, Physics Today 72, 7, 30 (2019)

A_{PV} = 550 ± 16 (stat) ± 8 (sys) ppb

R_{skin} = 0.278 ± 0.078 fm

→ L = ± 50 MeV

improvement by factor 2

ultimate determination of the neutron-skin thickness of ^{208}Pb

MREX @ MESA

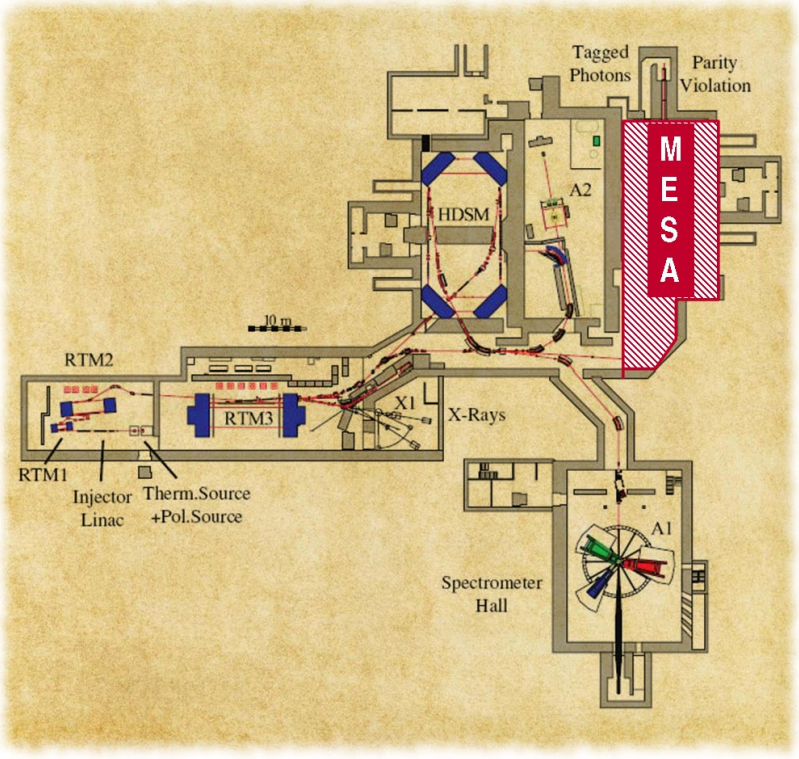
(Mainz Radius Experiment)

PLANS  REALITY

ultimate determination of the neutron-skin thickness of ^{208}Pb

MREX @ MESA

(Mainz Radius Experiment)



Mainz Energy recovering Superconducting Accelerator

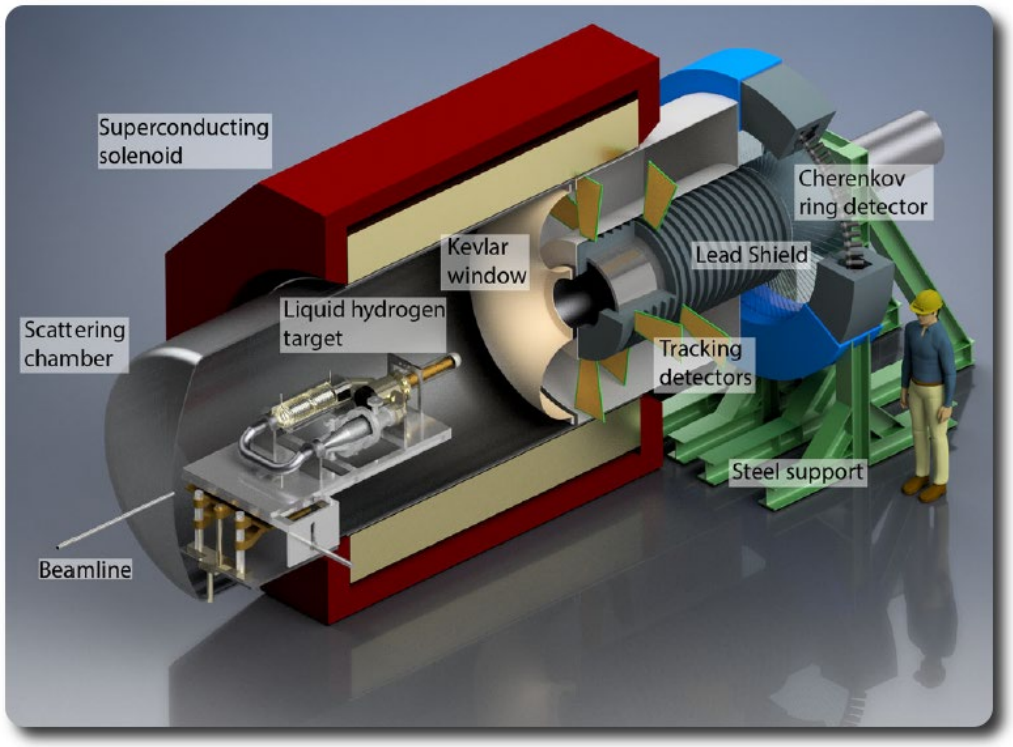
PLANS:

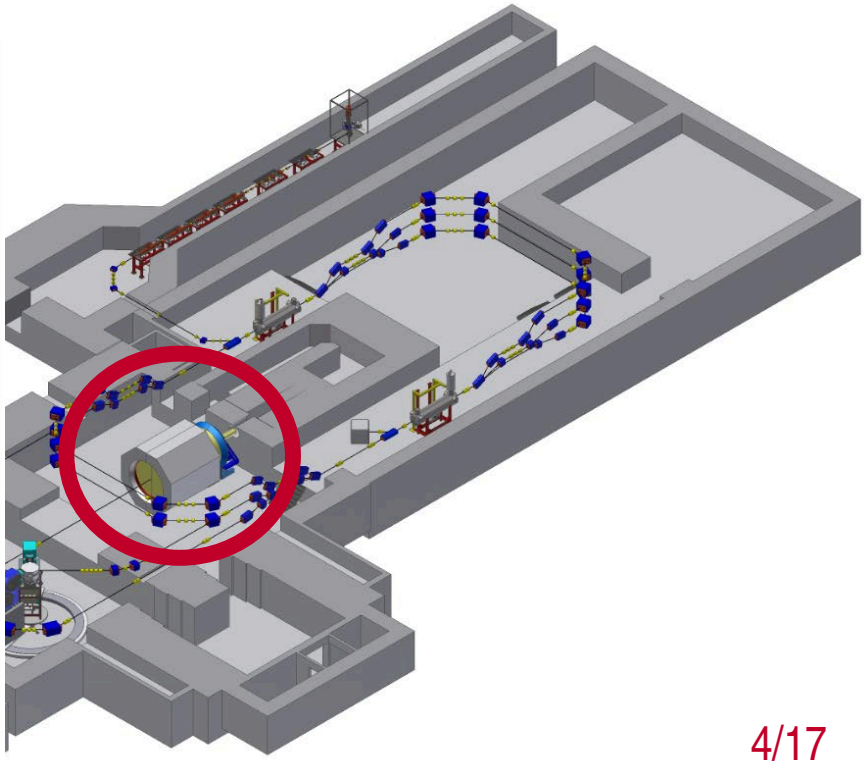
150 μA (pol.) @ 155 MeV

ultimate determination of the neutron-skin thickness of ^{208}Pb

MREX

(some people call it „P2“)





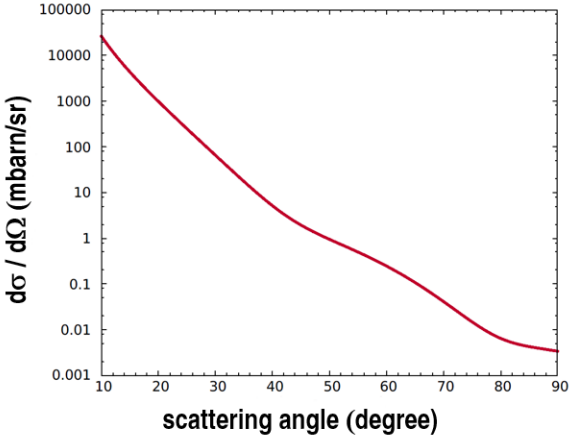
MREX: Figure Of Merit

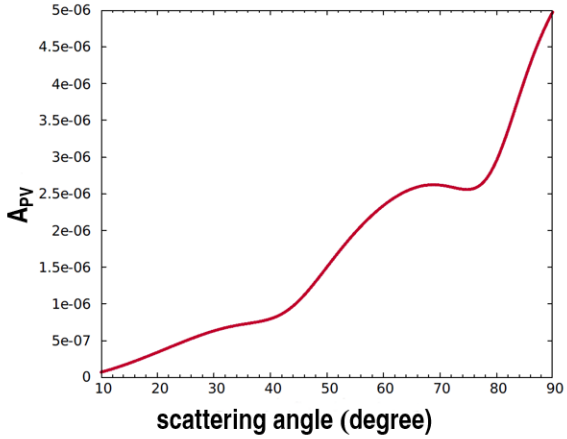
beam
energy: 155 MeV
current: 150μA

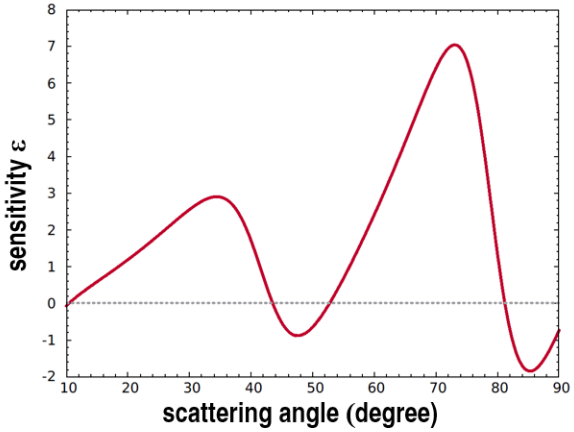
target
^{208}Pb 0.56 g/cm^2

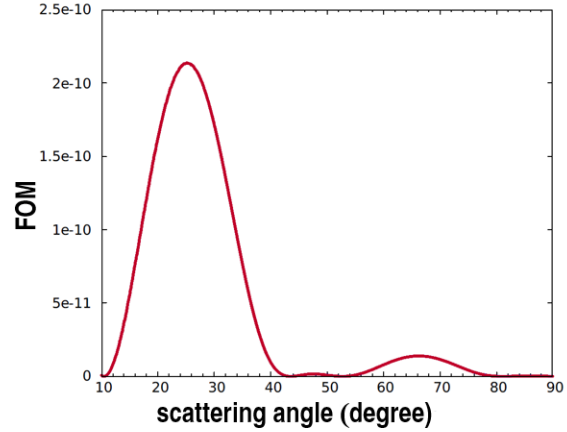
A_{PV}: 0.66 ppm
$\Delta\theta$ = 4°
polarization: 85%
q: 86 MeV/c

Chuck Horowitz









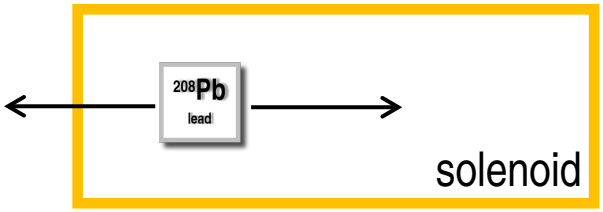
±0.03 fm determination of neutron-skin thickness (60 days)

MREX: ray trace simulation

vary magnetic field strength
(0.1 T to 0.6 T)

+

scan of target position
(-2500 mm to 0 mm)



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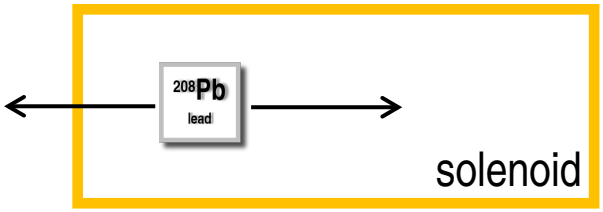
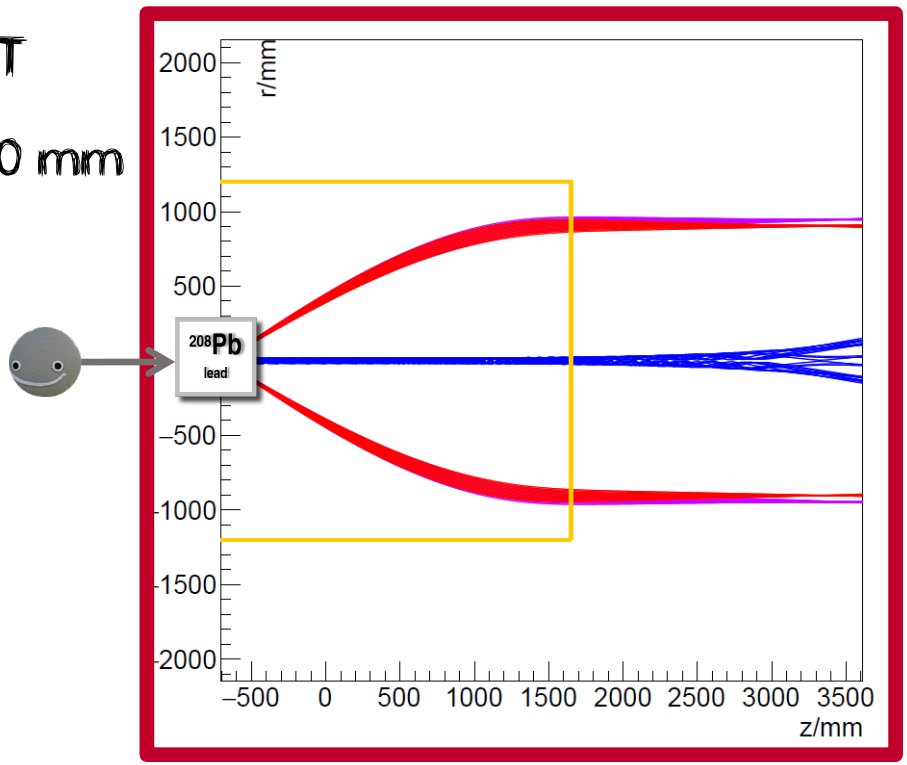


magnetic field: 0.6 T

target position: -700 mm



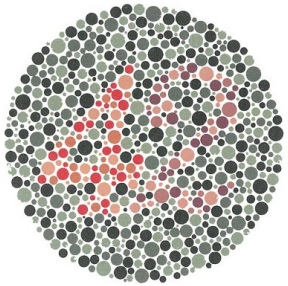
elastic e–Pb scattering
[30° to 34°]

inelastic e–Pb scattering
[30° to 34°]

Møller scattering
[5° to 90°]

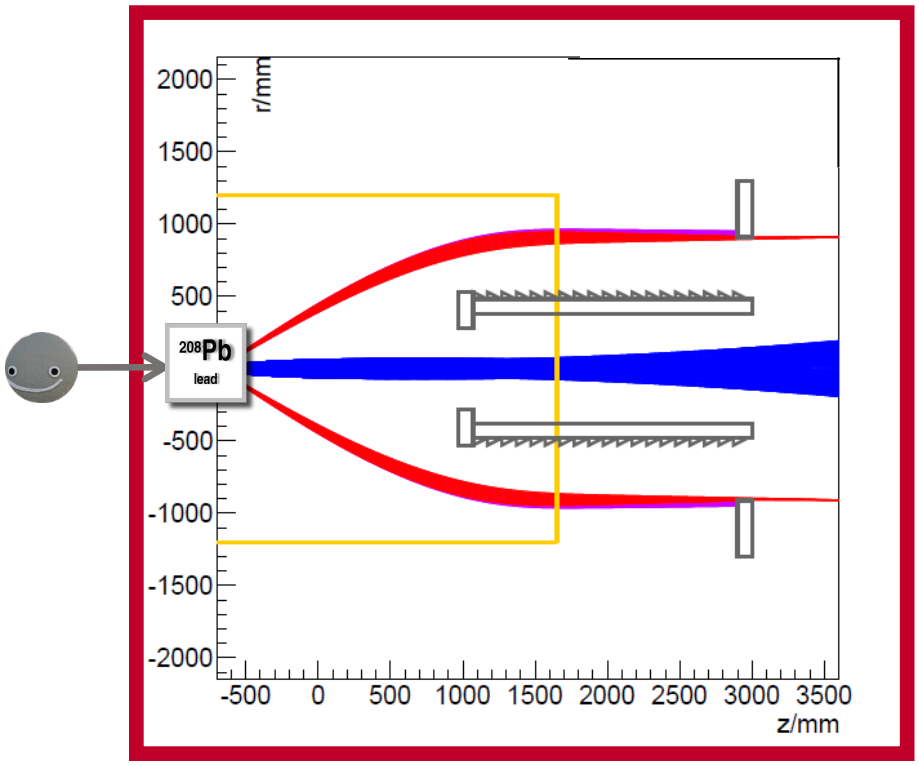
MREX: ray trace simulation

P2
shielding and detector configuration



resolve elastic?

ΔE (^{208}Pb) = 2.7 MeV



MREX: ray trace simulation

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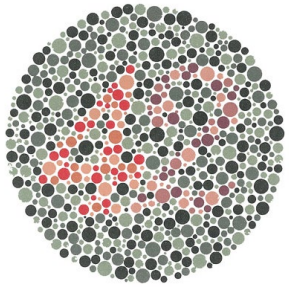

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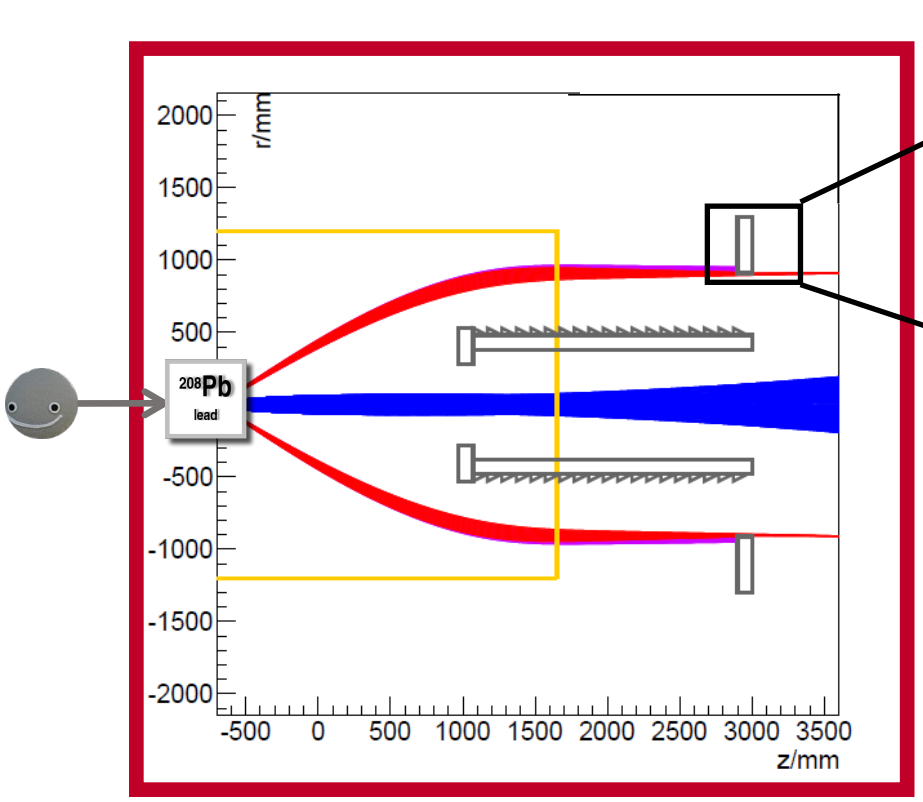
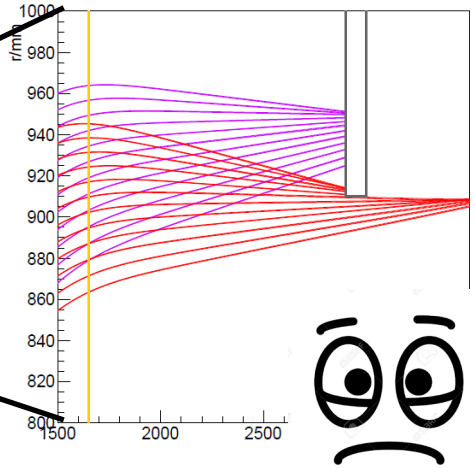




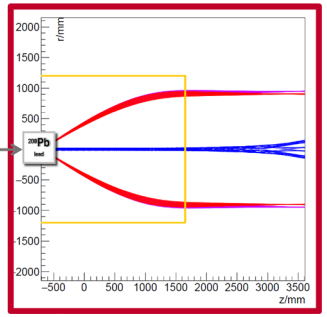
elastic

inelastic

separate shielding needed!

MREX: work in progress (status 2021)

detector

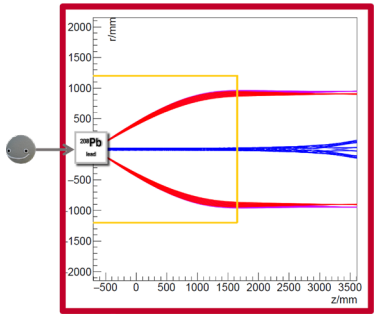


new shielding design

full simulation needed

MREX: work in progress (status 2021)

detector

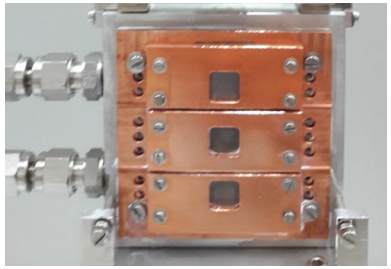


OK

new shielding design

full simulation needed

target

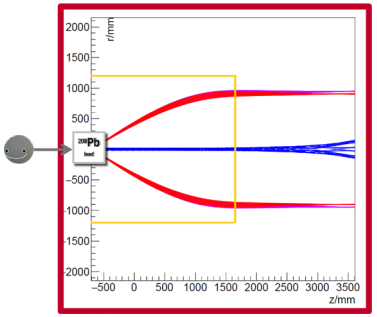


OK

commissioning @ A1

MREX: work in progress (status 2021)

detector

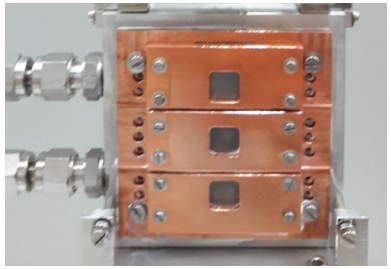


OK

new shielding design

full simulation needed

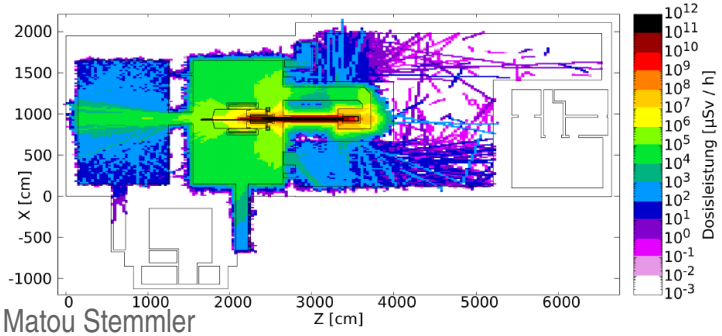
target



OK

commissioning @ A1

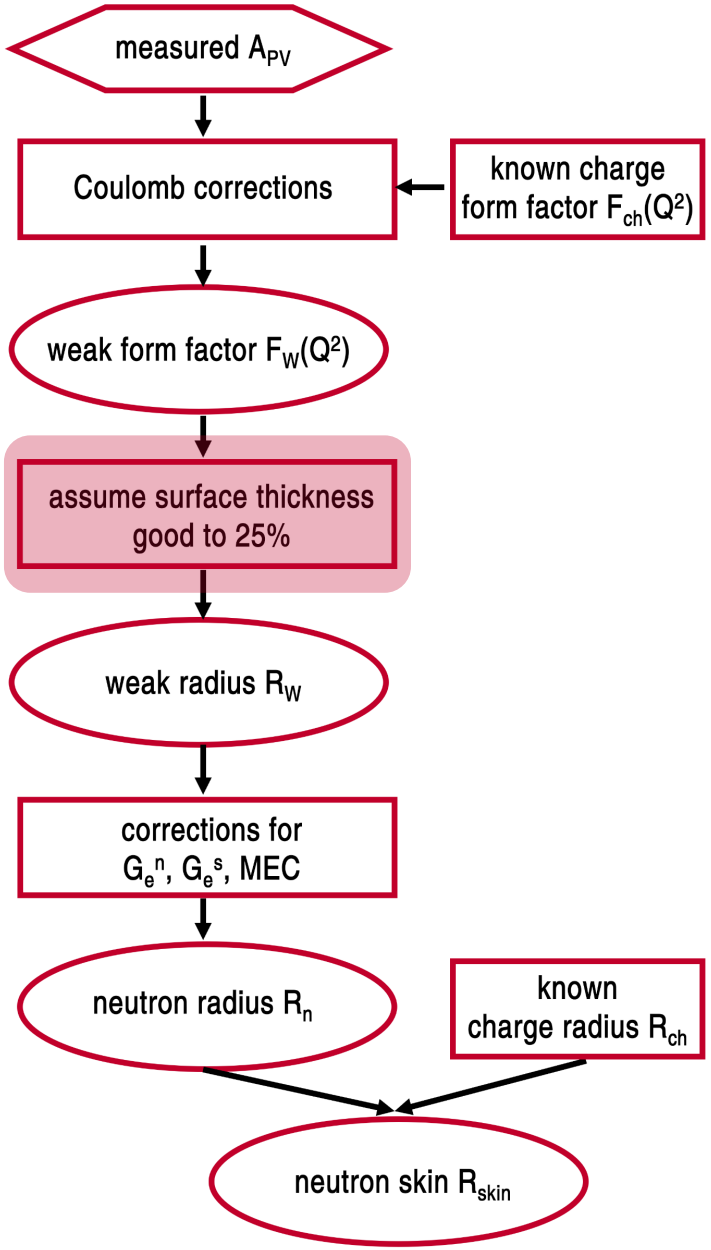
radiation



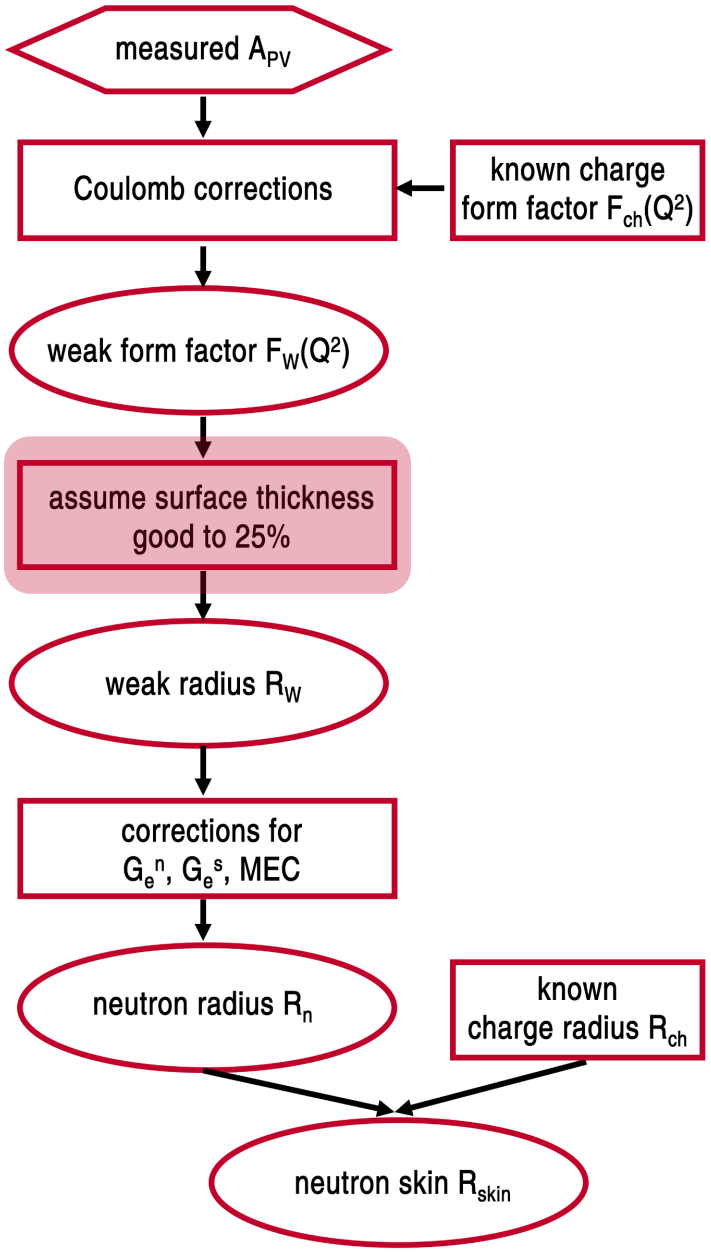
OK

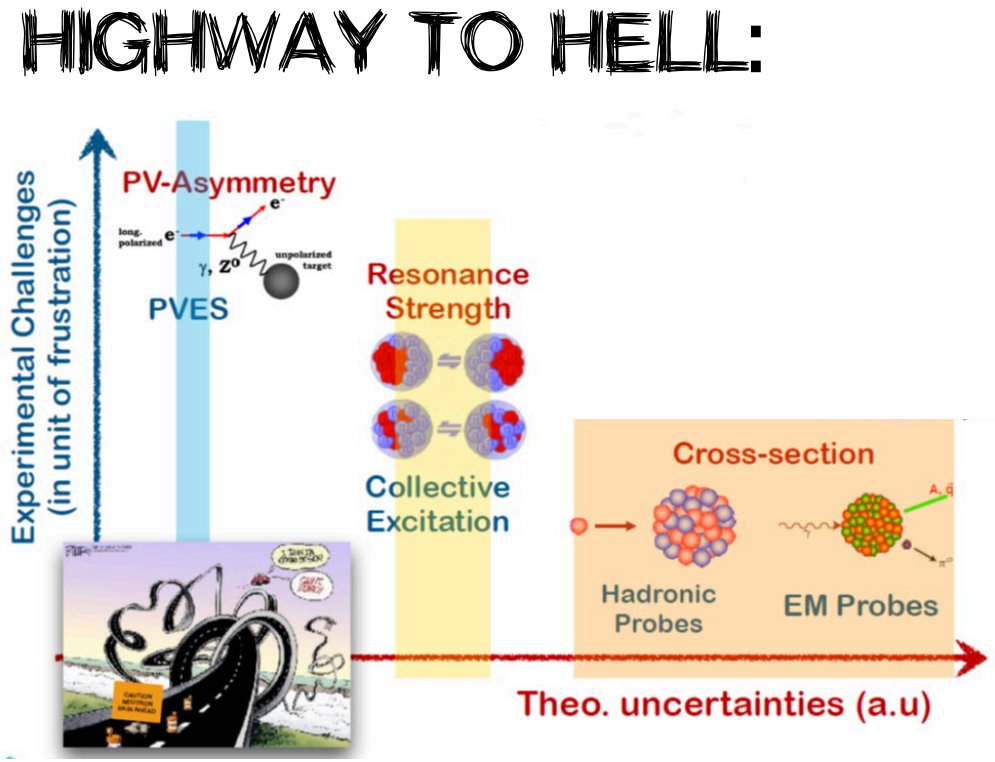
high, but no obstacle

the long road to the ultimate determination of NSkin

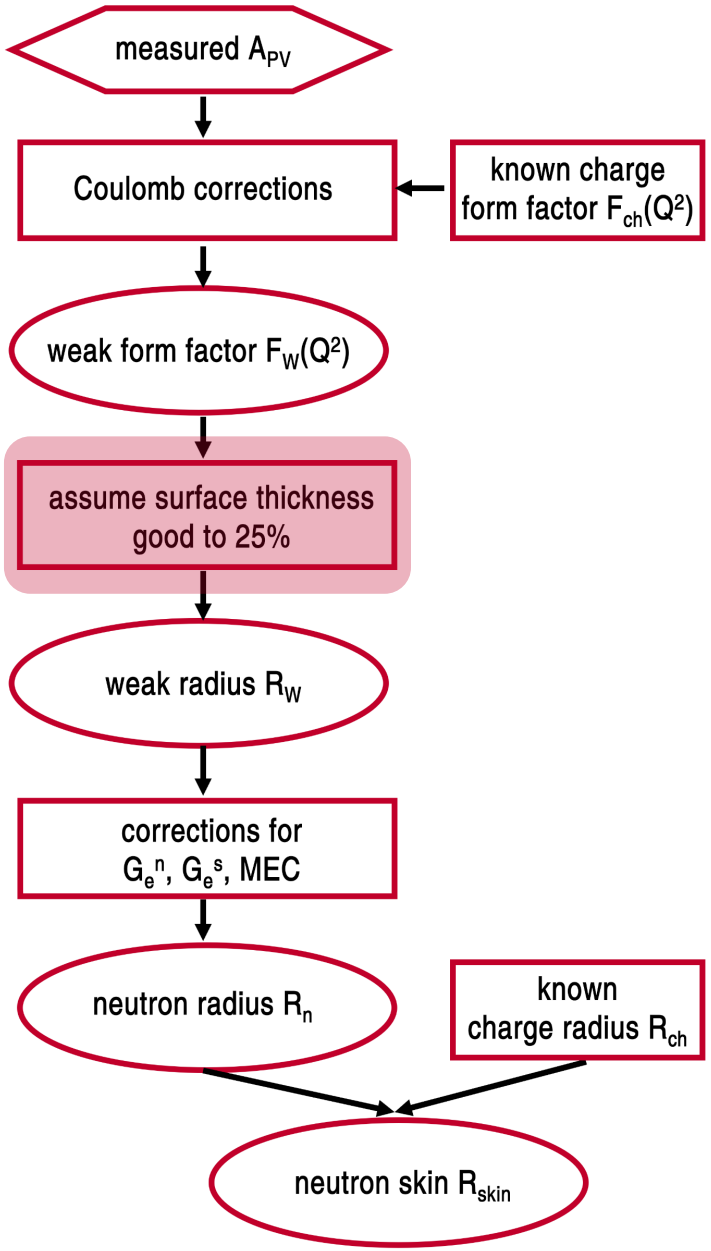


the long road to the ultimate determination of NSkin

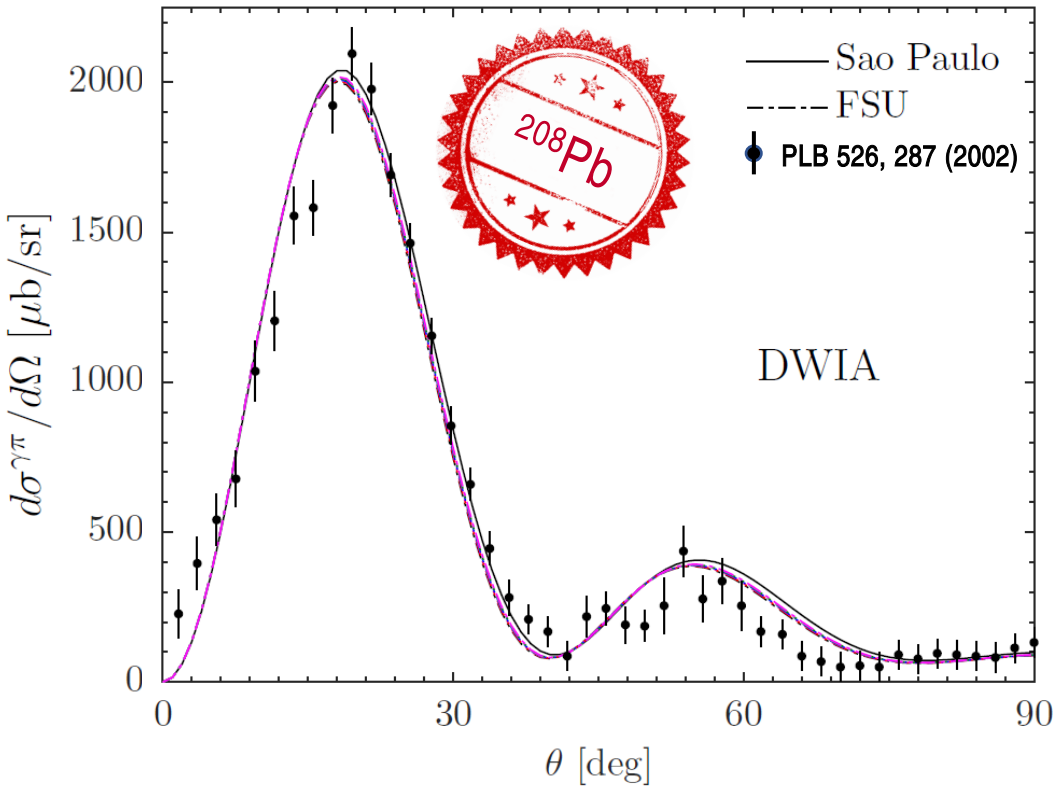




the long road to the ultimate determination of NSkin



coherent π^0 photoproduction

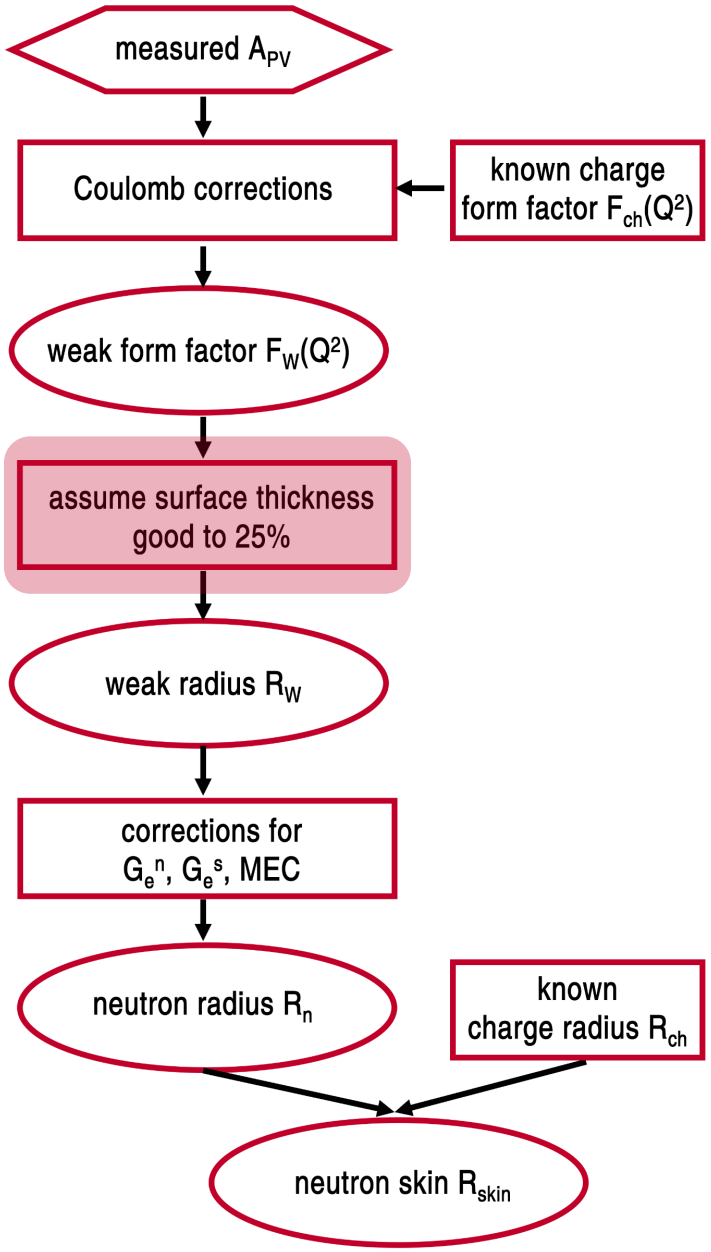


F. Colomer et al., arXiv:2204.13395v1

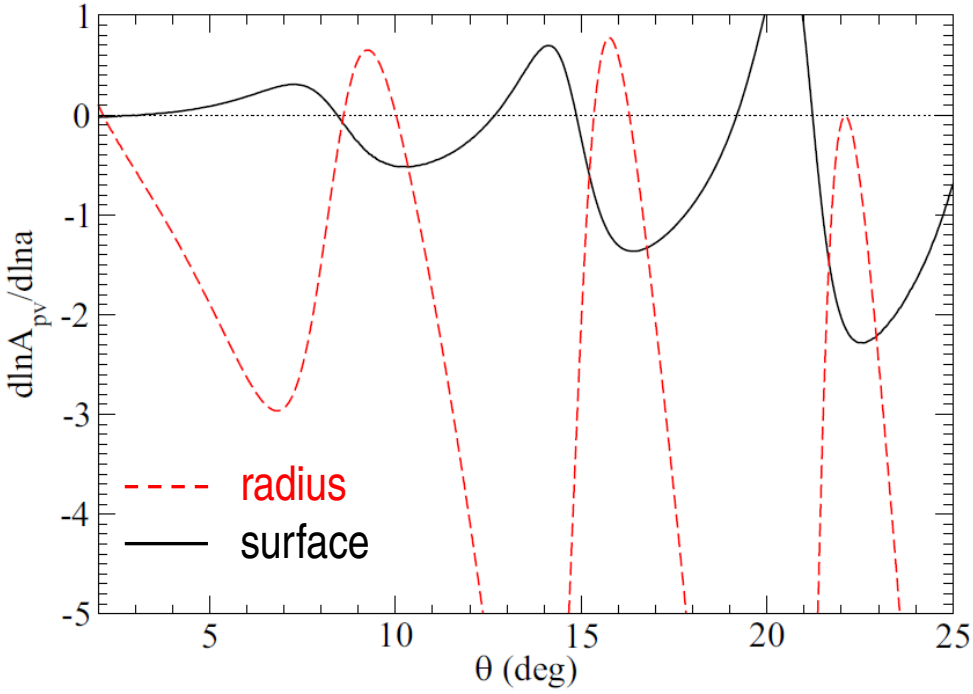
FSU band:

0.176 fm < NSkin < 0.286 fm

the long road to the ultimate determination of NSkin

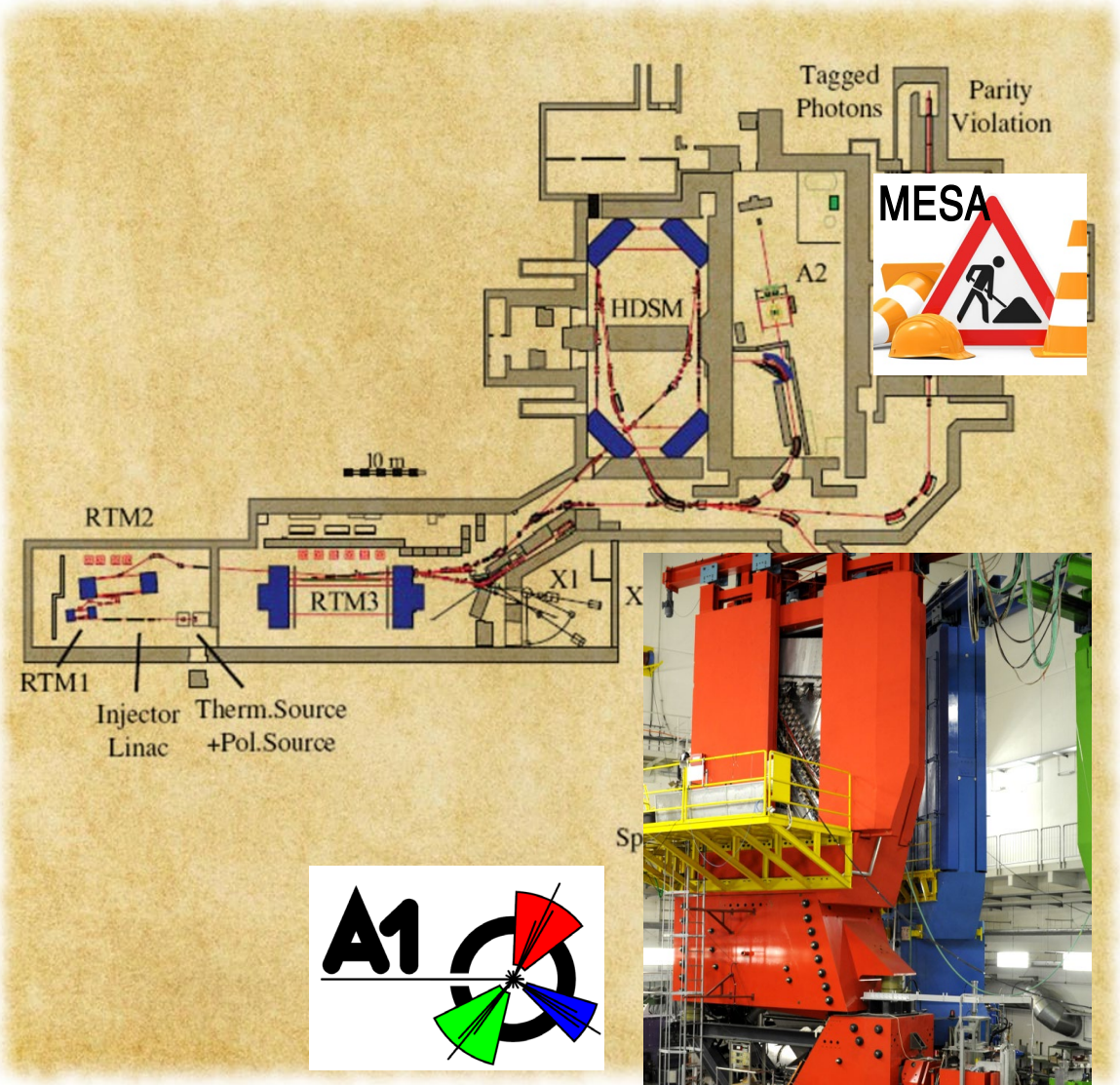


parity-violating electron scattering surface sensitivity studies (^{208}Pb):



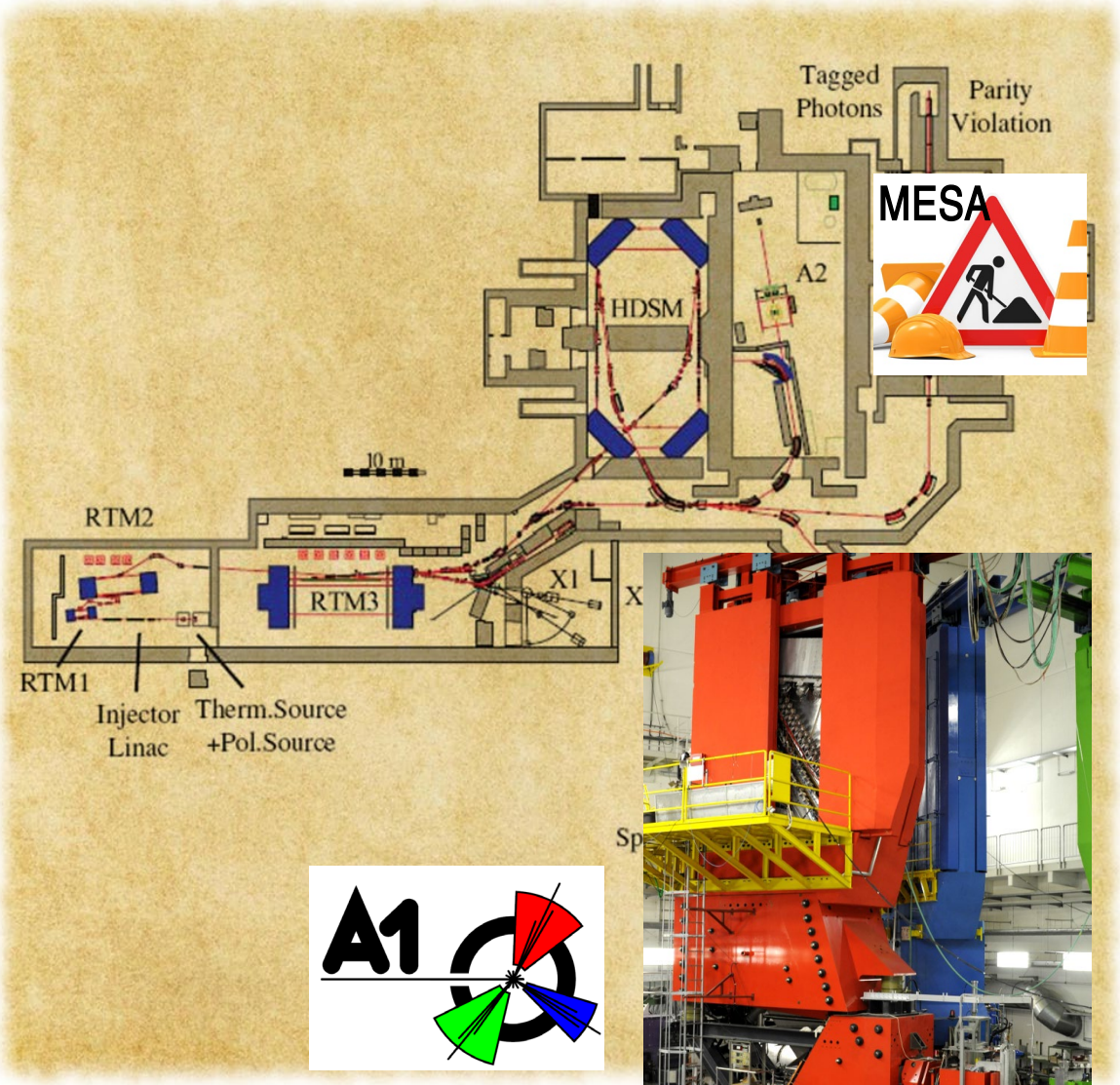
B.T. Reed et al., Phys. Rev. C 102, 064308 (2020)

determination of the surface thickness of ^{208}Pb



successful measurements
of transverse asymmetry @ A1:
^{12}C, ^{28}Si, and ^{90}Zr
(Anselm Esser on Tuesday)

determination of the surface thickness of ^{208}Pb



successful measurements of transverse asymmetry @ A1: ^{12}C, ^{28}Si, and ^{90}Zr (Anselm Esser on Tuesday)

can we do a **10% measurement** of the surface thickness of ^{208}Pb @ A1?

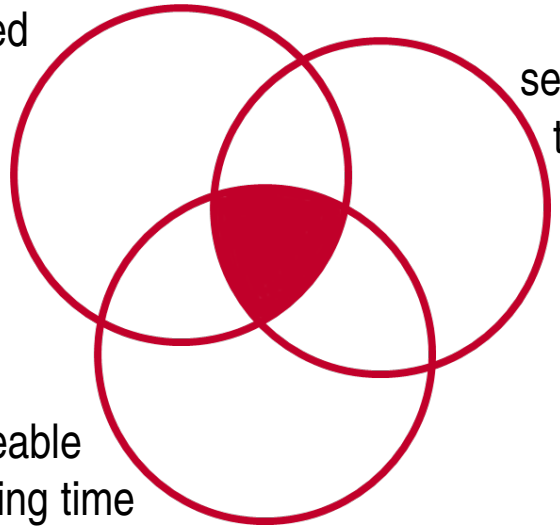
A1: determination of the surface thickness of ^{208}Pb

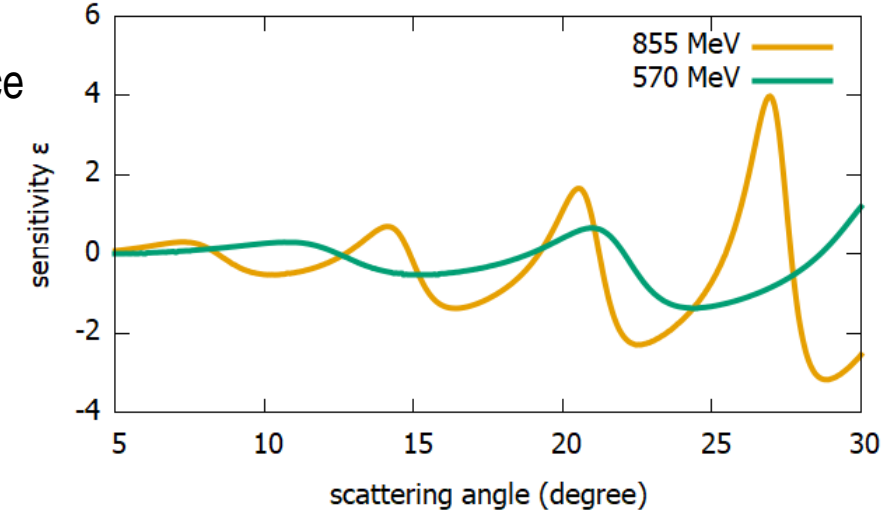
selection of kinematics

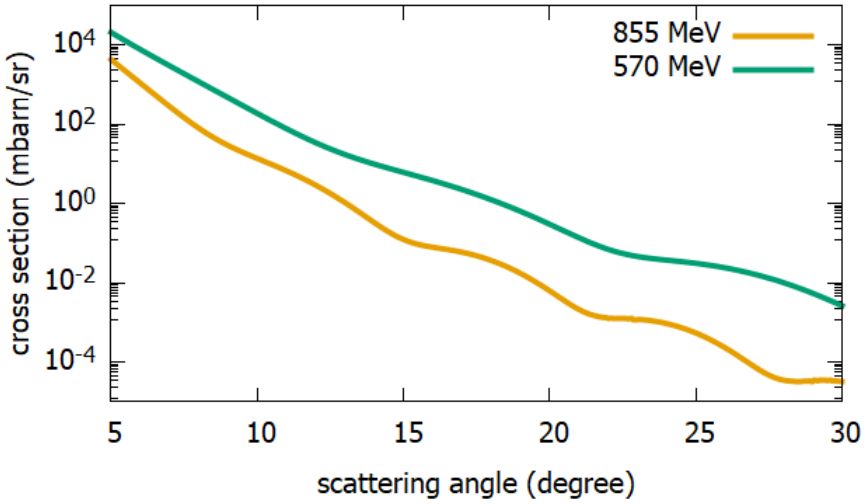
special stabilized beam energies

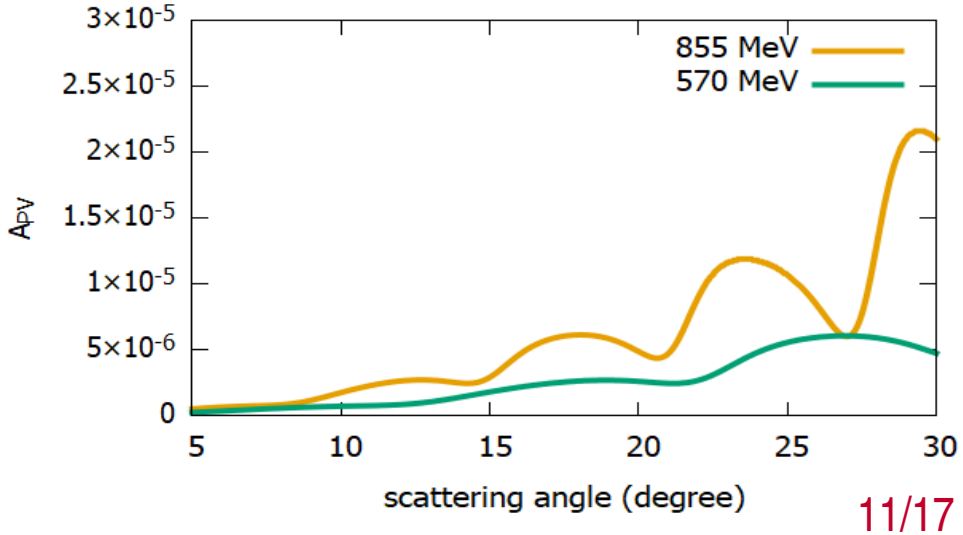
sensitivity to surface

manageable measuring time

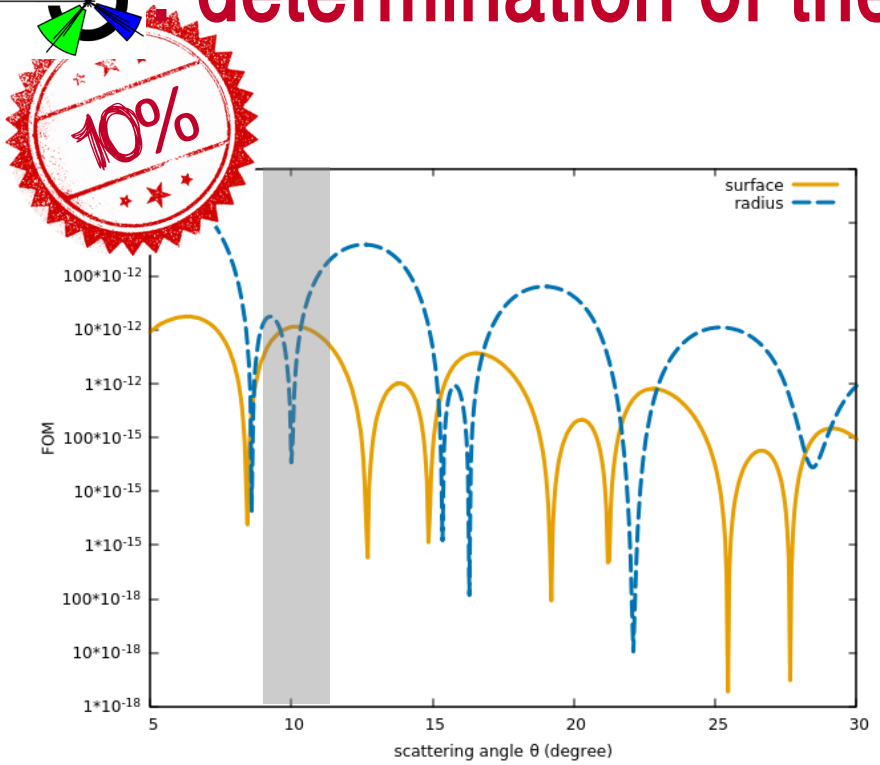


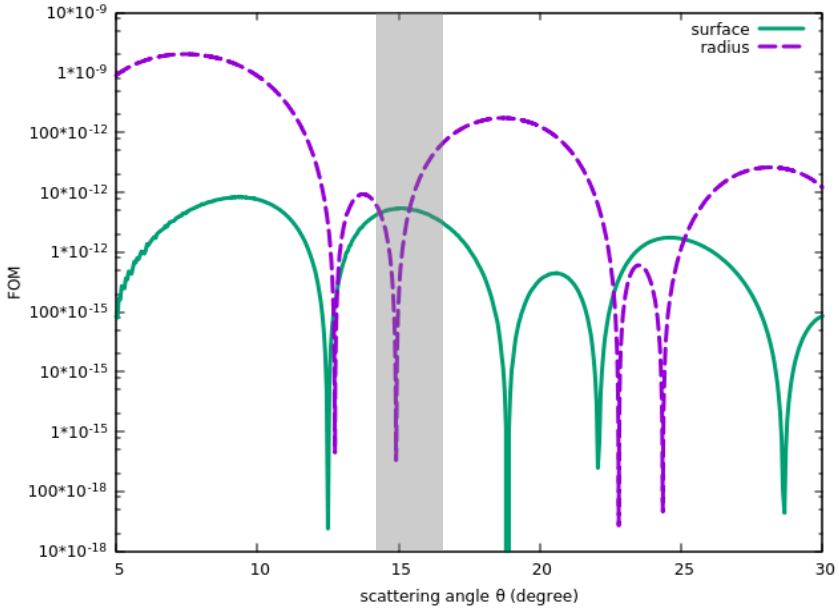






: determination of the surface thickness of ^{208}Pb





855 MeV

specB: 10.35°
Q^2: 0.02 GeV^2/c^2
I_{beam}: 20µA

running time: 78 days

☺ time, 😐 modified setup

570 MeV

specB: 15.2°
Q^2: 0.02 GeV^2/c^2
I_{beam}: 20µA

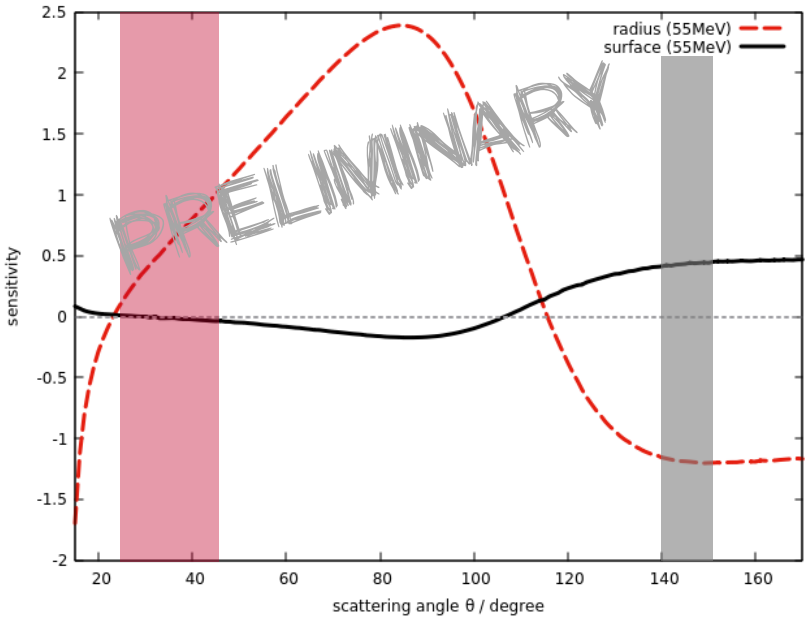
running time: 166 days

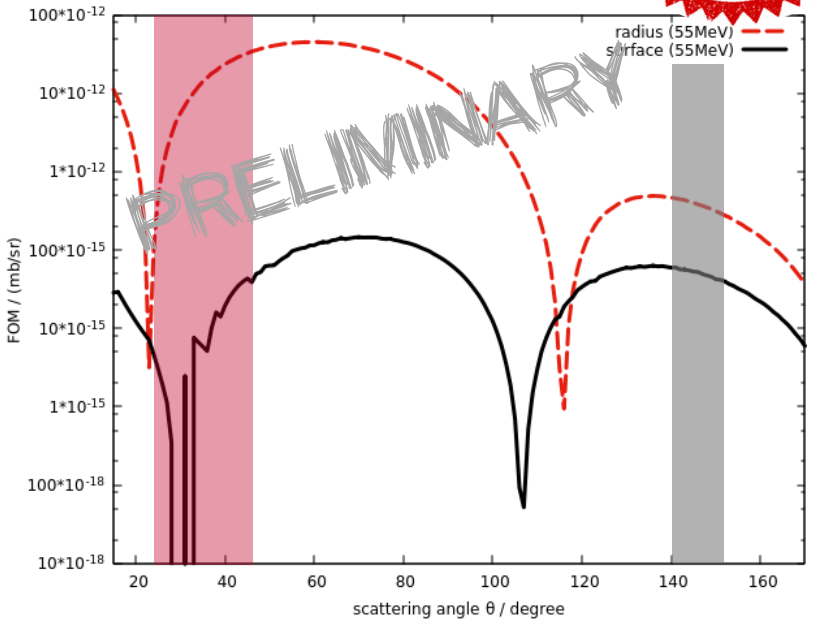
😐 time, ☺ well tested setup

MREX: determination of the surface thickness of ^{208}Pb

55 MeV

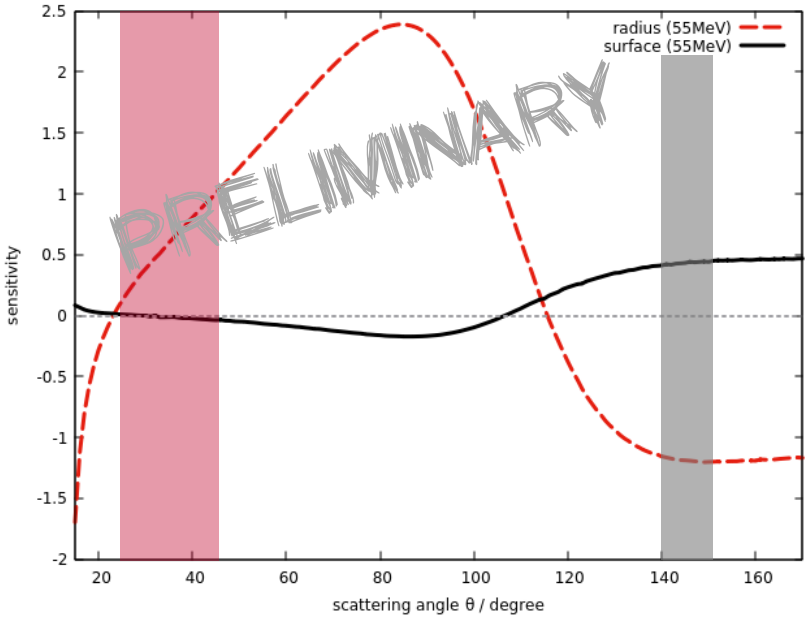
can we do it faster with MREX??

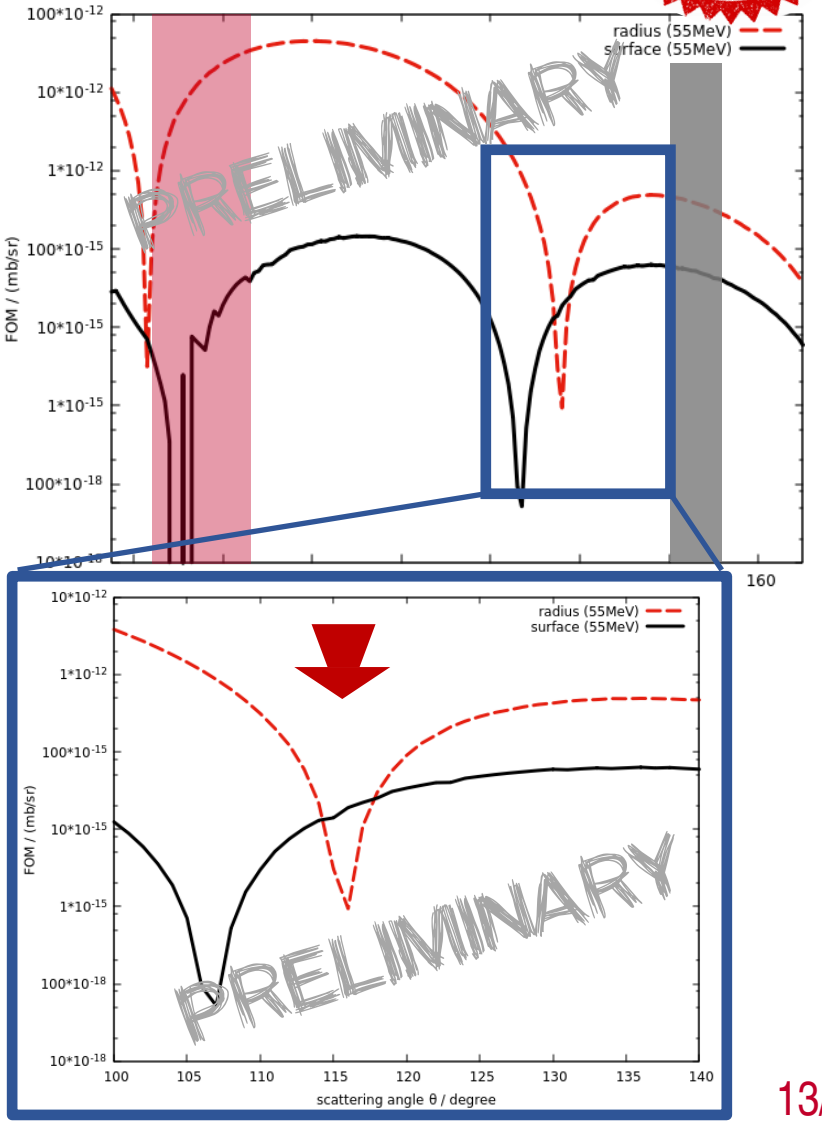




MREX: determination of the surface thickness of ^{208}Pb

can we do it faster with MREX??





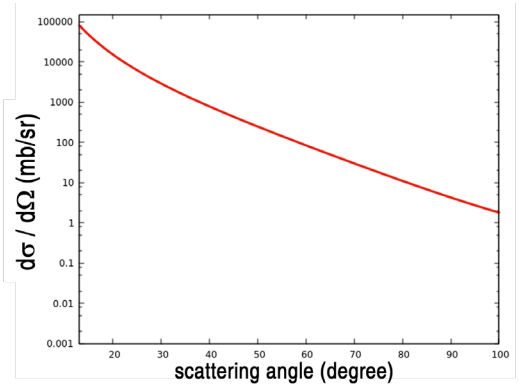
possible scenarios currently

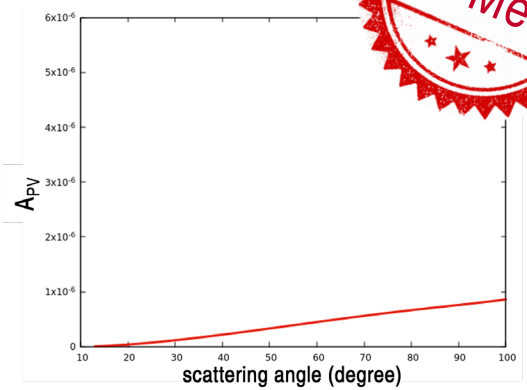
MREX: neutron-skin thickness

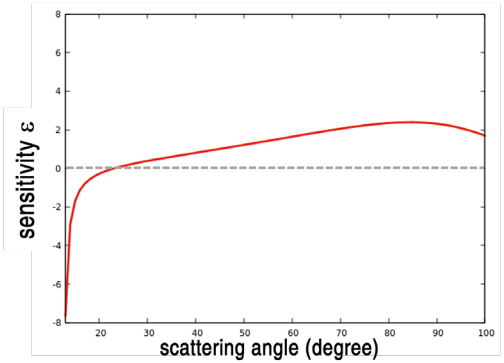
beam
energy: 55 MeV
current: 150μA

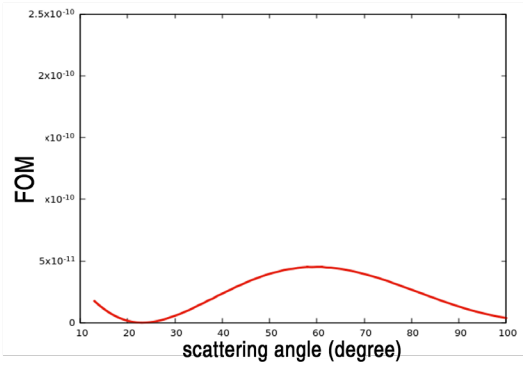
target
^{208}Pb 0.56 g/cm^2

A_{PV}: 0.49 ppm
$\Delta\theta = 4°$
polarization: 85%









62° - 66°:

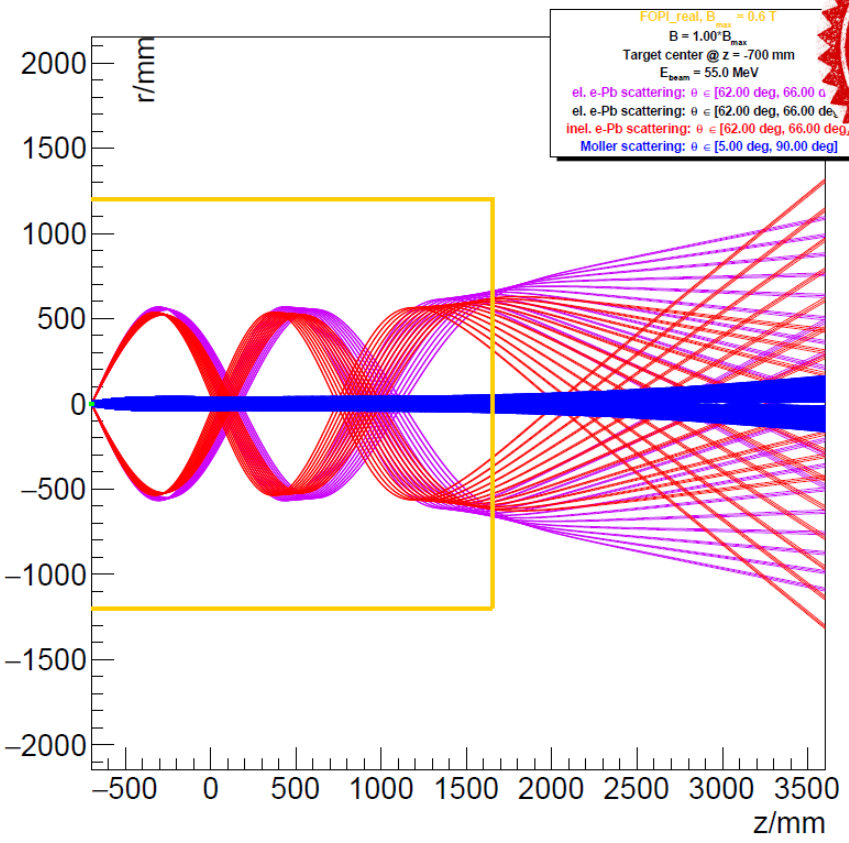
±0.03 fm determination of neutron-skin thickness (24 days)

MREX: neutron-skin thickness

beam
energy: 55 MeV
current: 150μA

target
^{208}Pb 0.56 g/cm^2

A_{PV}: 0.49 ppm
$\Delta\theta$ = 4°
polarization: 85%



55 MeV

62° - 66°:

±0.03 fm de

neutron-skin thickness (24 days)

summary

summary and outlook

summary and outlook

THINGS TO DO:

surface thickness:

- ☐ feasibility studies (55 MeV @MREX)
- ☐ **10% measurement @ A1 or MREX**

neutron skin thickness:

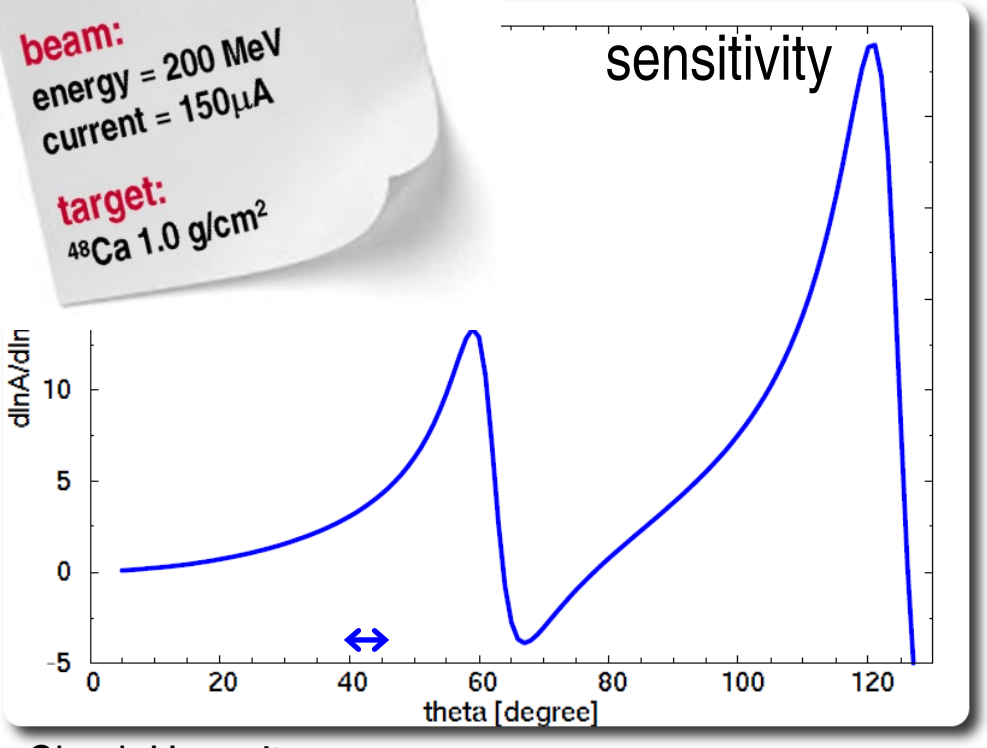
- ☐ efficiency studies (shielding)
- ☐ full simulation (rate studies)
- ☐ target frame commissioning + implementation in scattering chamber
- ☐ **± 0.03fm measurement**

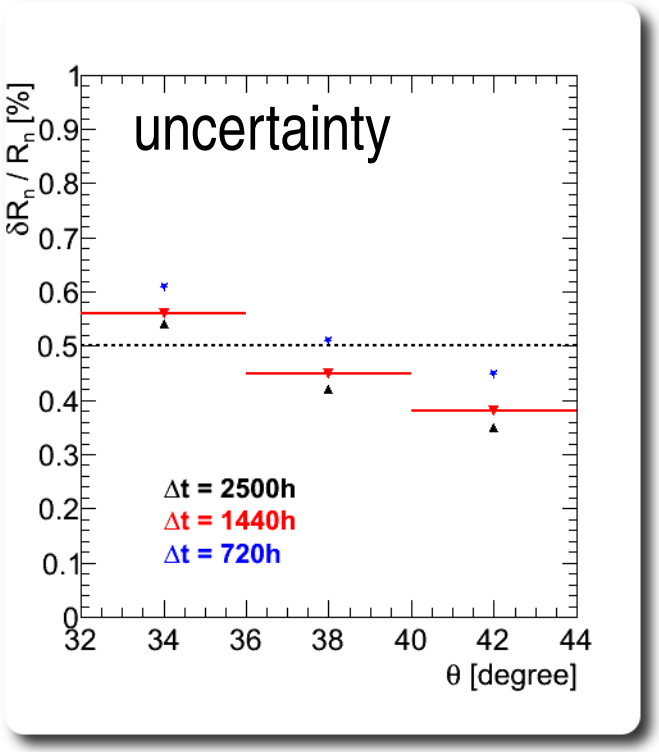
what about ^{48}Ca?

General condition:

beam:
energy = 200 MeV
current = 150μA

target:
^{48}Ca 1.0 g/cm^2





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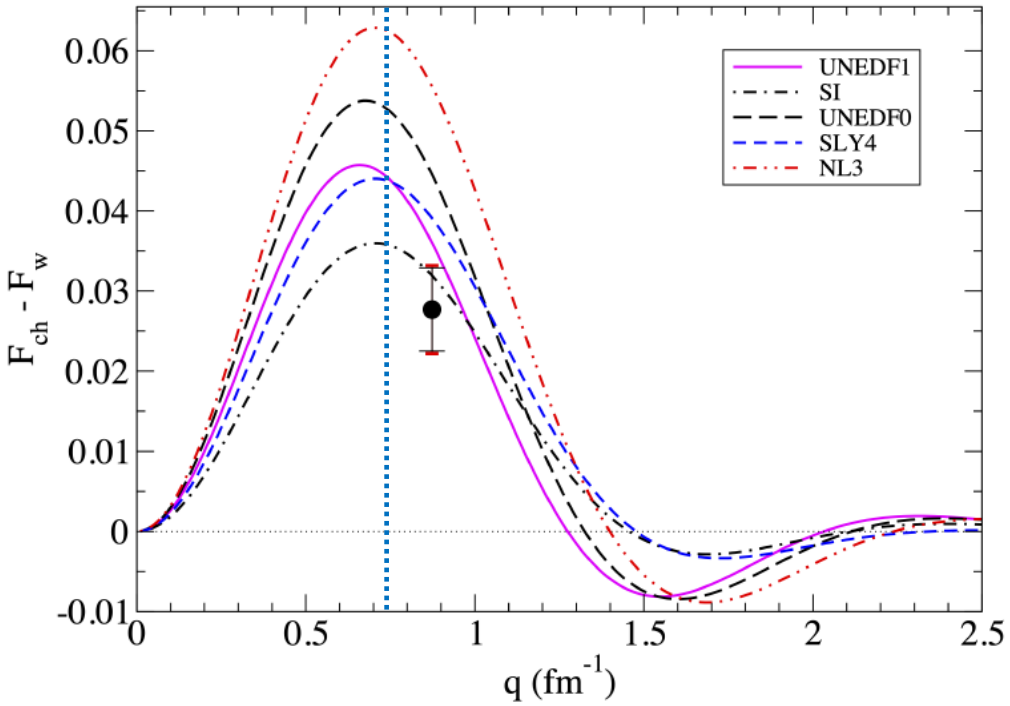
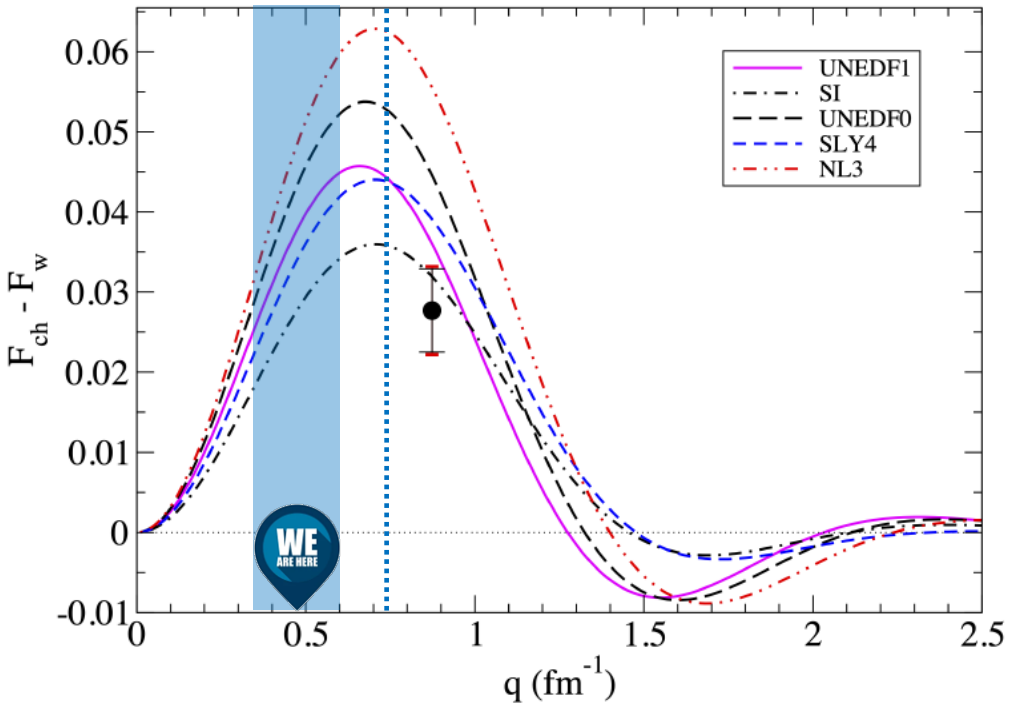
$\Delta\theta$=4° : expected rate = 0.87 GHz, A_{PV} = 2.14 ppm, P = 85%, Q ≈ 143 MeV

60 days → $\delta R_n/R_n$ = 0.38% (^{48}Ca @ 200 MeV)

what about ^{48}Ca?



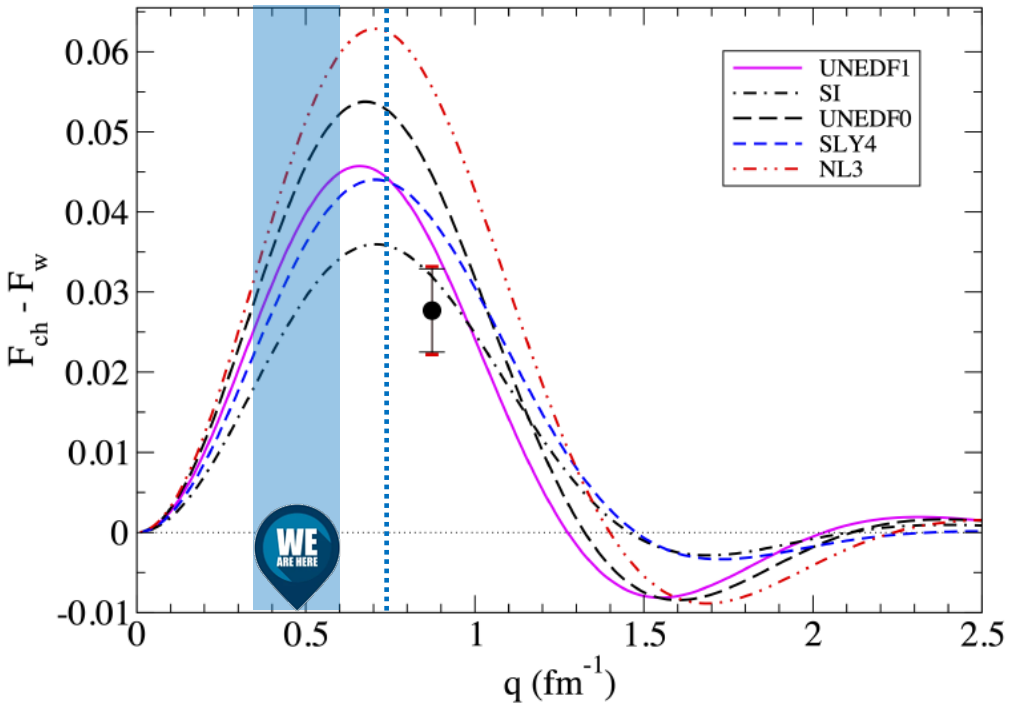
what about ^{48}Ca?



WE ARE HERE

detector covers 25° - 45°

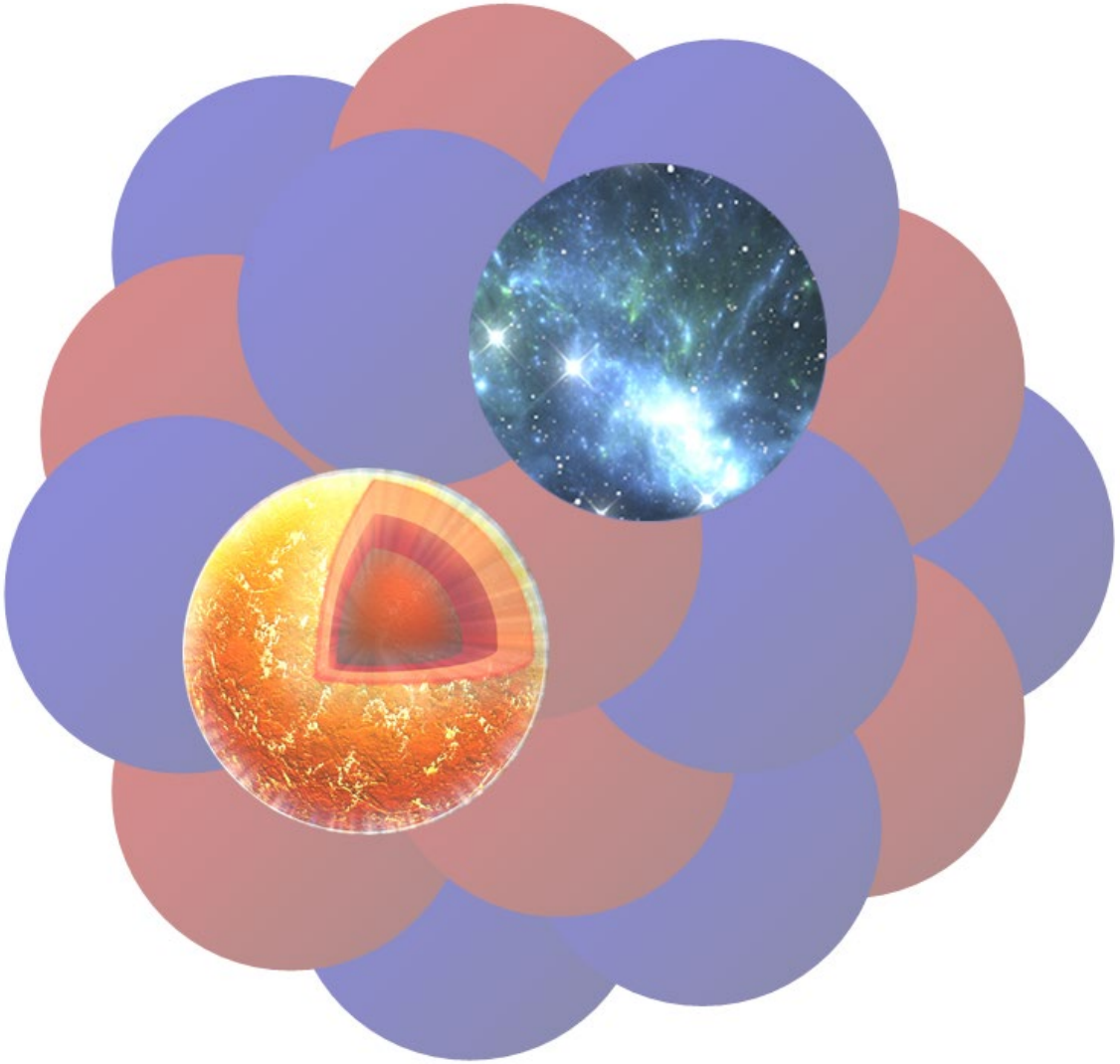
what about ^{48}Ca?



detector covers 25° - 45°

how important is a second ^{48}Ca measurement?

backup



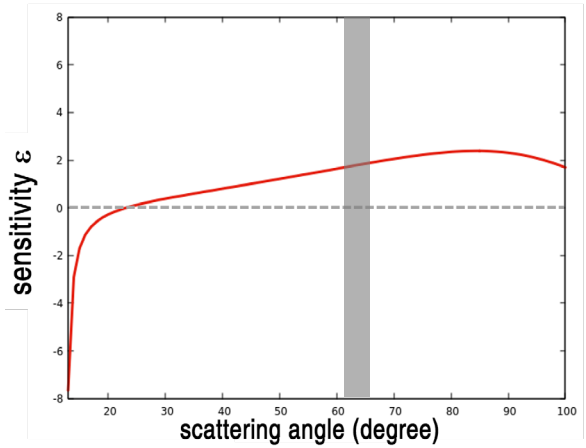
MREX: Figure Of Merit – 55 MeV

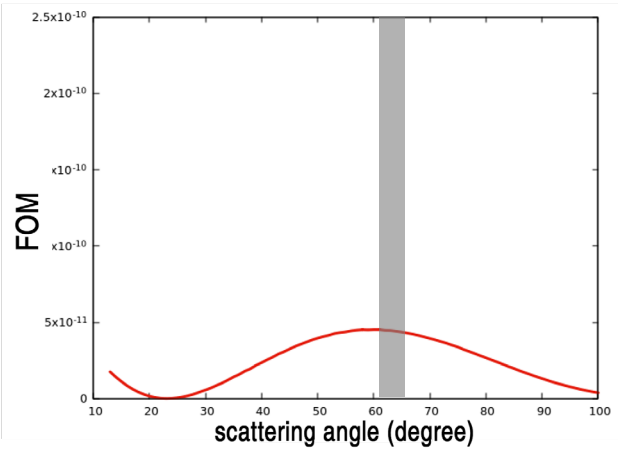
beam
energy: 55 MeV
current: 150μA

target
^{208}Pb 0.56 g/cm^2

A_{PV}: 0.13 ppm / 0.49ppm
$\Delta\theta = 4°$
polarization: 85%

Chuck Horowitz





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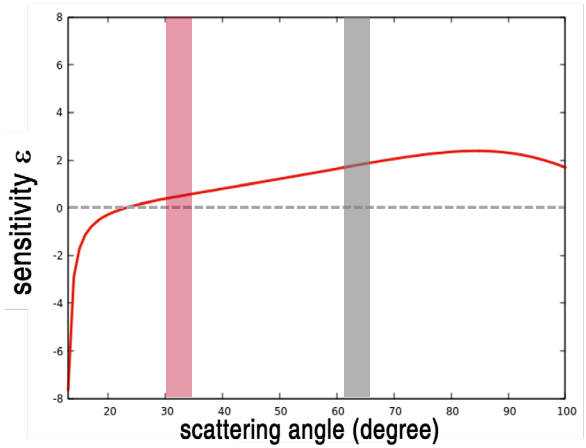

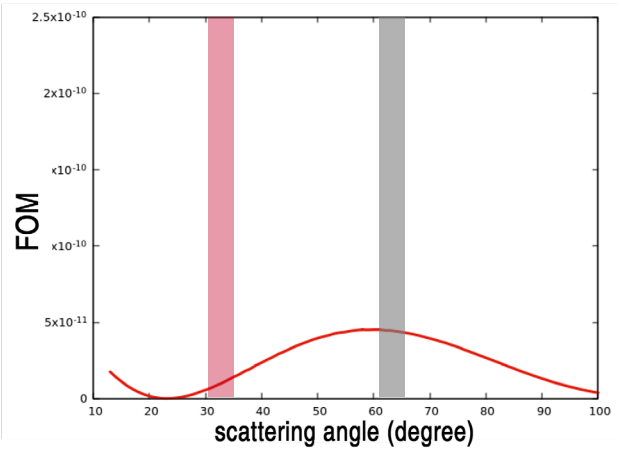

62° - 66°:

±0.03 fm determination of neutron-skin thickness (24 days)

30° - 34°:

±0.03 fm determination of neutron-skin thickness (220 days)