



## Proton Radius @ M2

# Communications 1.8.2019

- roadmap from the COMPASS++/AMBER Proposal drafting group:
  - July 10: final list of detailed update plans ready (i.e.: which sections of the proposal will be updated by whom and how)
  - August 14: first versions of specific updates ready for discussion
  - September 4: final versions of specific updates ready for insertion into proposal
  - September 18: updated proposal ready for reading by collaboration
  - hand in an update of the Proposal to SPSC (latest end of September)
- our roadmap: decide by „end of July“ on the target region geometry

# Next meetings

- follow-up vidyo meeting mid-August or beginning of September?
- workshop at Losinj 19. and/or 20.9. (vidyo for remote attendance), following the conference



The screenshot shows the website for the XIX International Conference on Science, Arts and Culture, titled "THE PROTON RADIUS". The event is held from 15-20 September 2019 in Veli Lošinj, Croatia. The website features a navigation menu on the left with links to HOME, PROGRAMME, COMMITTEES & CONTACTS, PARTICIPANTS, SUPPORTING INSTITUTIONS, PRACTICAL INFORMATION, REGISTRATION, LOŠINJ, HOW TO REACH LOŠINJ, and PAST ECSAC EVENTS. The main content area includes a map of the Adriatic coast with Trieste and Lošinj marked, and a vertical banner for "ECSAC 2019 - The Proton Radius". The ECSAC logo is also visible on the right side of the page.

**XIX International Conference on Science, Arts and Culture**  
**THE PROTON RADIUS**  
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The determination of the size of the proton, the most abundant hadron in our Universe, has been in the focus of intensive research for more than 60 years. Unlike the protons' electric charge or its magnetic moment, which have been determined with very high precision, there is much dispute about the charge distribution of the proton and thus the value of its mean square charge radius owing to conflicting measurements. This has recently spurred very active research programs pursued at various laboratories.

Traditionally, charge distributions are measured using low-energy elastic electron scattering. The determination of the electric form factor of the proton, from which the charge distribution is subsequently derived, has partly made use of the Rosenbluth method allowing to separate the electric and magnetic form factors. The determination of the proton radius from this method had been challenged about eight years ago by high-precision spectroscopy of muonic-hydrogen performed at the Paul Scherrer Institute in Switzerland leading to the so-called proton radius puzzle.

Despite much experimental efforts over the last years, this puzzle has plagued



# TPC material budget



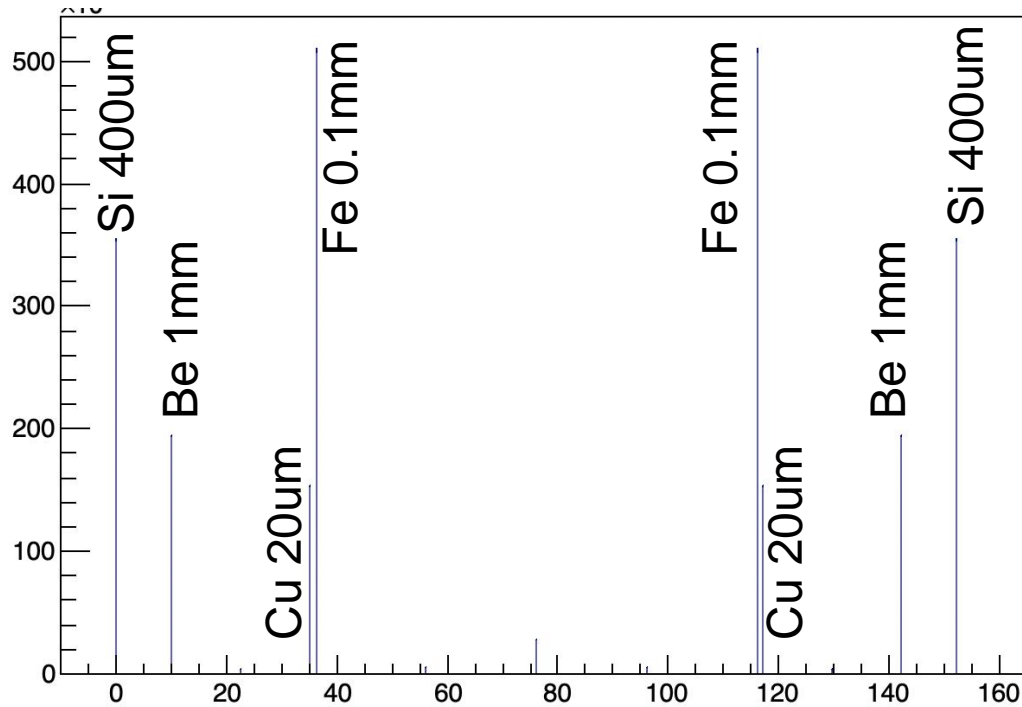
from Evgeni's email:

The material for inner part of the TPC for the mu-p experiment:

1. Cathode (diameter 600mm): The central circle (for beam) 30 um Aluminum foil (possibly less). Diameter of the central cathode depends on the beam size.
2. The grid (diameter- 600mm): 100 um diameter steel wires in 1 mm stepping.  
**that is 20% of the surface / events for each grid! Each wire 0.6% R.L.**
3. The Anode (diameter- 600mm): The central circle (for beam).  
80 um Kapton + 20 um copper (possible less).
4. The Be window : The hemisphere with diameter 70 mm and thickness - 1mm.  
The final design of the Be windows depends from the beam size and safety requirements (maximal test pressure ?).

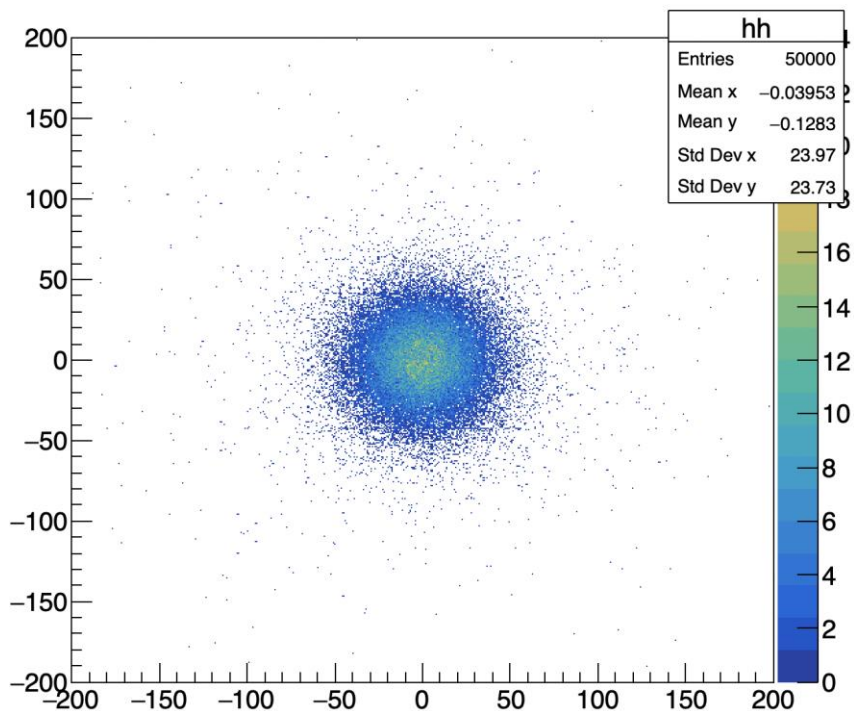
# Material budget: where is what

2zones / 150cm Si-Si

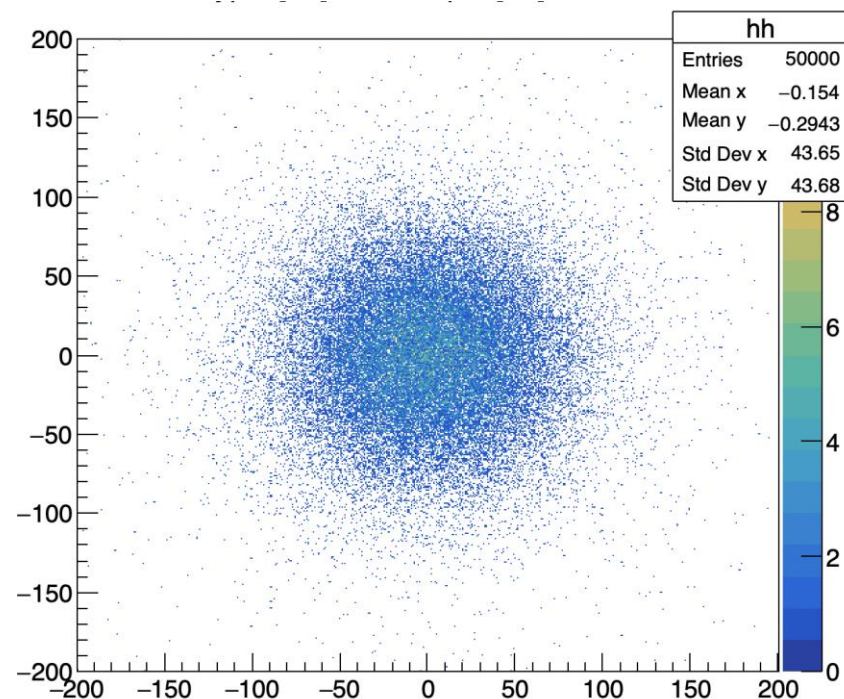


# Multiple scattering impact for different target options

2zones / 150cm Si-Si [ $\mu\text{m}$ ]



4zones / 240cm Si-Si [ $\mu\text{m}$ ]

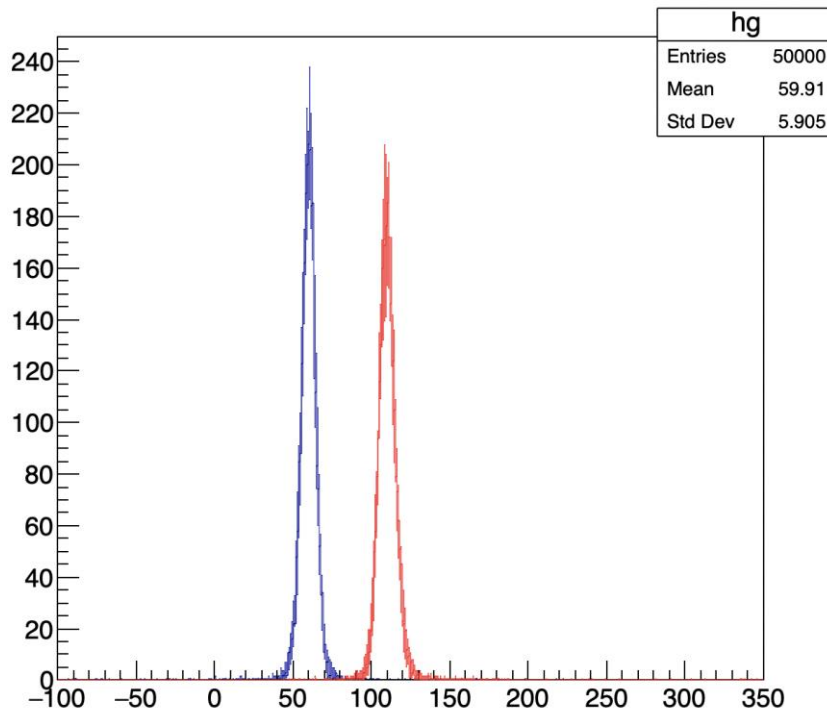




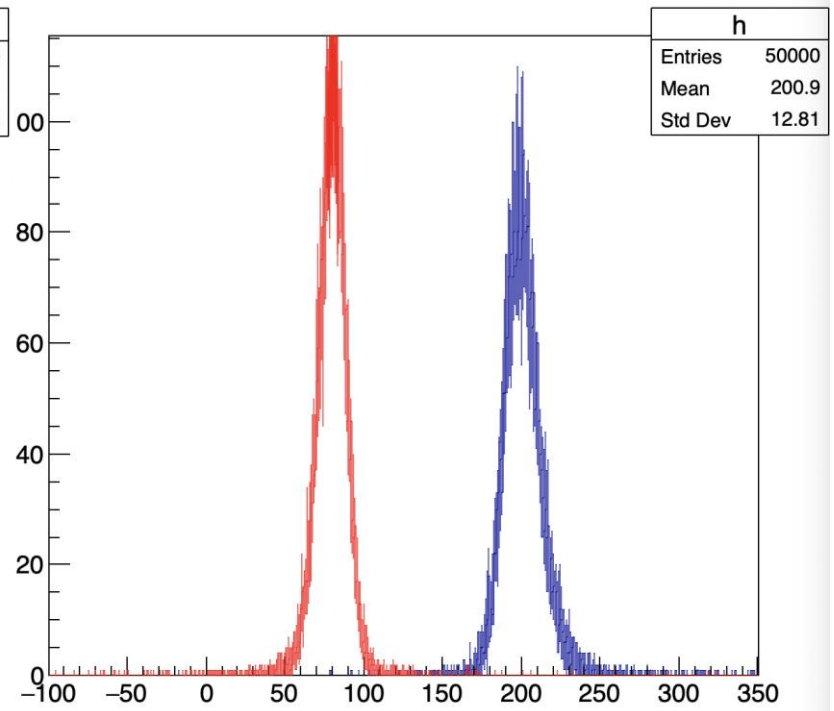
# Multiple scattering impact for different target options

reconstruction ideal Si detectors, 300 $\mu$ rad scattering angle

2zones / 150cm Si-Si [cm]



4zones / 240cm Si-Si [cm]





# Feedback from SPSC preliminary



Here is our feedback from the closed session of the SPSC. The preliminary minutes read:

"The Committee received with interest the Proposal SPSC-P-360 by the COMPASS++/AMBER Collaboration for measurements at the M2 beam line of the CERN SPS in 2022, 2023 and 2024. The Committee will further review the proposal."

There has been a first discussion of the AMBER proposal in the closed session. Given that the document was uploaded only recently, we (the referees) did not have time to look into all the details, so the discussion has been held at a fairly general level. Several questions were raised that we want to convey to you now and more detailed questions will follow in due course.

Regarding the Proton Radius part, the SPSC likes to see some study of the expected systematic errors. At the moment there is no information to support the hope that the systematic errors are under control and at the level required for a 1% determination of the proton radius by AMBER. The committee would also like to see a more detailed account of the differences w.r.t. MUSE and the advantages and disadvantages of using a higher muon energy beam. The comments about the Coulomb distortion of the low-velocity muon wave function in the proposal should for instance be further elaborated on in order for us to assess their importance.

Program	Physics Goals	Beam Energy [GeV]	Beam Intensity [ $s^{-1}$ ]	Trigger Rate [kHz]	Beam Type	Target	Earliest start time, duration	Hardware Additions
$\mu p$ elastic scattering	Precision proton-radius measurement	100	$4 \cdot 10^6$	100	$\mu^\pm$	high-pr. H2	2022 1 year	active TPC SciFi trigger silicon veto
Hard exclusive reactions	GPD $E$	160	$10^7$	10	$\mu^\pm$	$NH_3^\uparrow$	2022 2 years	recoil silicon, modified PT magnet
Input for DMS	$\bar{p}$ production cross-section	20-280	$5 \cdot 10^5$	25	$p$	LH2, LHe	2022 1 month	LHe target
$\bar{p}$ -induced Spectroscopy	Heavy quark exotics	12, 20	$5 \cdot 10^7$	25	$\bar{p}$	LH2	2022 2 years	target spectr.: tracking, calorimetry
Drell-Yan	Pion PDFs	190	$7 \cdot 10^7$	25	$\pi^\pm$	C/W	2022 1-2 years	
Drell-Yan (RF)	Kaon PDFs Nucleon TMDs	$\sim 100$	$10^8$	25-50	$K^\pm, \bar{p}$	$NH_3^\uparrow$ , C/W	2026 2-3 years	"active absorber", vertex det.
Primakoff (RF)	Kaon polarizability & pion life time	$\sim 100$	$5 \cdot 10^6$	$> 10$	$K^-$	Ni	n/e 2026 1 year	
Prompt Photons (RF)	Meson gluon PDFs	$\geq 100$	$5 \cdot 10^6$	10-100	$K^\pm$ $\pi^\pm$	LH2, Ni	n/e 2026 1-2 years	hodoscope
$K$ -induced Spectroscopy (RF)	High-precision strange-meson spectrum	50-100	$5 \cdot 10^6$	25	$K^-$	LH2	2026 1 year	recoil TOF forward PID
Vector mesons (RF)	Spin Density Matrix Elements	50-100	$5 \cdot 10^6$	10-100	$K^\pm, \pi^\pm$	from H to Pb	2026 1 year	

Table 5: Requirements for future programs at the M2 beam line after 2021. **Standard muon beams** are in blue, **standard hadron beams** in green, and **RF-separated hadron beams** in red.