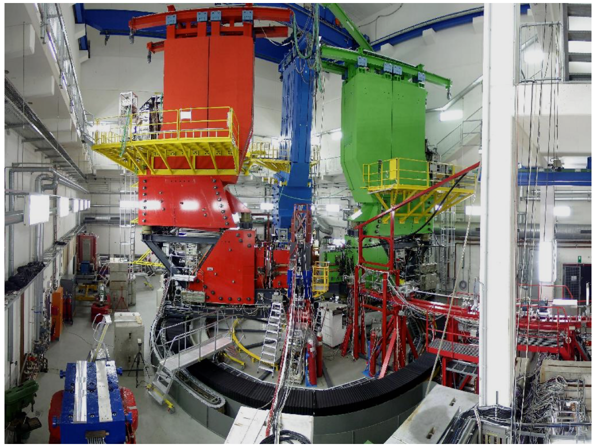
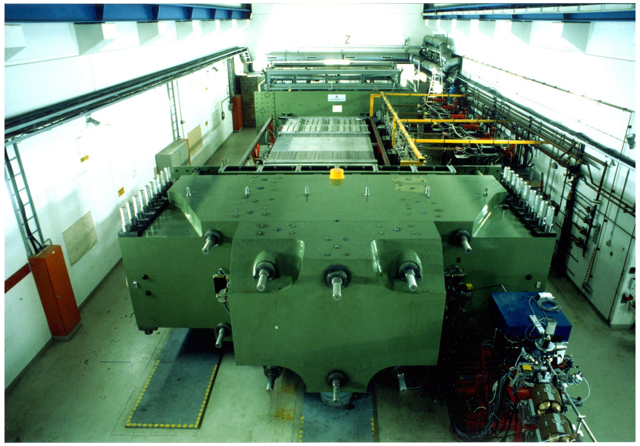




ISR Experiment at A1

Miha Mihovilovic for A1 Collaboration

JGU Mainz and JSI

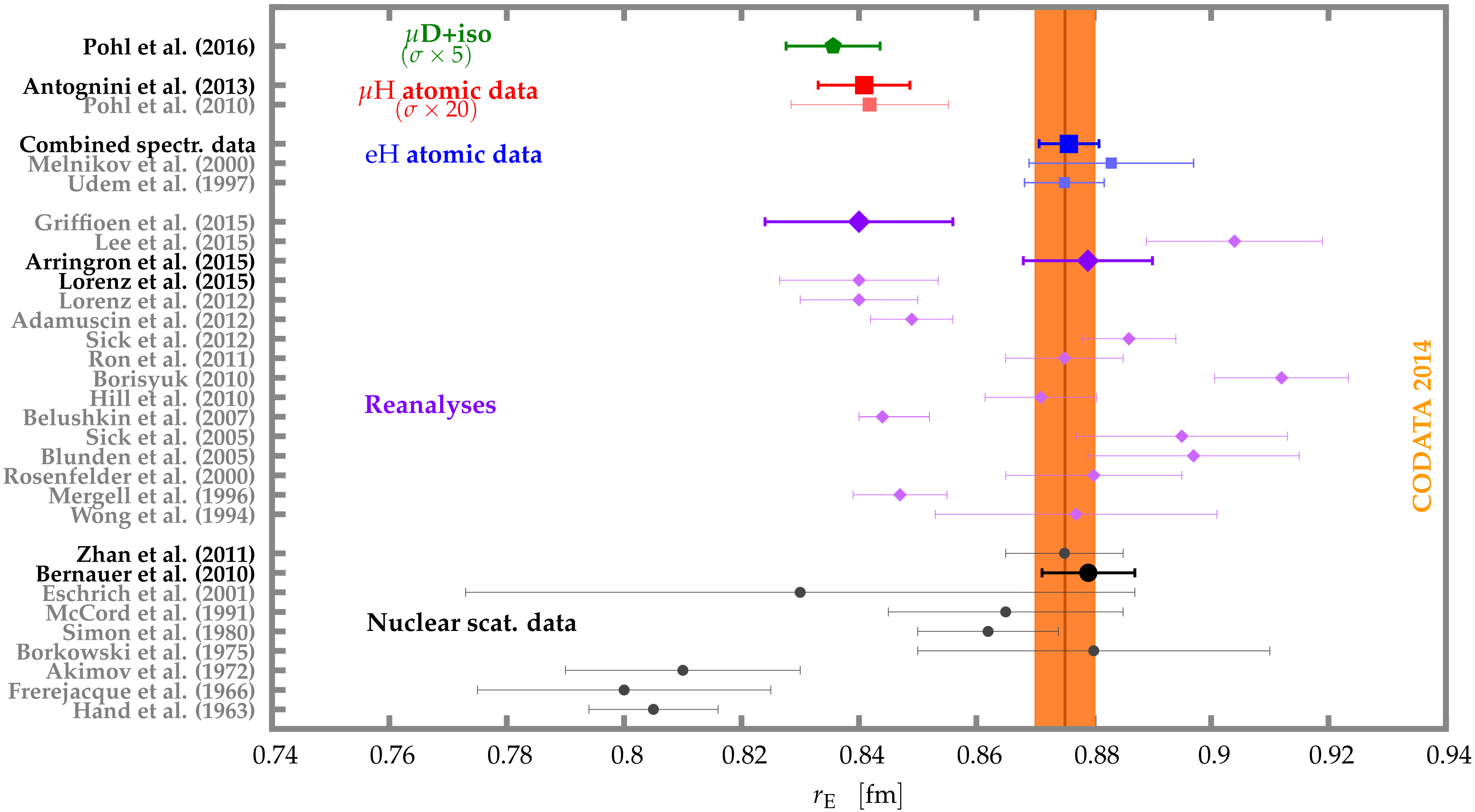
PhiPsi 2017

THE LOW-ENERGY FRONTIER OF THE STANDARD MODEL

SLOVENIAN RESEARCH AGENCY

The proton radius problem

- The 6σ discrepancy in the r_p measurements.

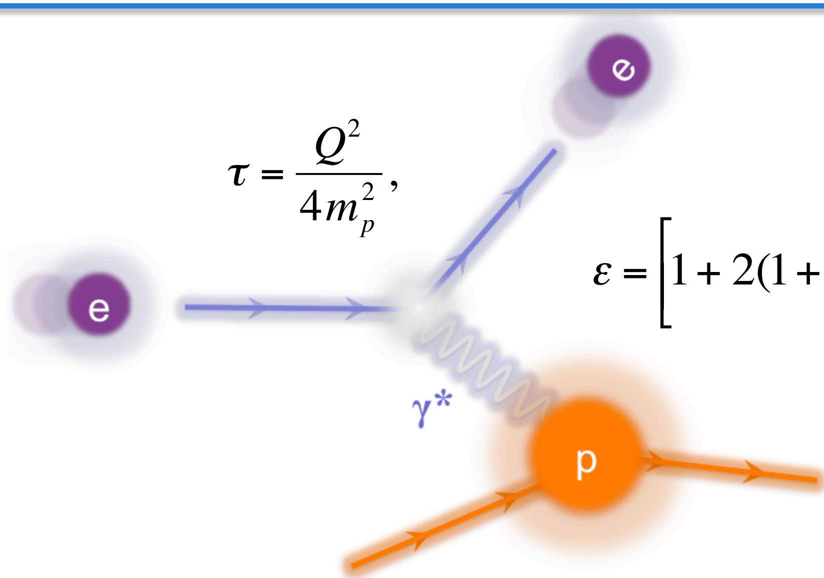


- See talks of R. Pohl and C.E. Carlson on Wednesday.

Why is the puzzle so important?

- Knowledge of basic properties of the nucleon.
- The radius is strongly correlated to the Rydberg constant.
- Problems in nuclear scattering data?
- Bringing different interpretations of nuclear scattering data to an agreement.
- Do we understand QED?

Radius via Cross-section measurement



$$\tau = \frac{Q^2}{4m_p^2},$$

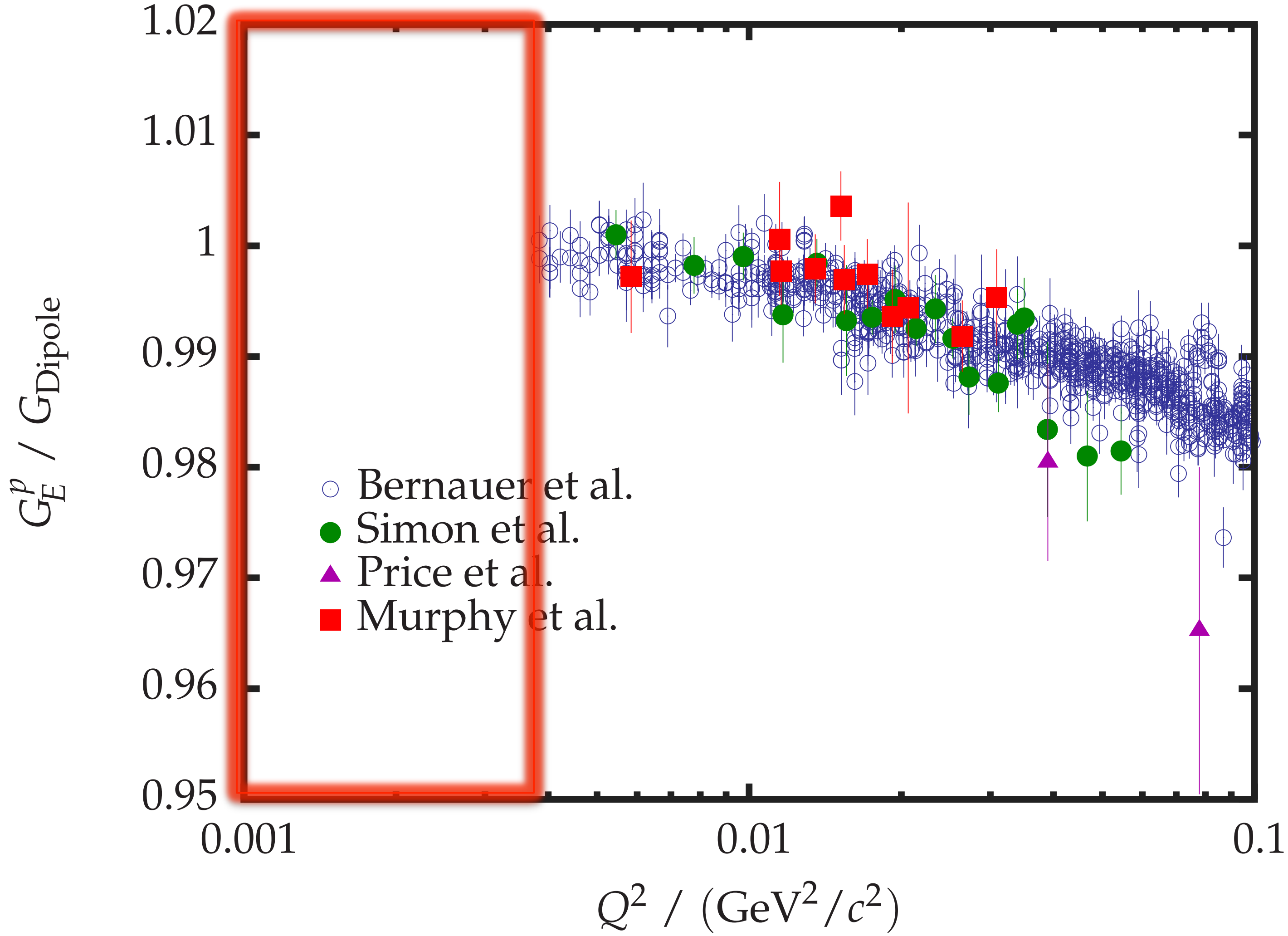
$$\varepsilon = \left[1 + 2(1+\tau)\tan^2\frac{\vartheta_e}{2}\right]^{-1}$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \frac{1}{1+\tau}\left[G_E^2(Q^2) + \frac{\tau}{\varepsilon}G_M^2(Q^2)\right]$$

- Extraction of FF via Rosenbluth Separation.
- Best estimate for radius:

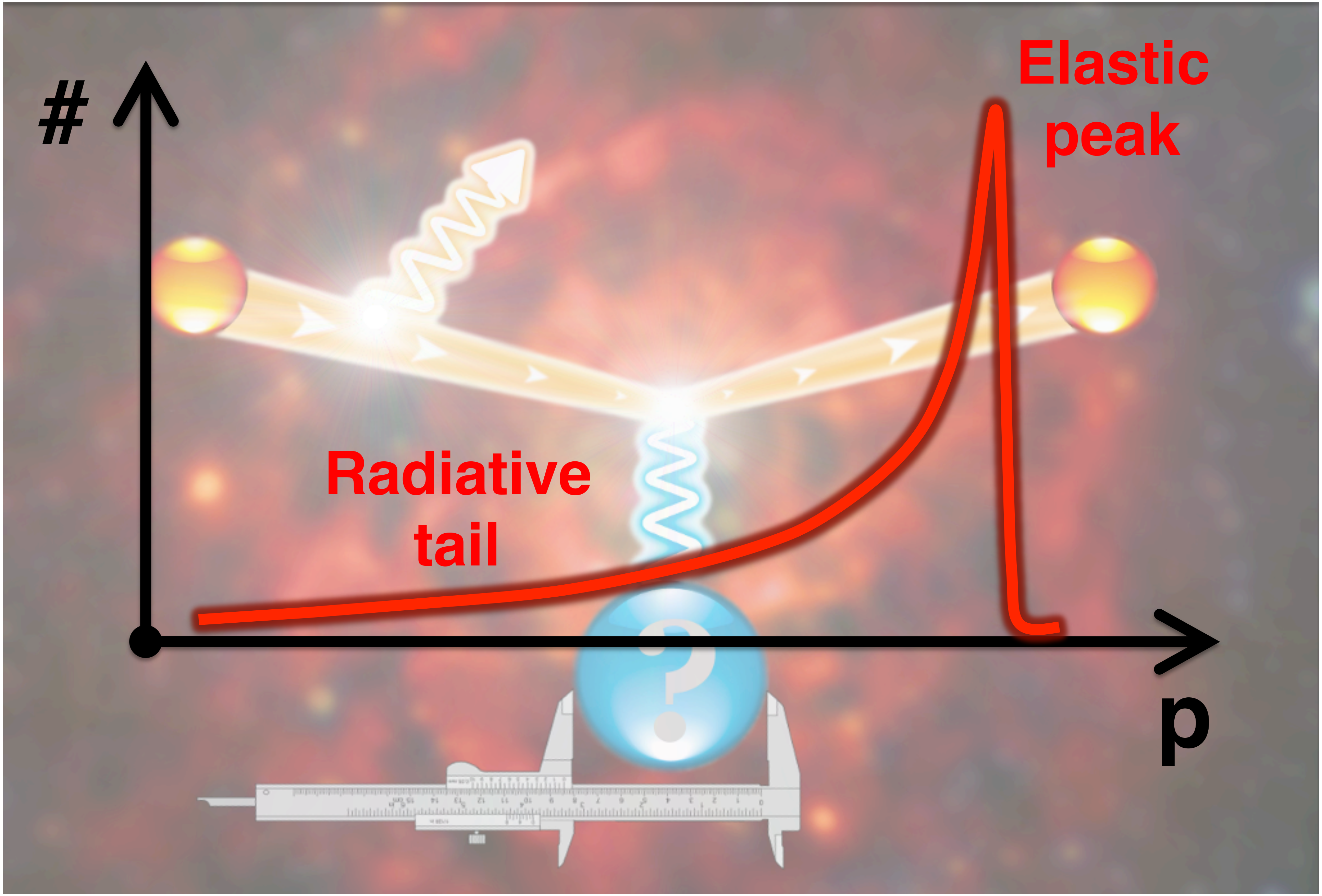
$$r_E^2 = -6\hbar^2 \frac{d}{dQ^2} G_E(Q^2)\Big|_{Q^2=0}$$

Proton's charge form-factor



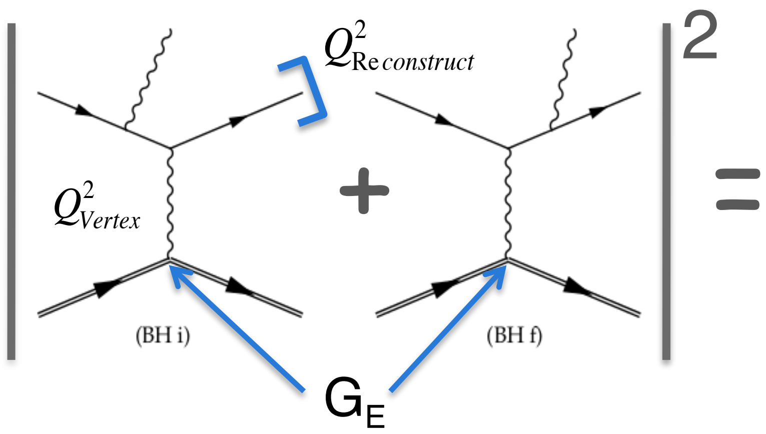
- **Data available only for $Q^2 > 0.004$ (GeV/c)^2.**
- **<u>Extrapolations to zero are needed!</u>**

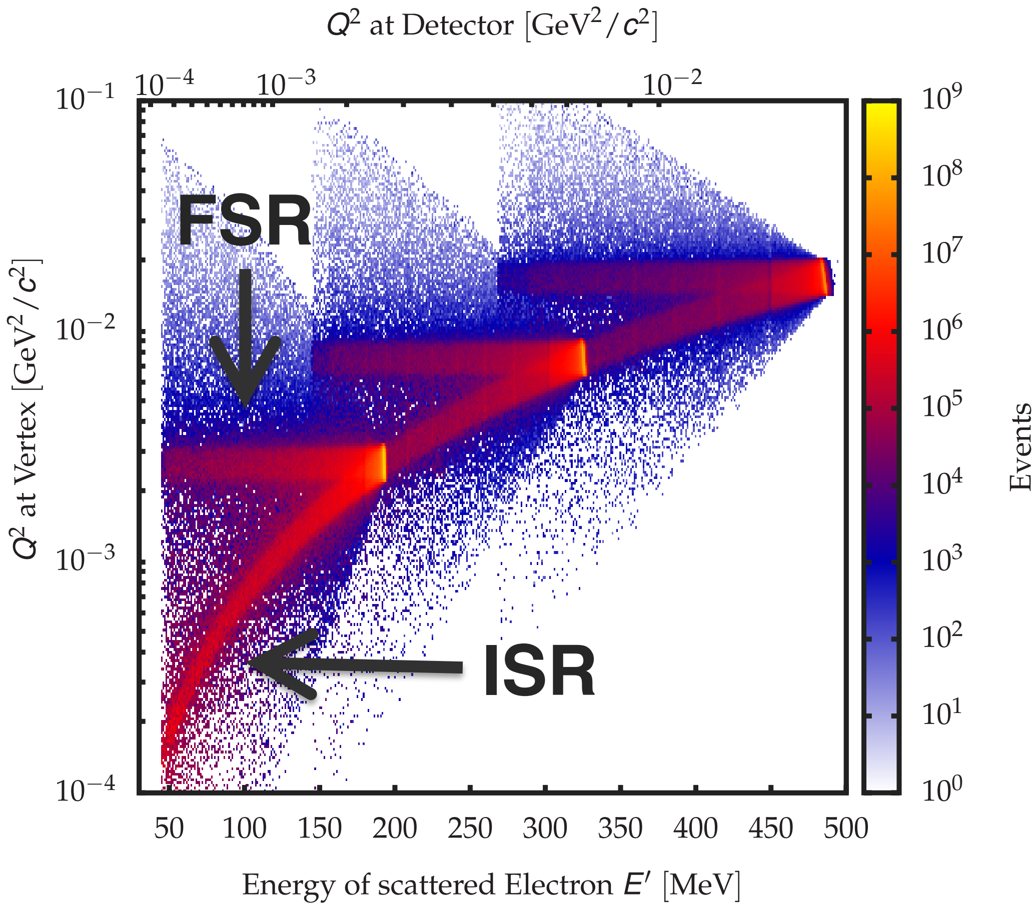
ISR Experiment at MAMI



Full Simulation

- Dominated by coherent sum of two Bethe-Heitler diagrams.





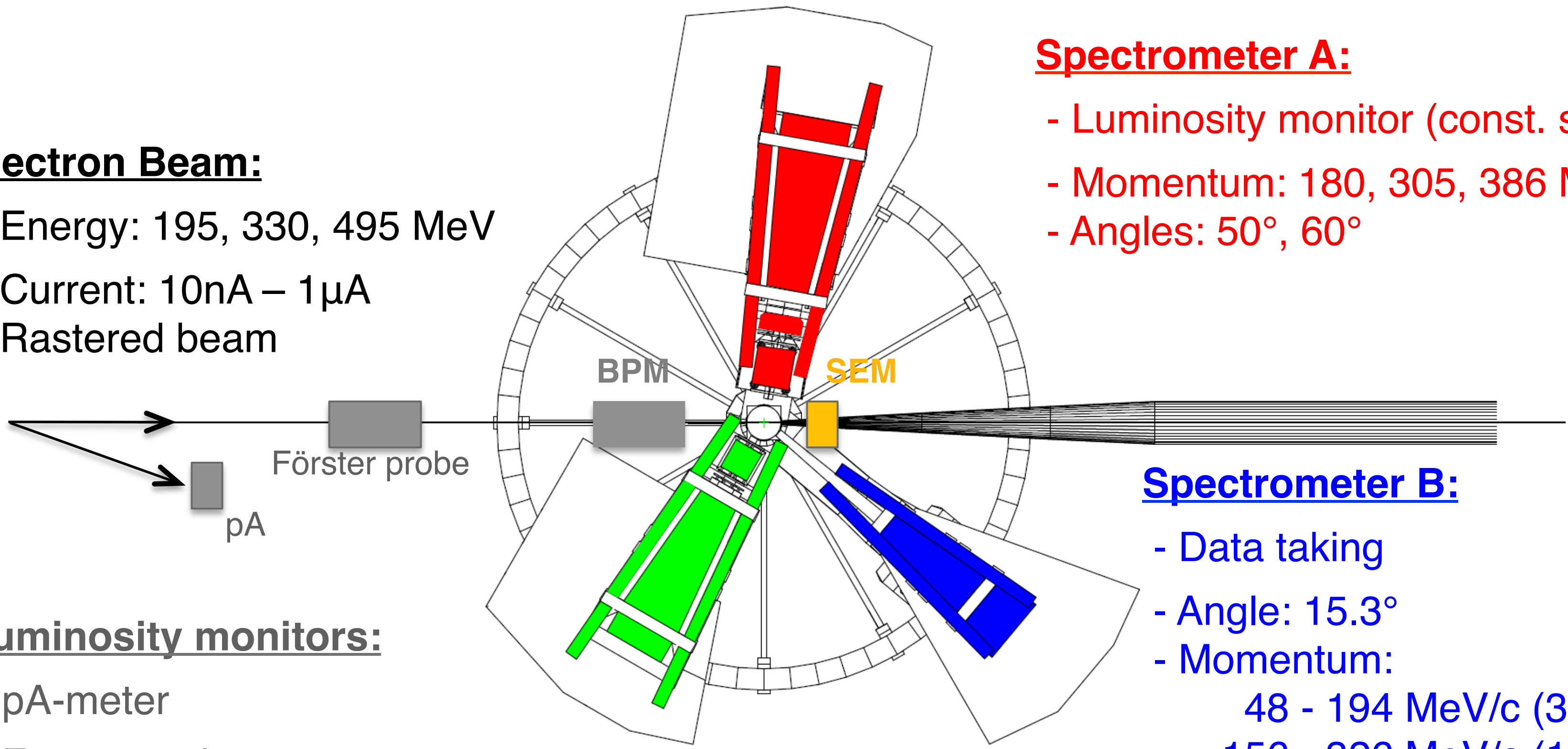
- By comparing data to simulation ISR information can be reached.
- **Measured δσ linearly proportional to the δG_E between data and model.**

The ISR experiment

- Full experiment done in August 2013. Four weeks of data taking.

Electron Beam:

- Energy: 195, 330, 495 MeV
- Current: 10nA – 1μA
- Rastered beam



Spectrometer A:

- Luminosity monitor (const. setting)
- Momentum: 180, 305, 386 MeV/c
- Angles: 50°, 60°

Spectrometer B:

- Data taking
- Angle: 15.3°
- Momentum:
  48 - 194 MeV/c (35 setups)
  156 - 326 MeV/c (12 setups)
  289 - 486 MeV/c (9 setups)

Luminosity monitors:

- pA-meter
- Förster probe
- SEM

Spectrometer C:

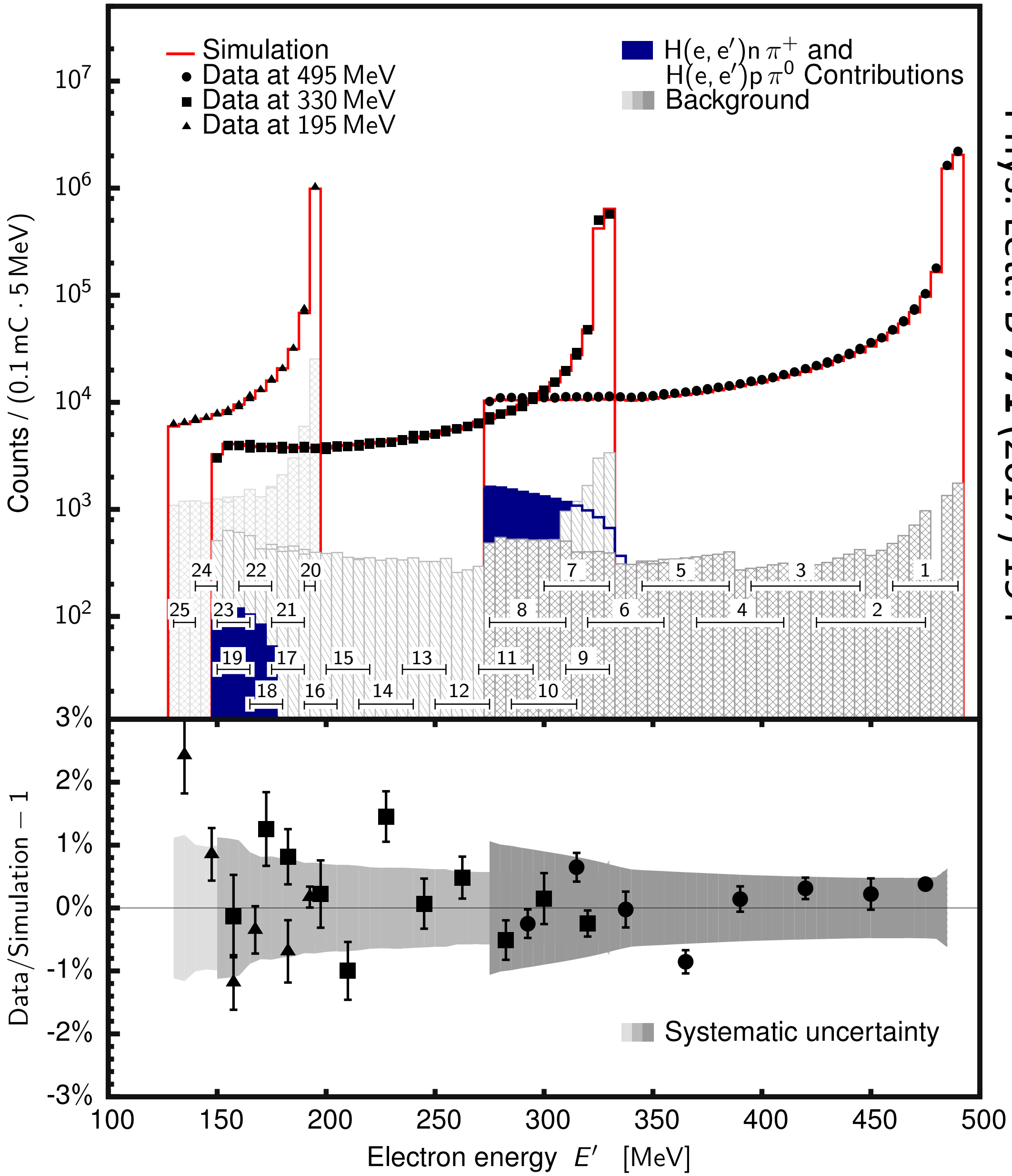
- Not used

Results

- Existing apparatus limited reach of ISR experiment to E' ~ 130 MeV.

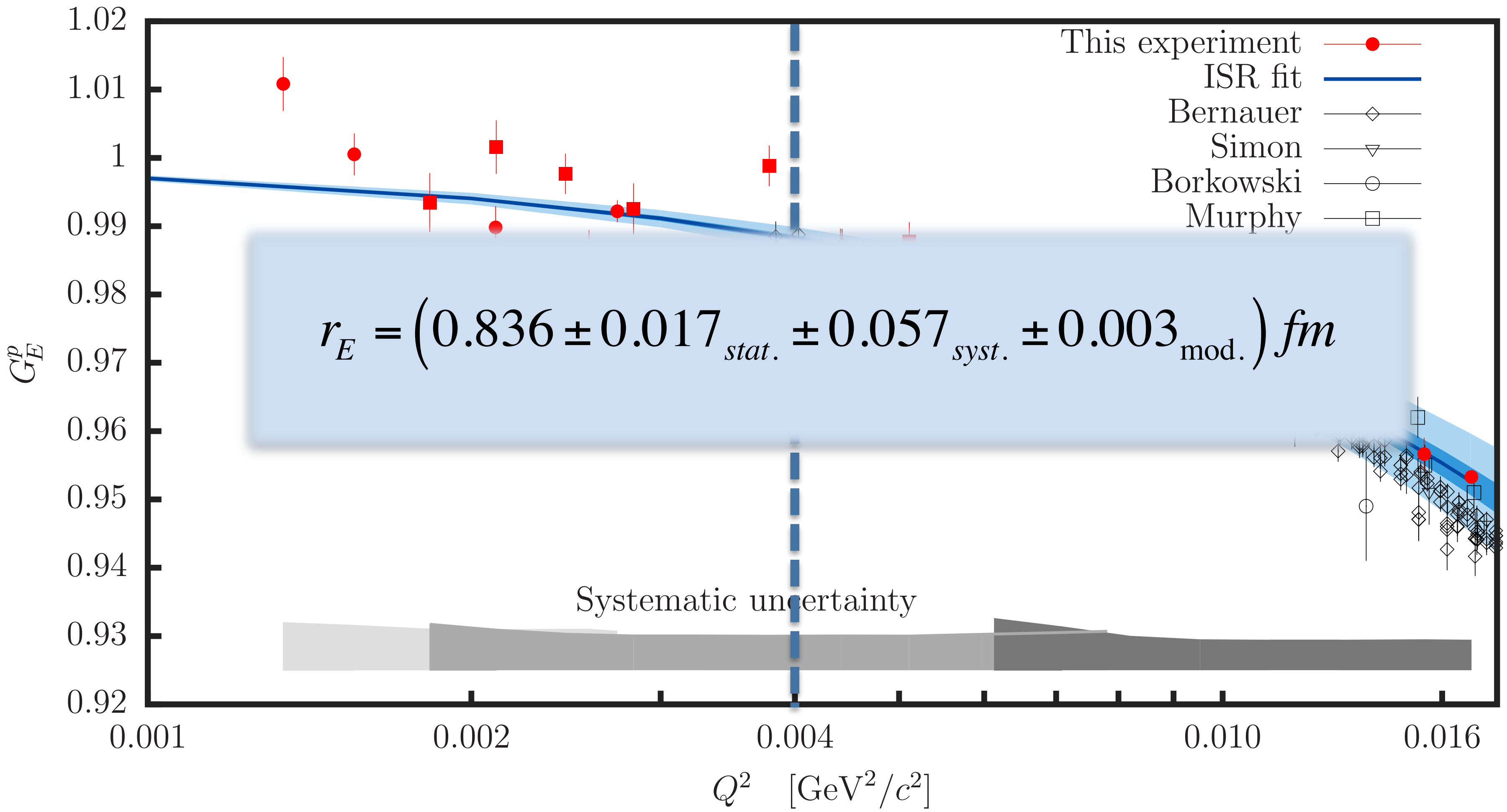
- Simulation performed with Bernauer parameterization of form factors.

- A percent agreement between the data and simulation demonstrates that the radiative corrections are well understood!



Phys. Lett. B **771** (2017) 194

ISR form-factors

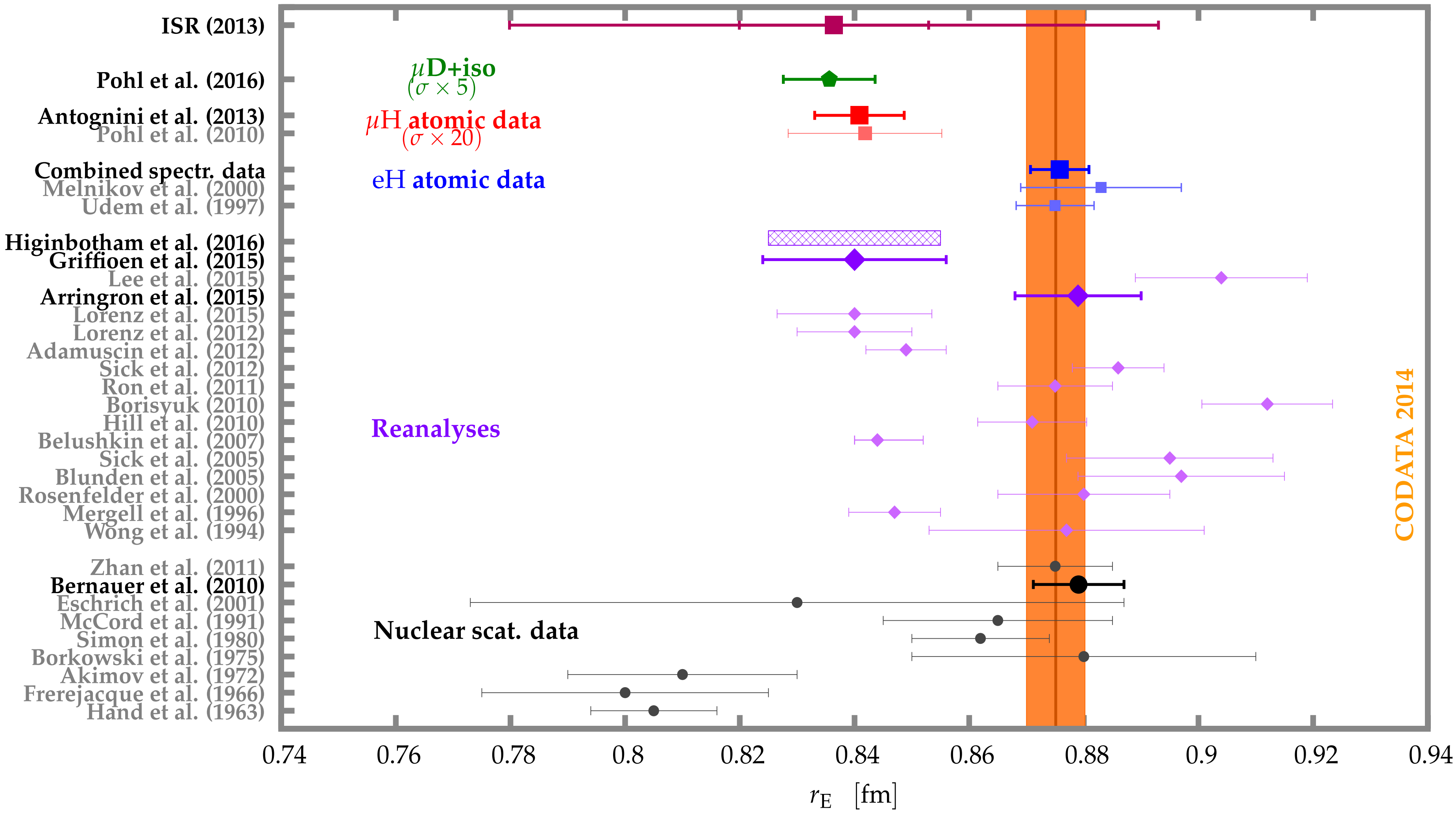


$$r_E = \left(0.836 \pm 0.017_{stat.} \pm 0.057_{syst.} \pm 0.003_{\mathrm{mod.}}\right) fm$$

Phys. Lett. B **771** (2017) 194

- Assuming flawless description of radiative corrections, form factors can be extracted from the data.
- **First measurement of G_E^p at $0.001\ \mathrm{GeV}^2 \leq Q^2 \leq 0.004\ \mathrm{GeV}^2$**

The ISR proton radius



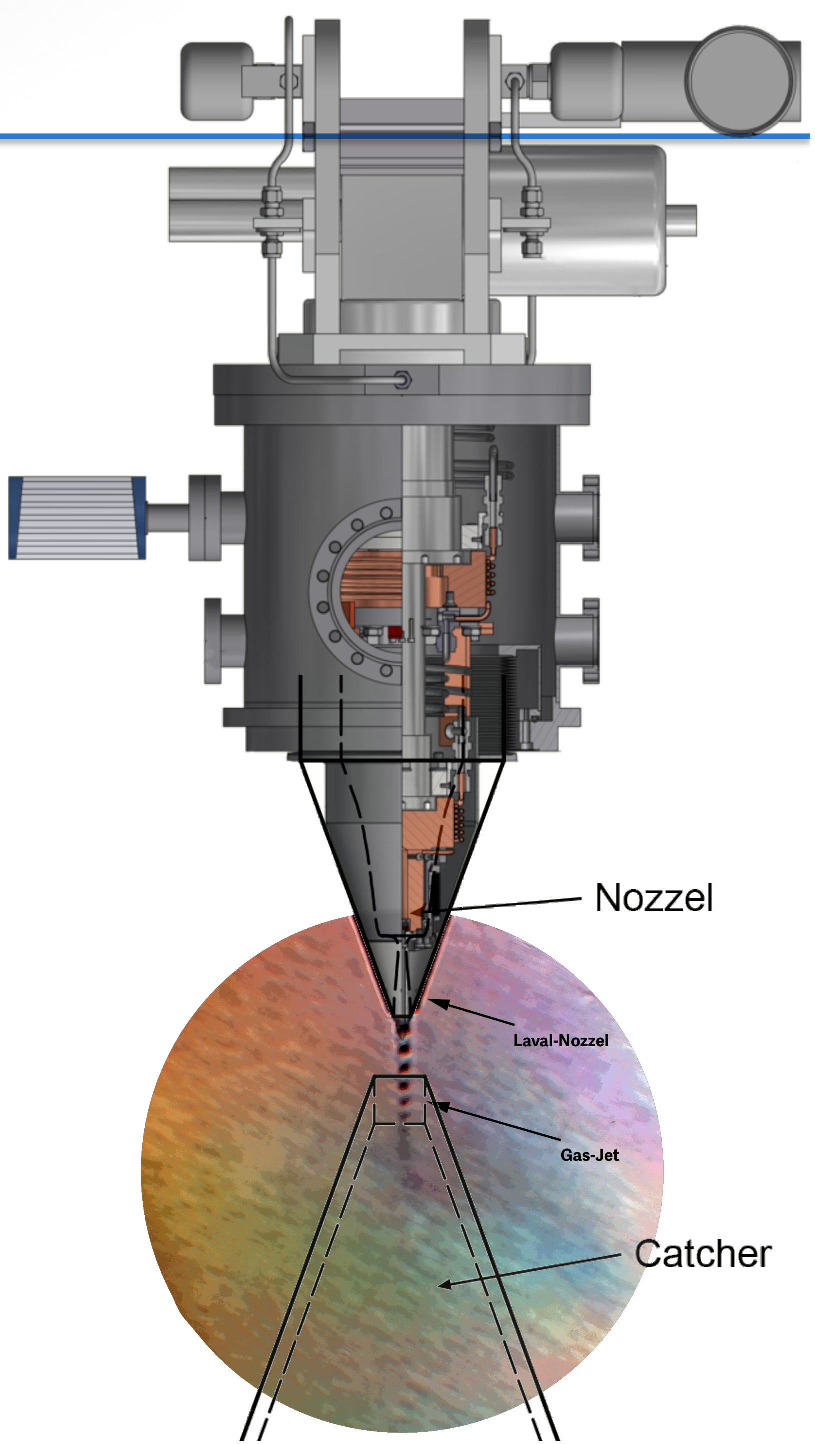
- Only ISR data considered in the result.
- Result limited by the systematic uncertainty.

Hypersonic jet target

- Target developed for MAGIX, but could be used also in A1.

- No metal frame near the vertex.
- No target walls.
- Width of the jet 2mm (point-like target)

- Density of **10^{-4} g/cm^3** at 15 bar.
- Luminosity of **10^{34}/cm^{2}s** can be achieved at MAMI.



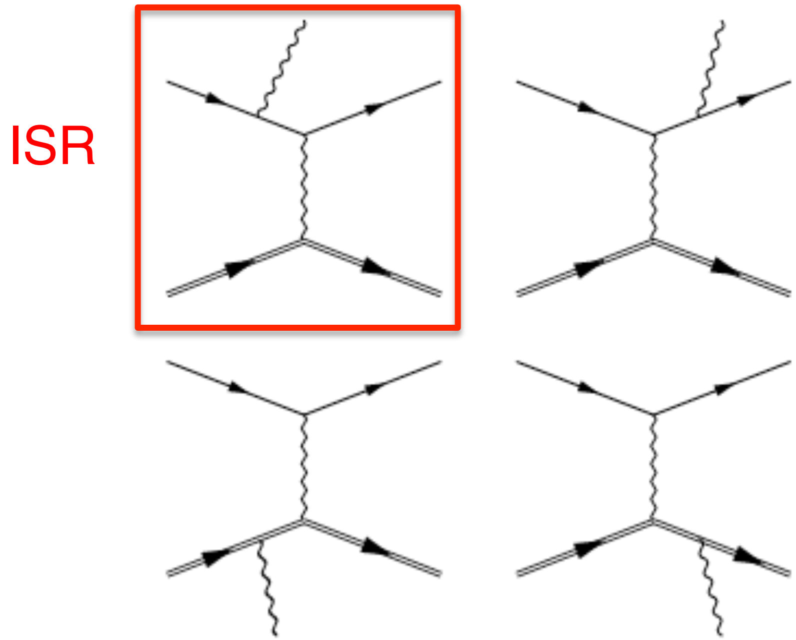
Summary

- A pilot experiment has been performed at MAMI to measure G_E^p at very low Q^2.
- A new technique for FF determination based on ISR has been successfully validated.
- Reach of the first ISR experiment limited by unforeseen backgrounds.
- **Experiment approved by PAC 2016**
- **The jet target opens possibility for reaching the ultimate goal of measuring form factors at 10^{-4} GeV^2.**

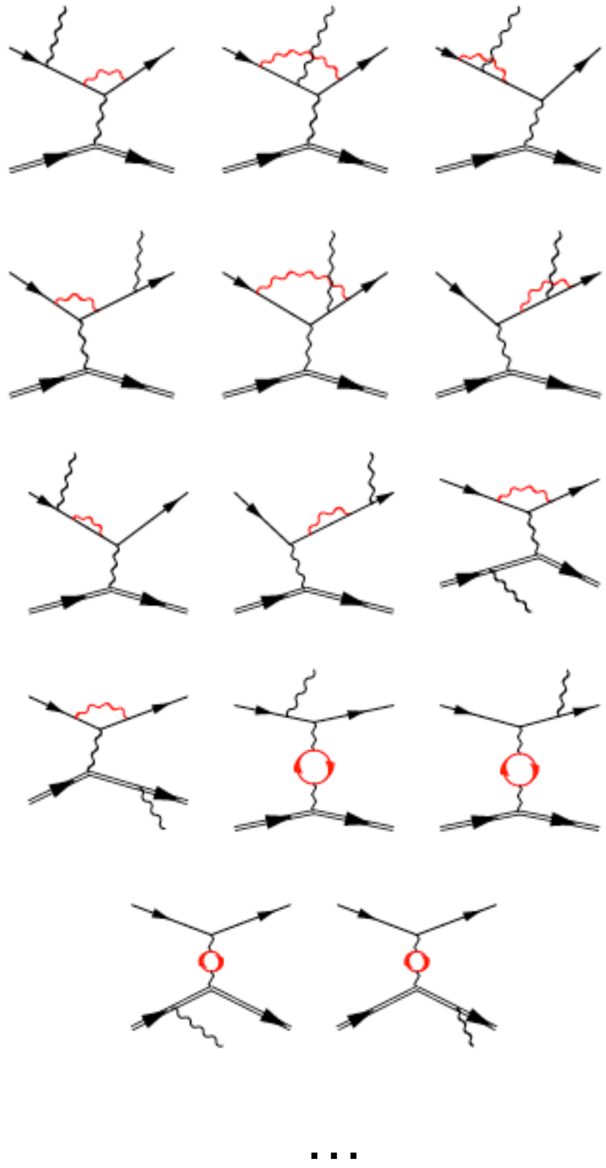
Thank you!

Simul++

- Based on standard A1 framework.
- Detailed description of apparatus.
- Exact calculation of the leading order diagrams:

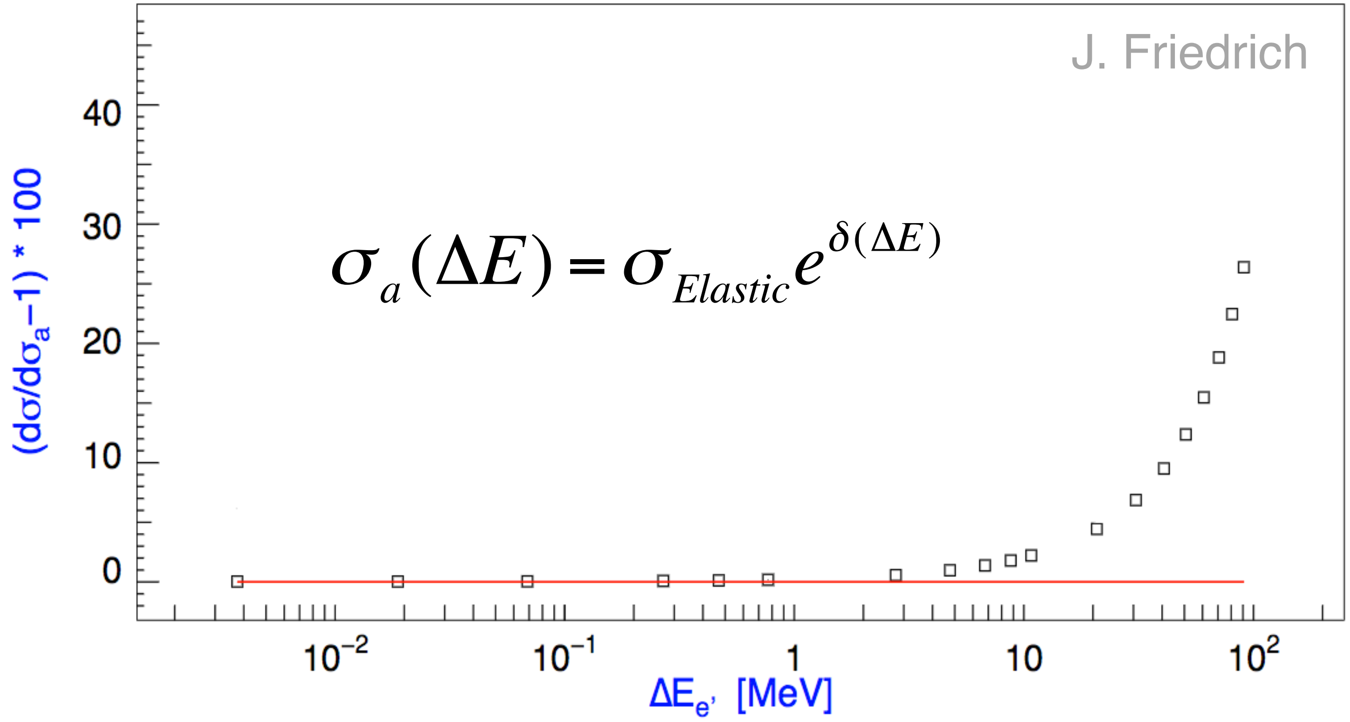


- The NL-order **virtual and real** corrections together with external corrections included via effective corrections to the cross-section.



Going beyond peaking approximation

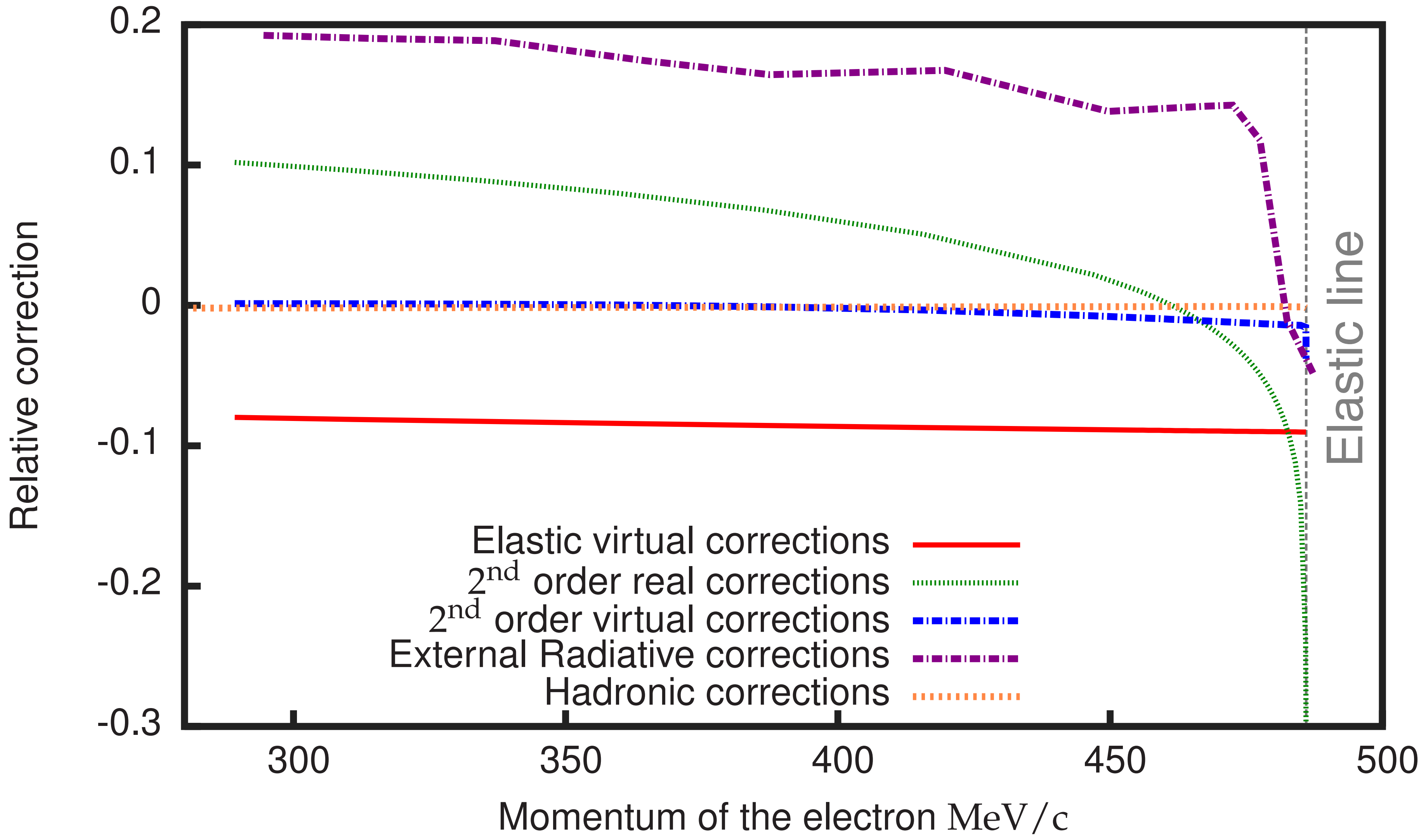
- Traditional peaking approximations insufficient for such experiment.



- **Secondary objective:** Measurements at higher Q^2 for validating the radiative corrections in a region, where FFs are well known.

  Important for experiments, e.g. VCS, which require high-precision knowledge of the radiative corrections.

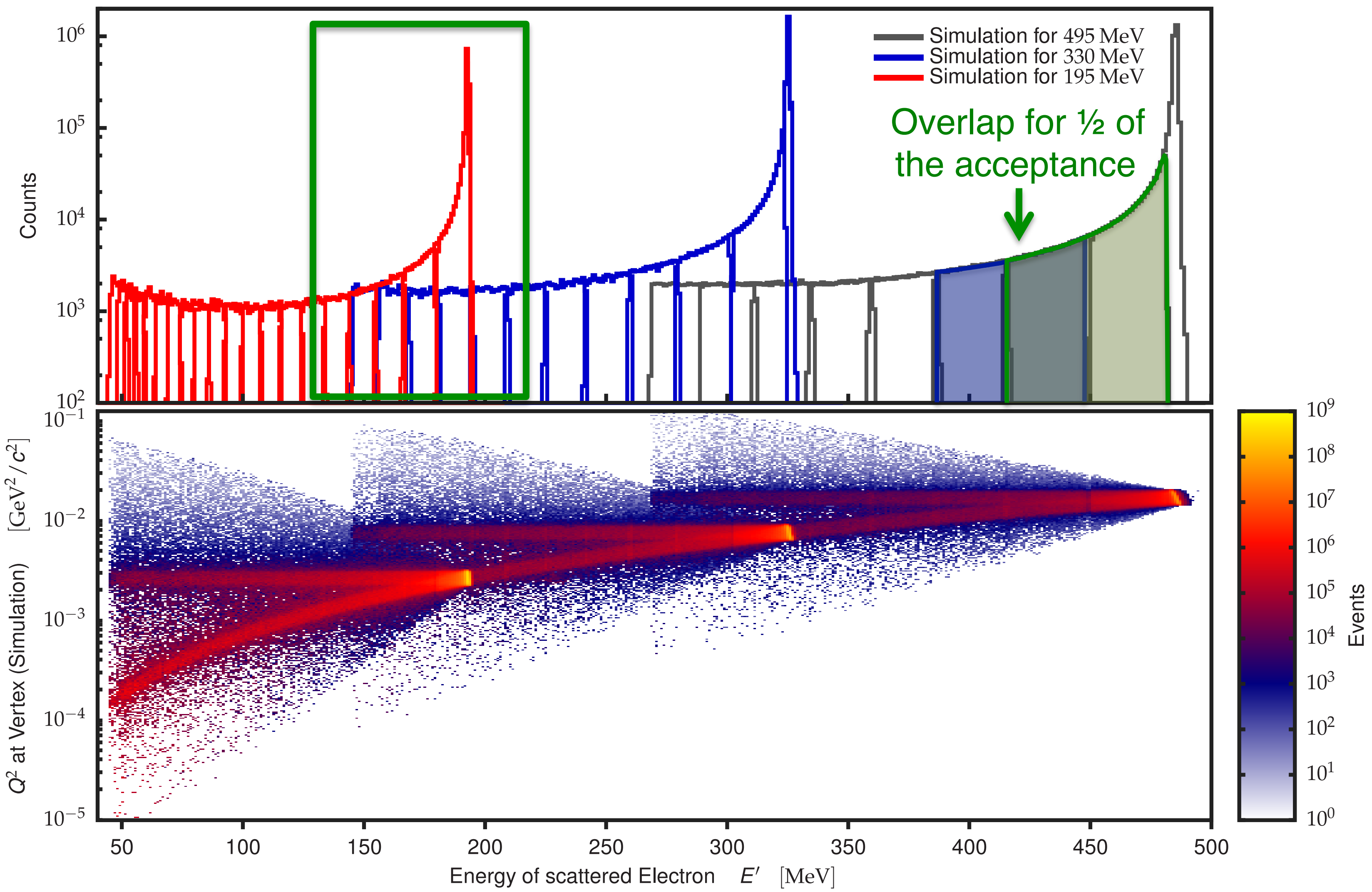
Size of effective corrections



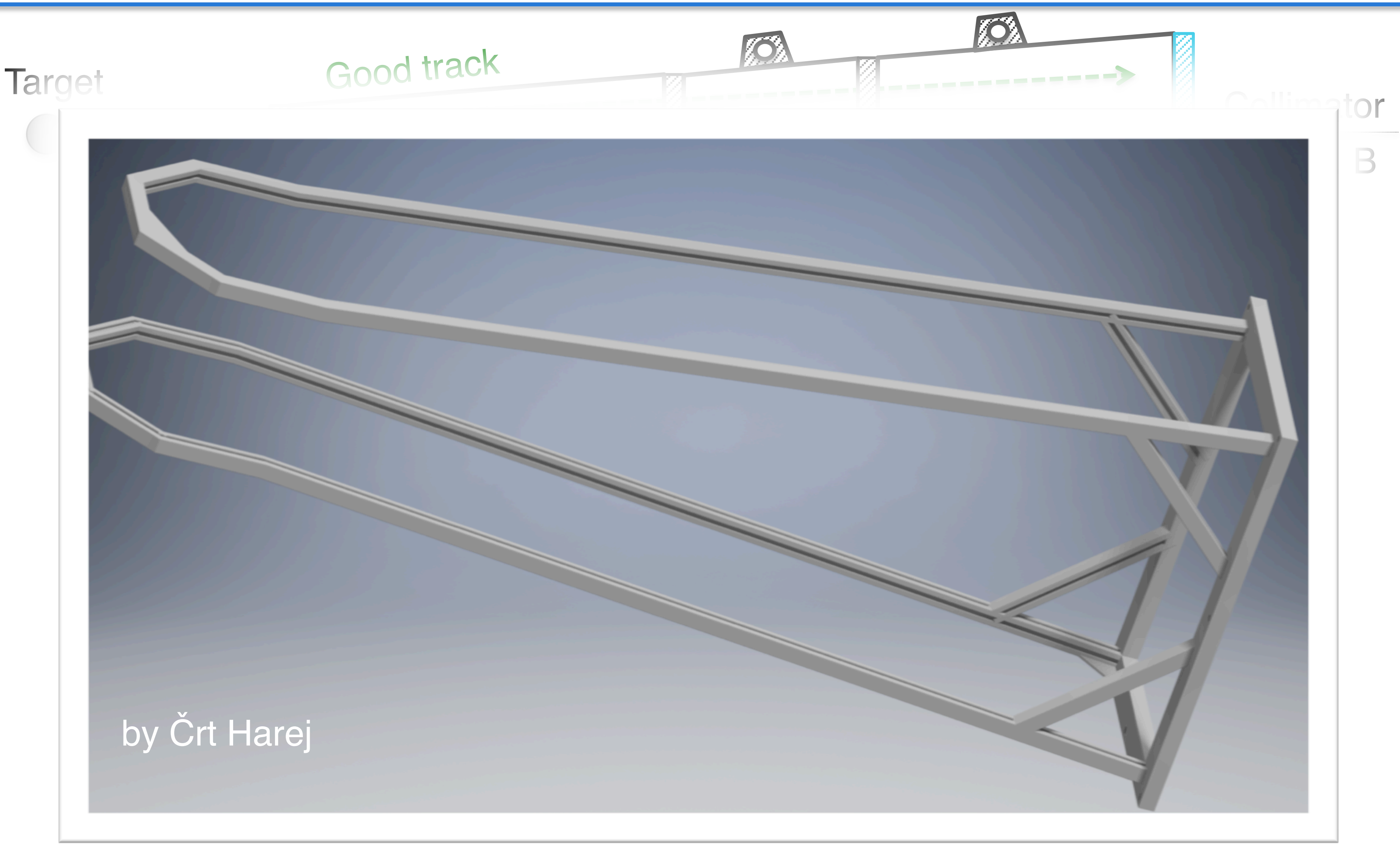
- **Careful handle of all the corrections is required.**

Kinematic settings

- Overlapping settings to control systematic uncertainty.



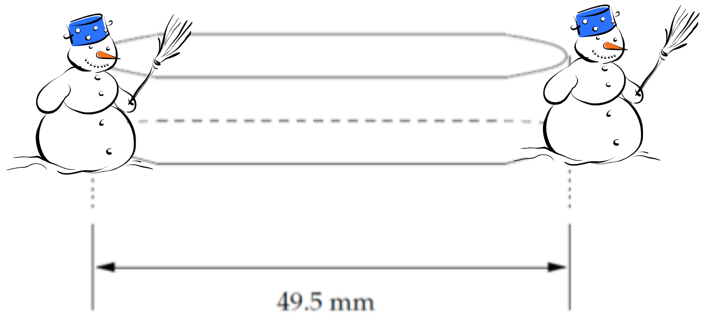
Entrance flange contributions



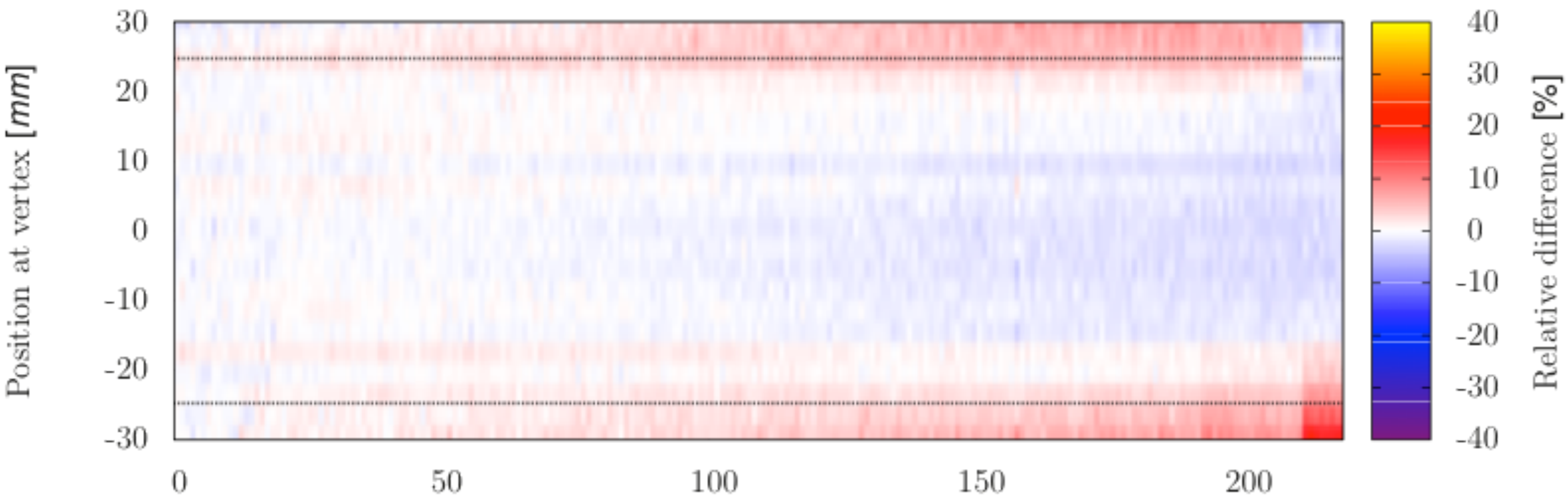
- Spec. B encompasses a long entrance flange.
- Events rescattered from the snout cover the whole vertex acceptance.

Cryogenic depositions

- Disturb luminosity determination and calculation of energy losses and radiative corrections.

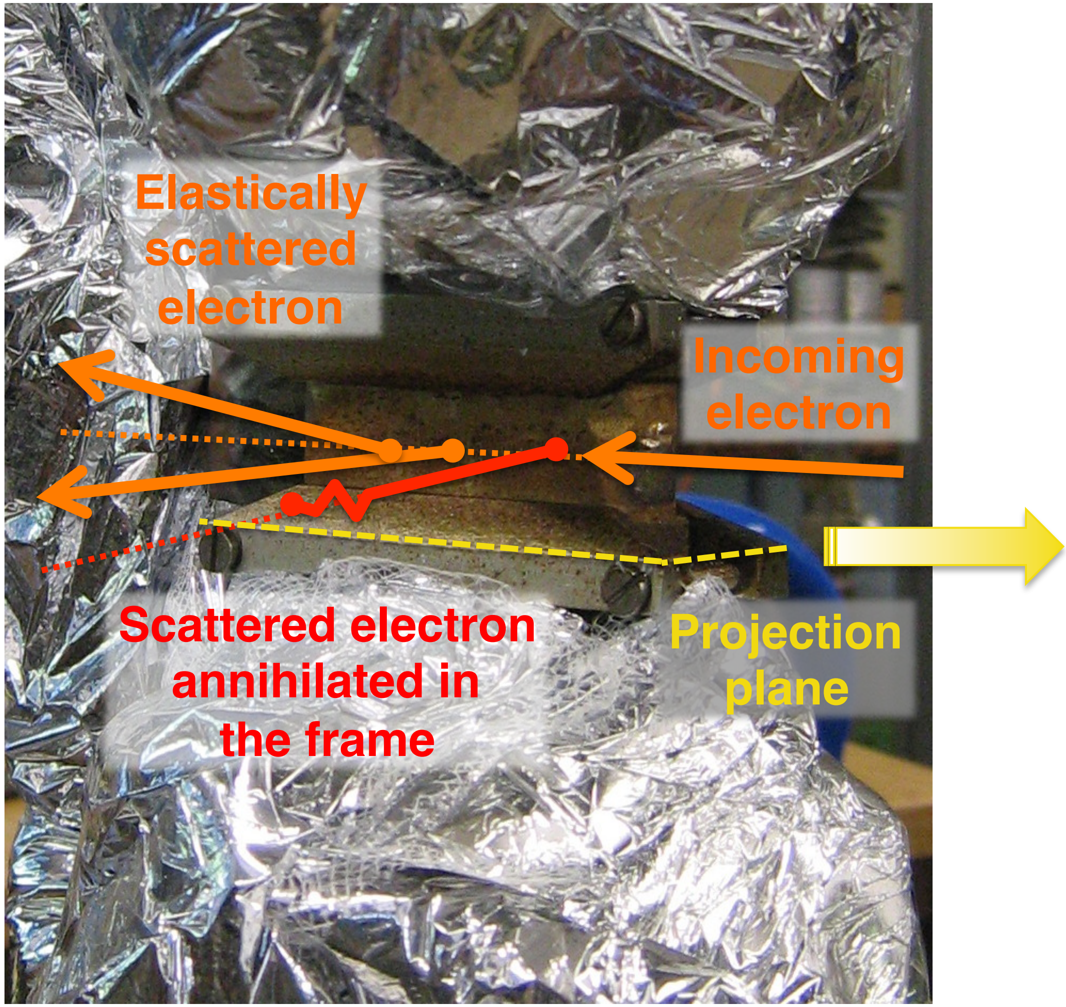


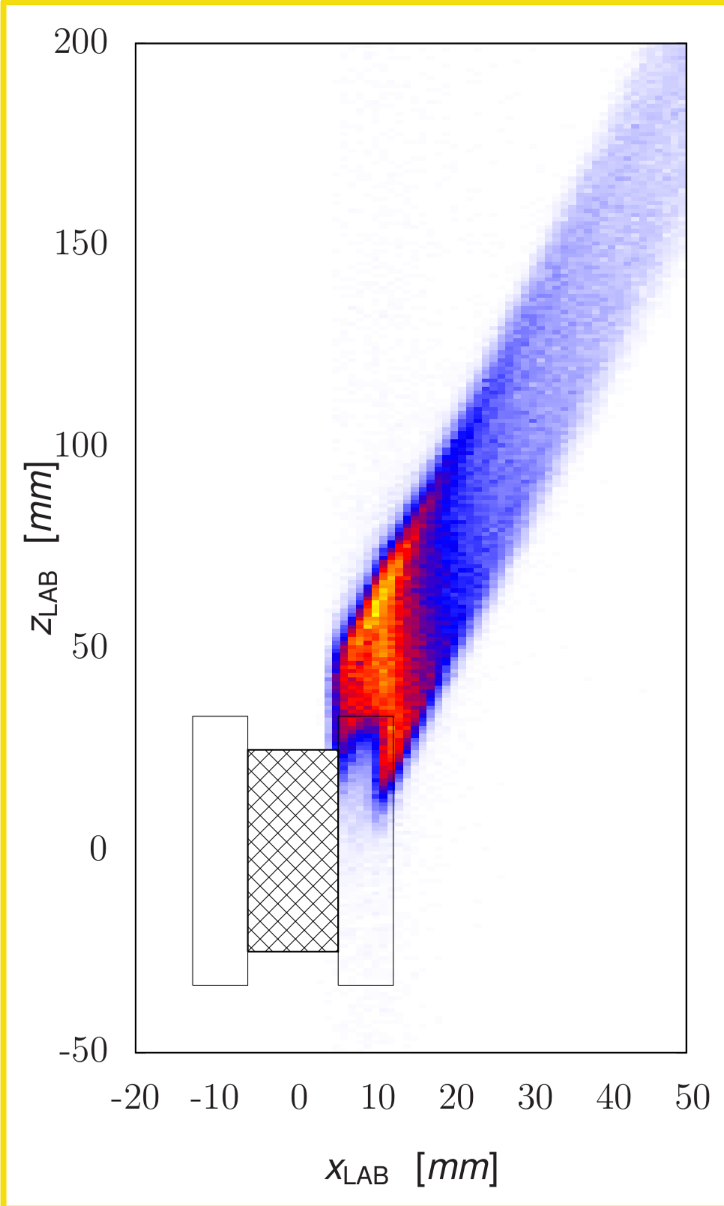
- **<u>Good vacuum</u>** in target chamber (10^{-6} mbar)



Target Frame contributions #1

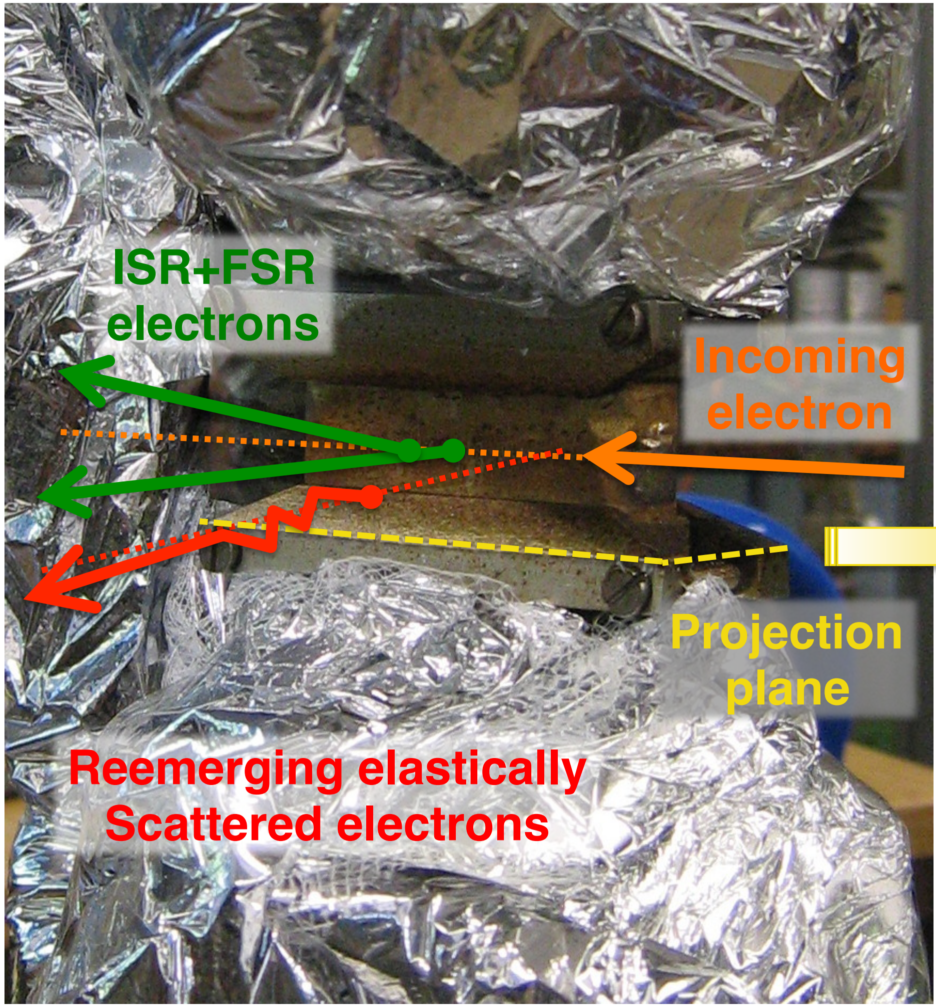
- Presence of target frame results in the deficiency of the elastic events .

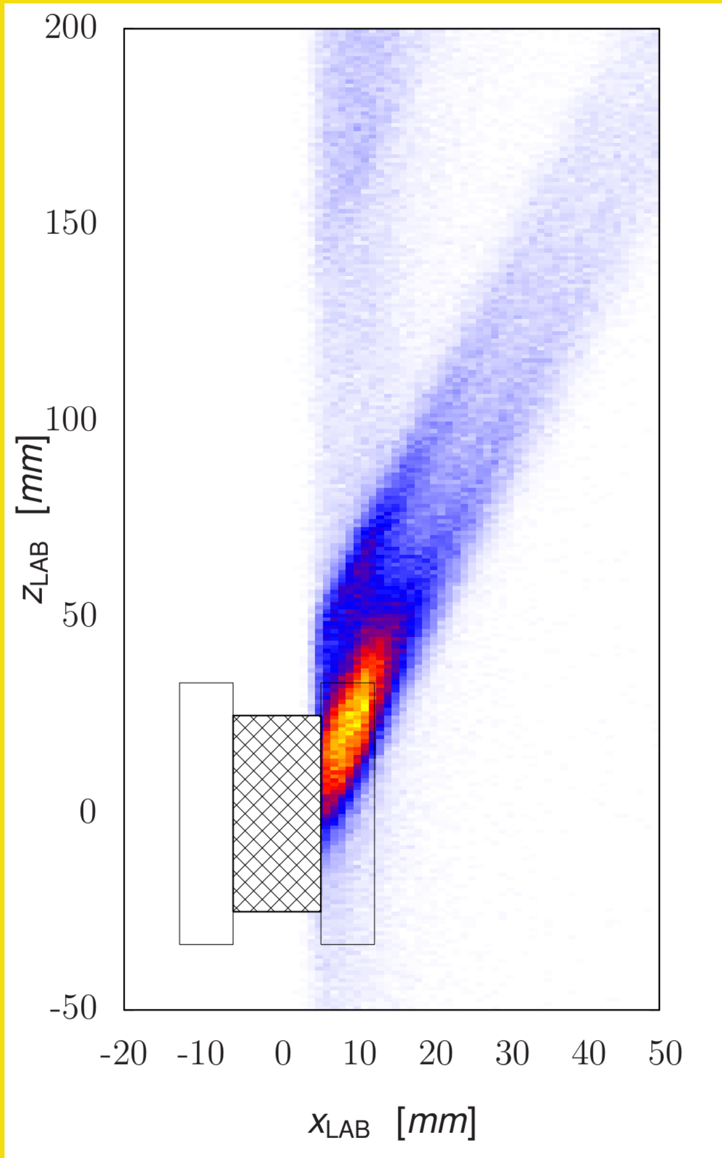




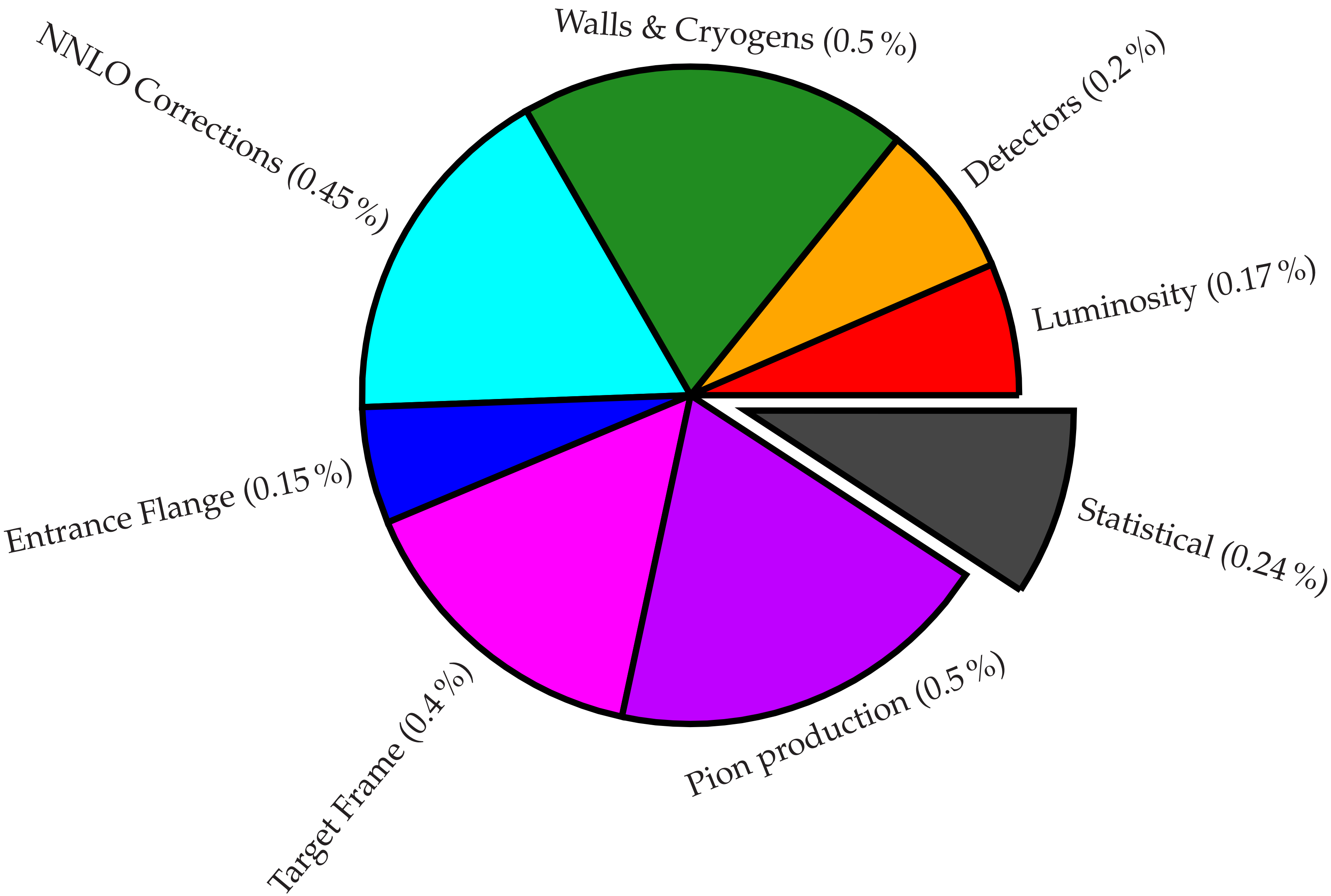
Target Frame contributions #2

- … and in the abundance of bogus events in radiative tail of the elastic peak.



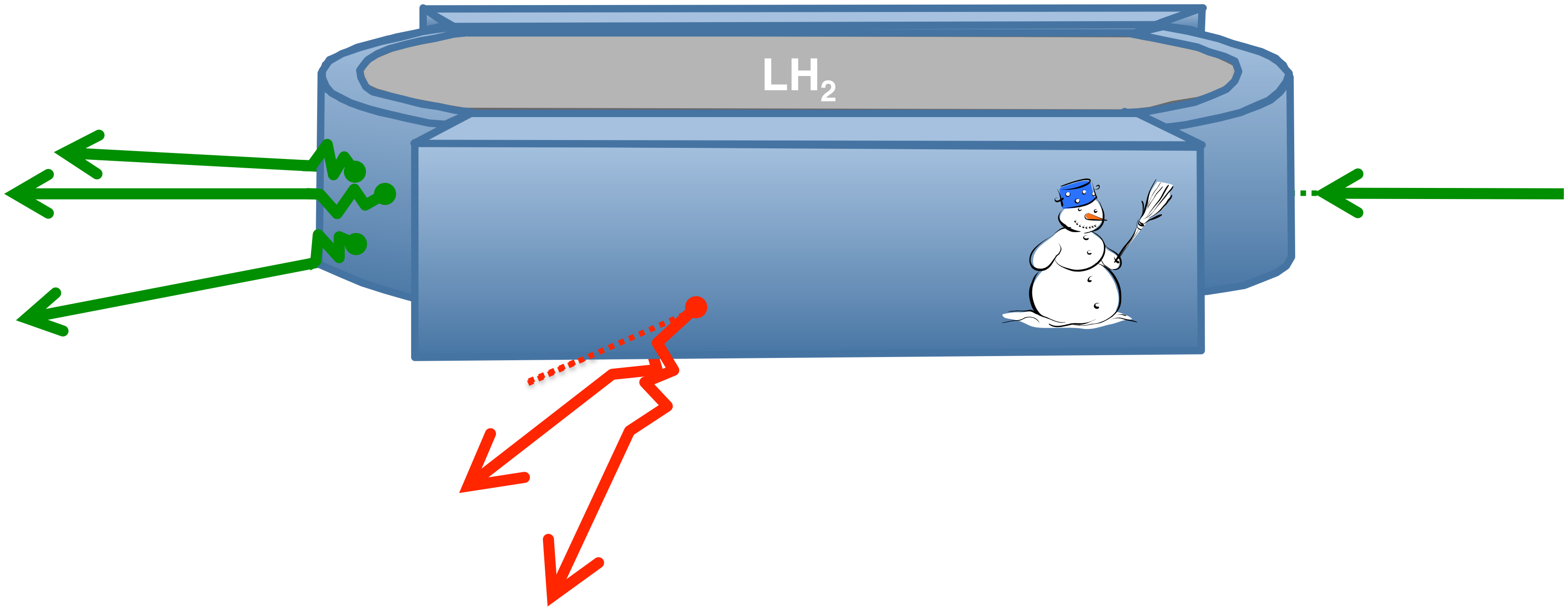


Uncertainties



Total systematic uncertainty of cross-section $\leq$ 1.0 %

Shortcomings of Cryogenic target

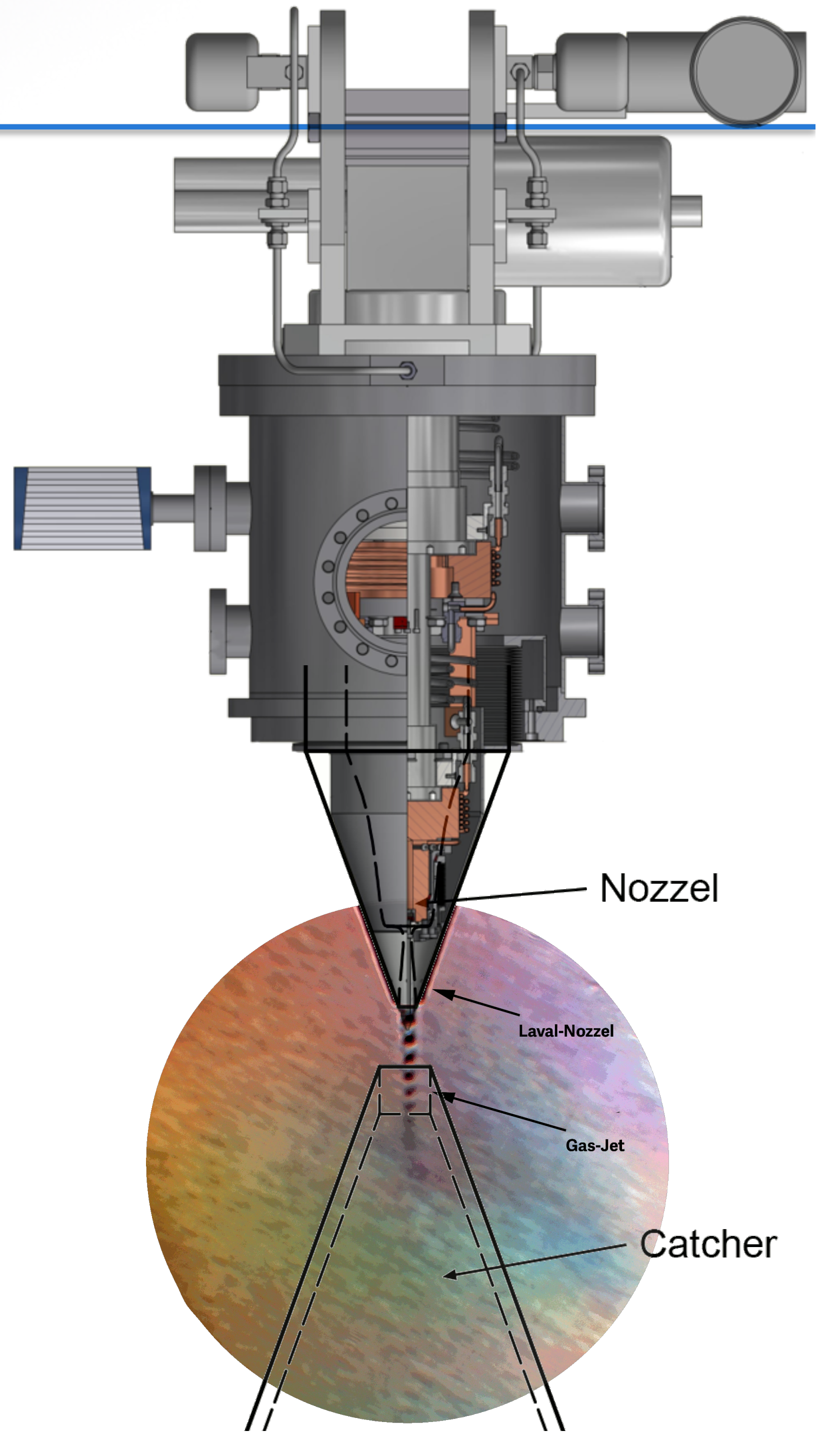


- Employed an extended cryogenic target.
- Backgrounds from target walls and supporting frame.
- Spectra distorted due to cryogenic depositions on the walls.
- Cryogenic layer on the sides much thicker than in the beam direction. Huge effect on the elastic data! **<u>No control over the thickness of the layer.</u>**

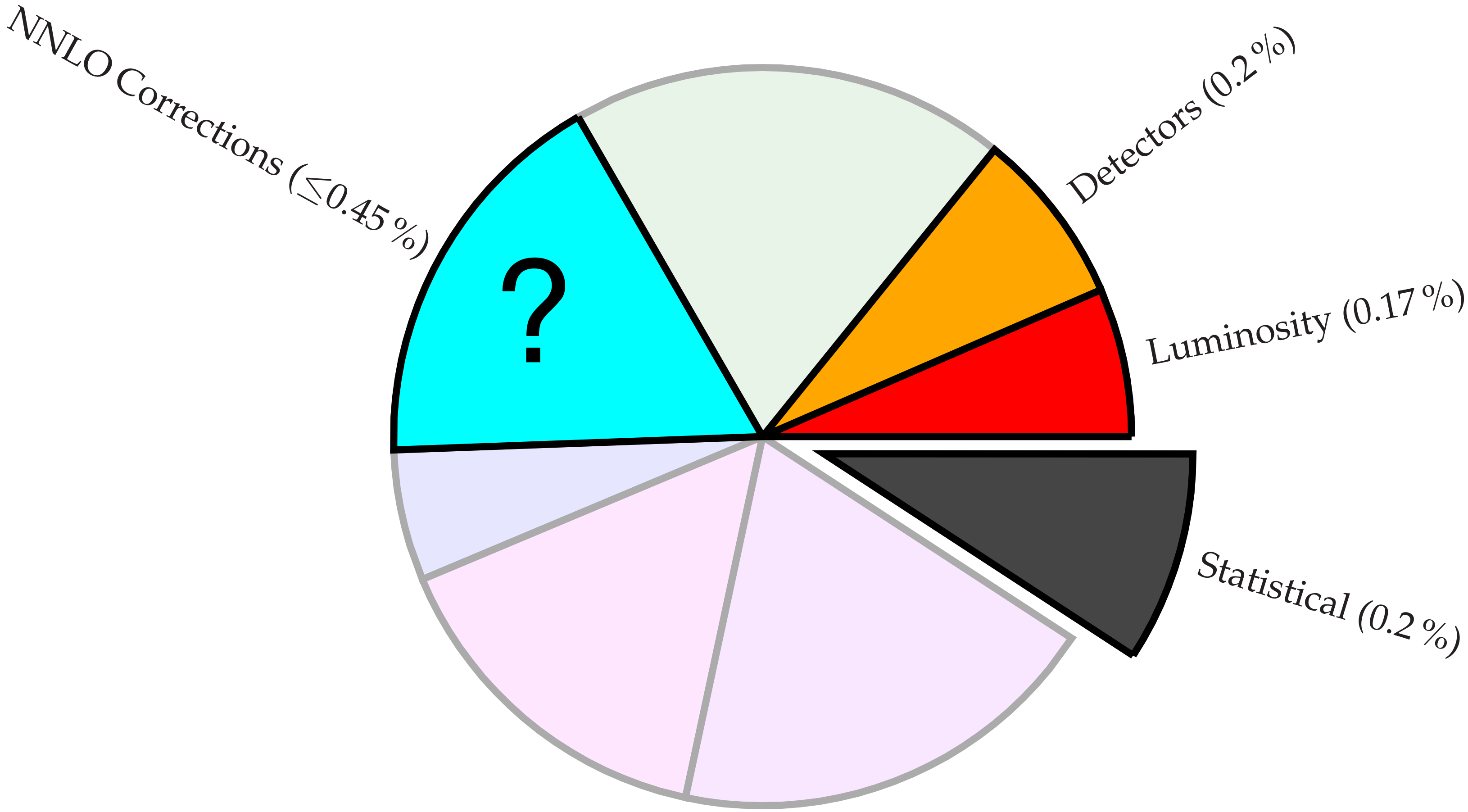
Hypersonic jet target

- Target developed for MAGIX, but could be used also in A1.

- No metal frame near the vertex.
- No target walls.
- Width of the jet 2mm (point-like target)



Expected uncertainties with JetISR



Total systematic uncertainty of cross-section $\leq$ 0.5 %

- Uncertainty of NNLO theoretical corrections will be reduced to 0.2% and total uncertainty to 0.3%.