Measurements of the η'-meson radiative decay width with the GlueX setup

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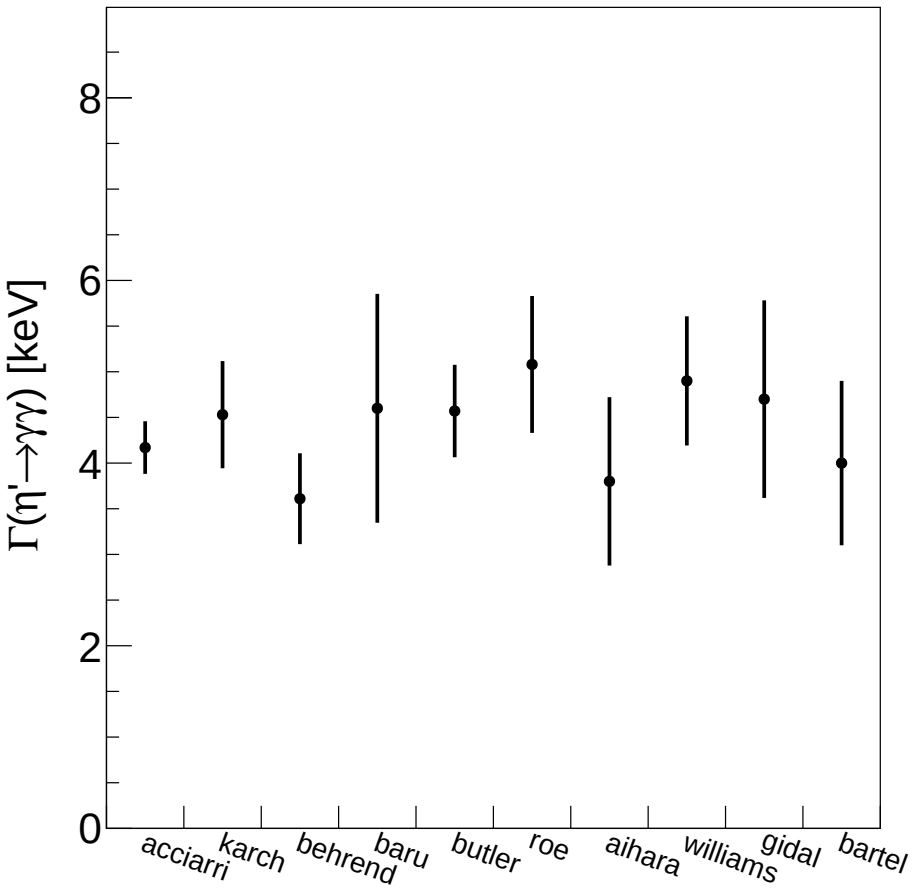
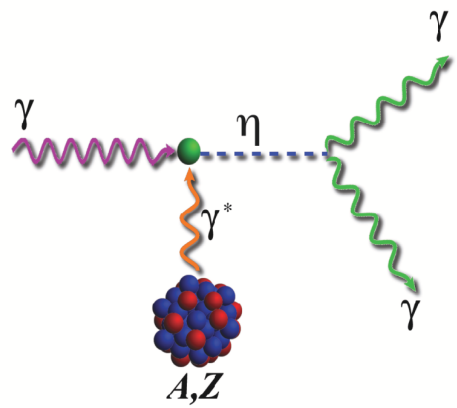
Introduction

$\eta'(958)$ partial widths in PDG are coming from collider measurements

- PDG average, 4.28±0.19 keV
- Best measurements has a 6.9% precision (and collected 2000 events)



- A precision measurements can be done with the upgraded GlueX setup in HallD
- Proof of conceipt and possibly first measurements with the SRC and CT data set



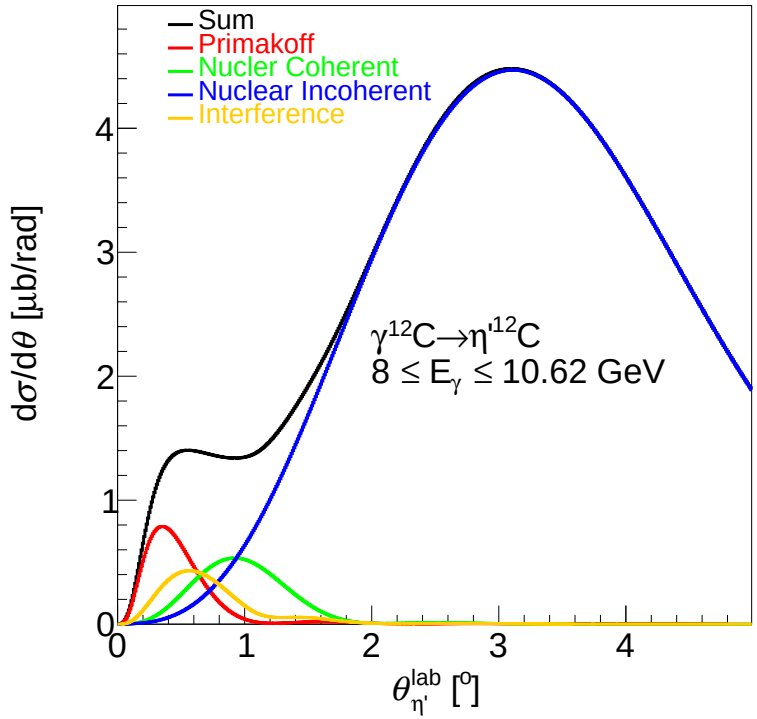
First attempt to measure the partial decay width via the Primakoff process

$\gamma^{12}C \rightarrow \eta'^{12}C$

Calculation of the differential cross-section by Alexander Fix (Tomsk Polytechnic University):

- $\frac{d\sigma_T}{d\theta} = \frac{d\sigma_P}{d\theta} + \frac{d\sigma_{NC}}{d\theta} + 2\sqrt{\frac{d\sigma_P}{d\theta}\frac{d\sigma_{NC}}{d\theta}}cos(\phi) + \frac{d\sigma_{NI}}{d\theta}$
- Primakoff contribution is directly proportional to $\Gamma_{\eta' \rightarrow \gamma\gamma}$

  $\frac{d\sigma_P}{d\theta} = \boxed{\Gamma_{\eta' \rightarrow \gamma\gamma}} \frac{8\alpha Z^2}{m_\eta^3} \frac{\beta^3 E^4}{Q^4} |F_{e.m.}(Q)|^2 \sin^2(\theta)$
- Expected cross-section for 2021-11 electron beam energy:
  - $\Gamma_{\eta' \rightarrow \gamma\gamma} = 4.33716$ keV
  - $\phi = 57.5^o$



Focus on 3 decays:

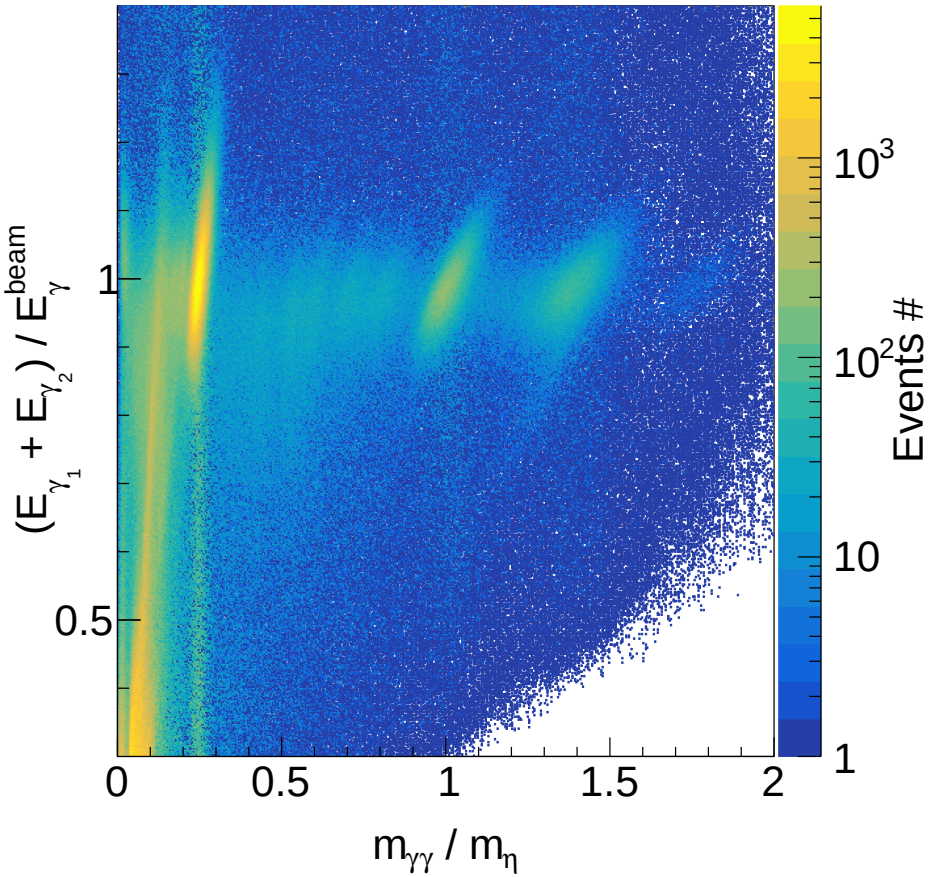
- $\eta' \rightarrow \gamma\gamma$, BR $= 2.22\%$
- $\eta' \rightarrow \eta\pi^0\pi^0$ and $\eta \rightarrow \gamma\gamma$, BR $= 8.34\%$
- $\eta' \rightarrow \eta\pi^-\pi^+$ and $\eta \rightarrow \gamma\gamma$, BR $= 17\%$

Expecting few 100s events for $\mathcal{L} = 6.14$ pb^{-1}

Selection criteria, $\eta' \to \gamma\gamma$

Two clusters in Forward Calorimeter (but 3 inner squares excluded):

- Barrel Calorimeter used to veto hadronic backgrounds
- Time-Of-Flight wall used to veto charged particles
- Elasticity required
- No tracks reconstructed



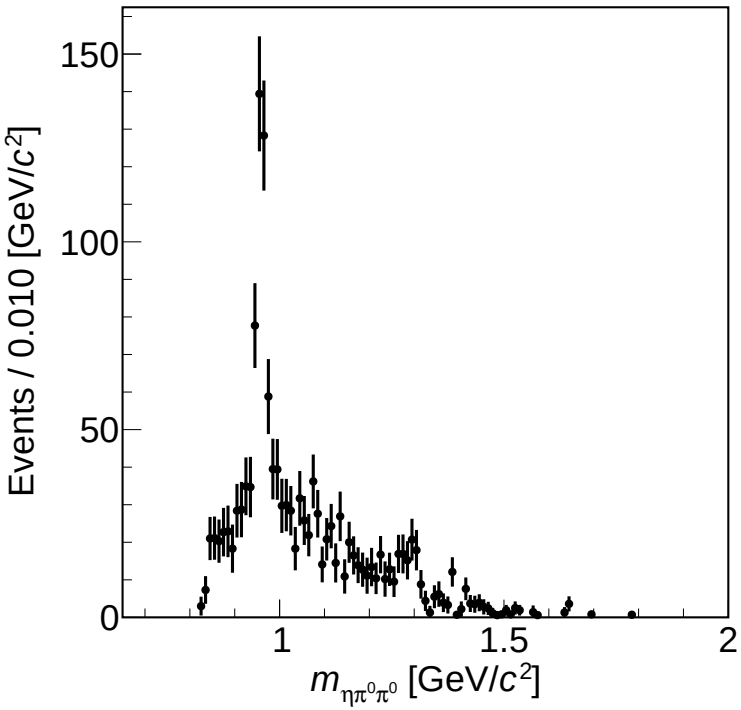
$\gamma_{\text{beam}}\,{}^{12}\text{C} \to \eta^{(\prime)}/\pi^0\,{}^{12}\text{C}$ and $\eta^{(\prime)}/\pi^0 \to \gamma_1\gamma_2$
In Primakoff process, most of the energy is transfered to η-meson
$=> \text{E}_\gamma^{\text{beam}} - \text{E}_{\gamma_1}^{\text{cluster}} - \text{E}_{\gamma_2}^{\text{cluster}} \sim 0$ (elasticity)

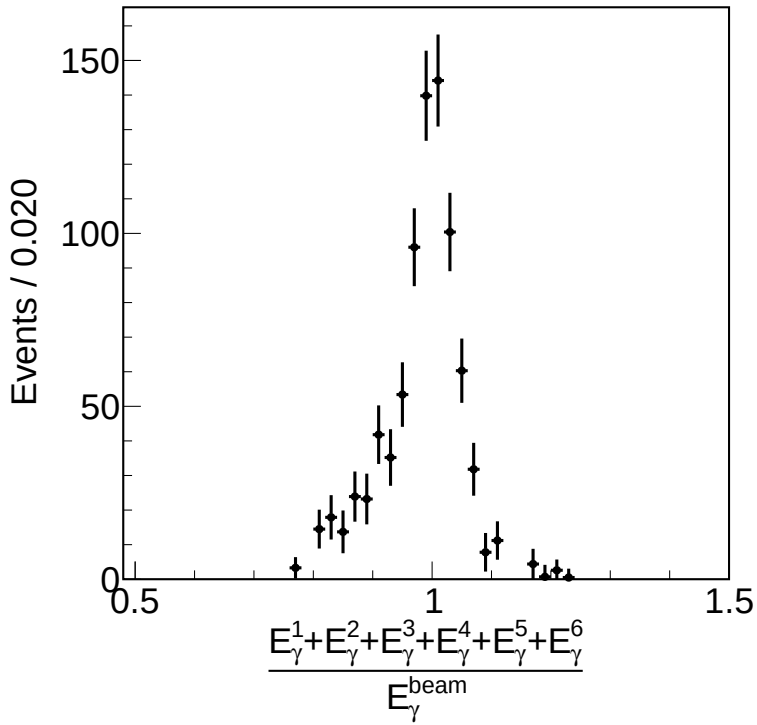
Clear signal but includes Primakoff and (in)coherent events, and large backgrounds

Selection criteria, $\eta' \to \eta\pi^0\pi^0$ and $\eta \to \gamma\gamma$

Six clusters in Forward Calorimeter (but 3 inner squares excluded):

- Barrel Calorimeter used to veto hadronic backgrounds
- Time-Of-Flight wall used to veto charged particles
- Elasticity required
- No tracks reconstructed
- Select via a χ^2-test, the best combination passing all mass cuts

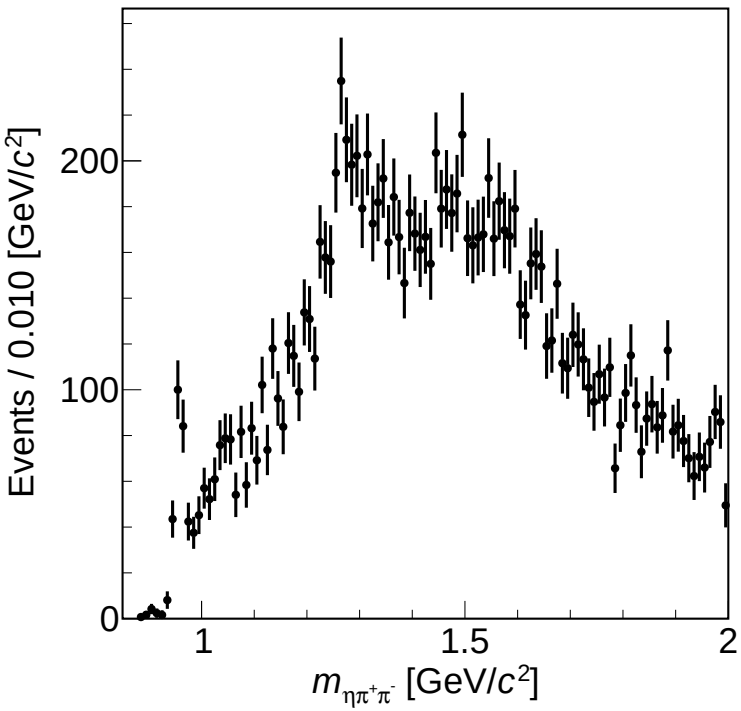


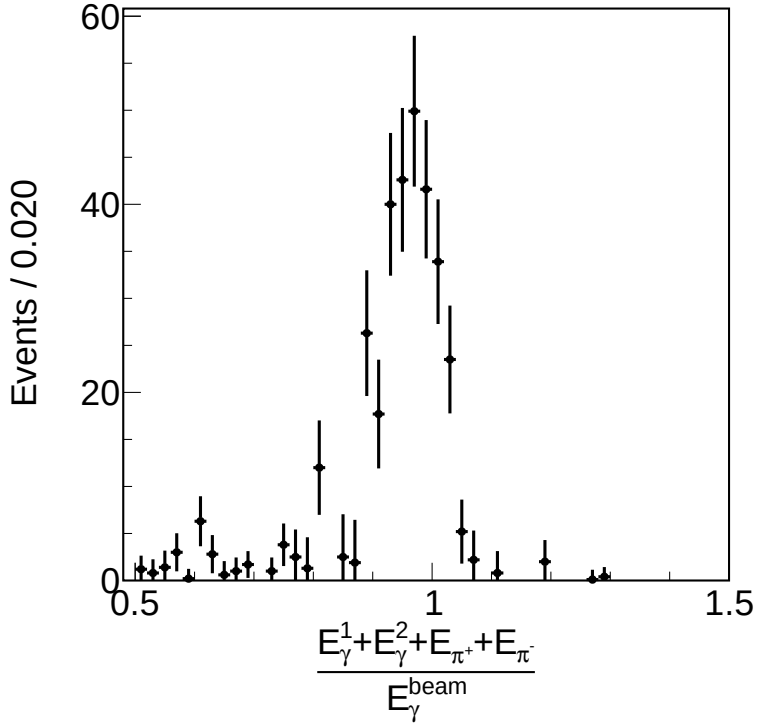


Clear signal but includes Primakoff and (in)coherent events, and small backgrounds

Selection criteria, $\eta' \to \eta\pi^+\pi^-$ and $\eta \to \gamma\gamma$

- Two neutral clusters in Forward Calorimeter (but 3 inner squares excluded):
- Two tracks of opposite charge
- Elasticity required
- 3 inner squares excluded

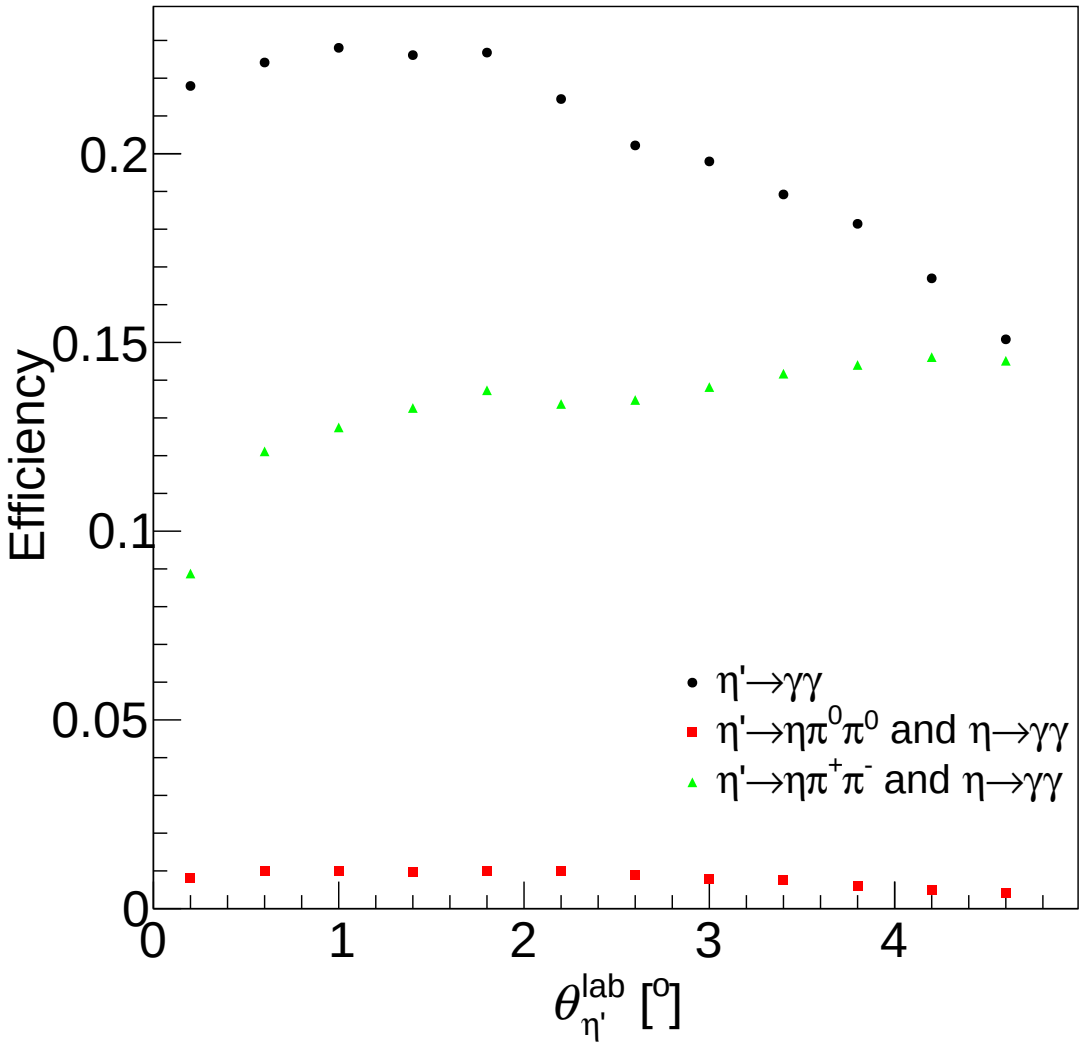




Clear signal but includes Primakoff and (in)coherent events, and small backgrounds

Detection efficiencies

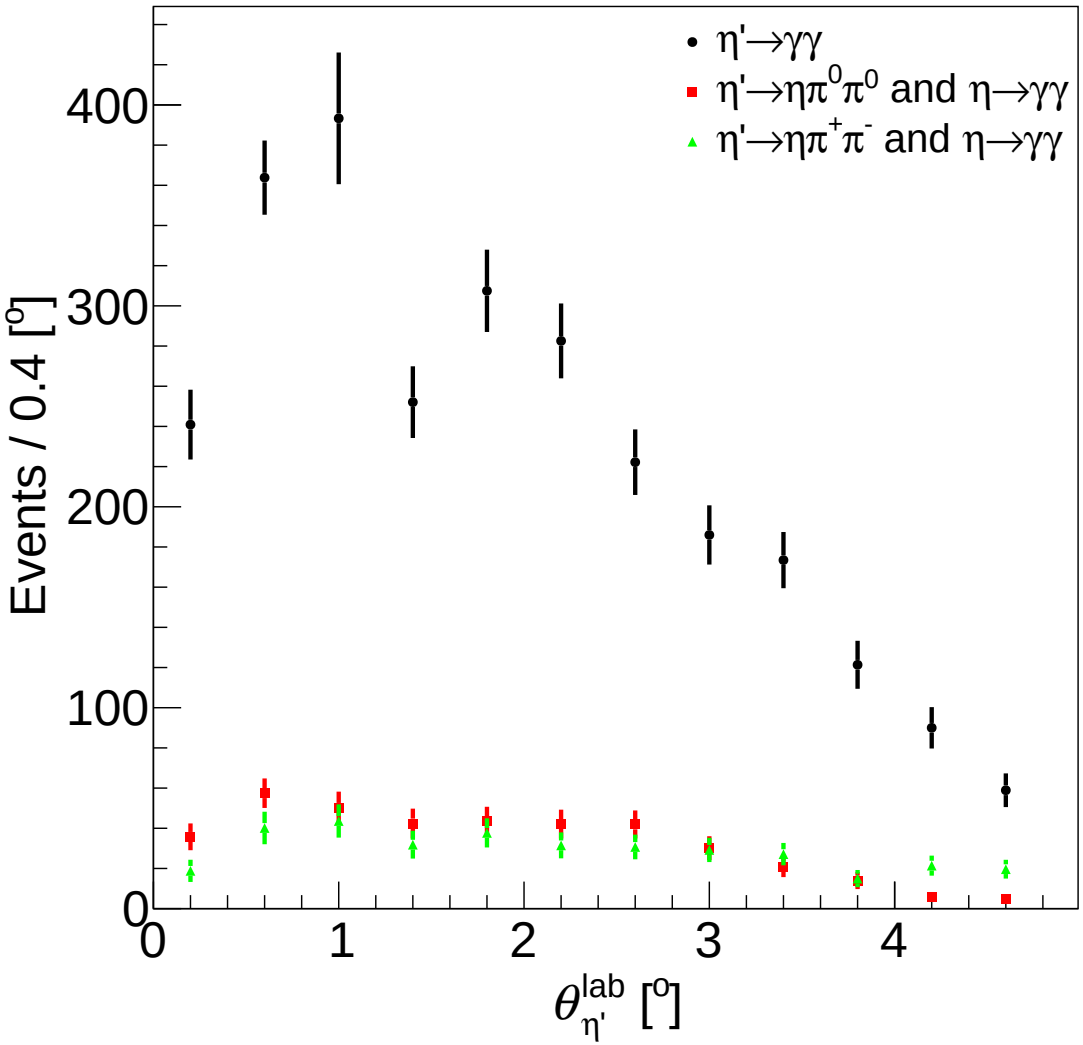
Selection criteria not yet optimized



Software trigger not properly used for tracks

Yields

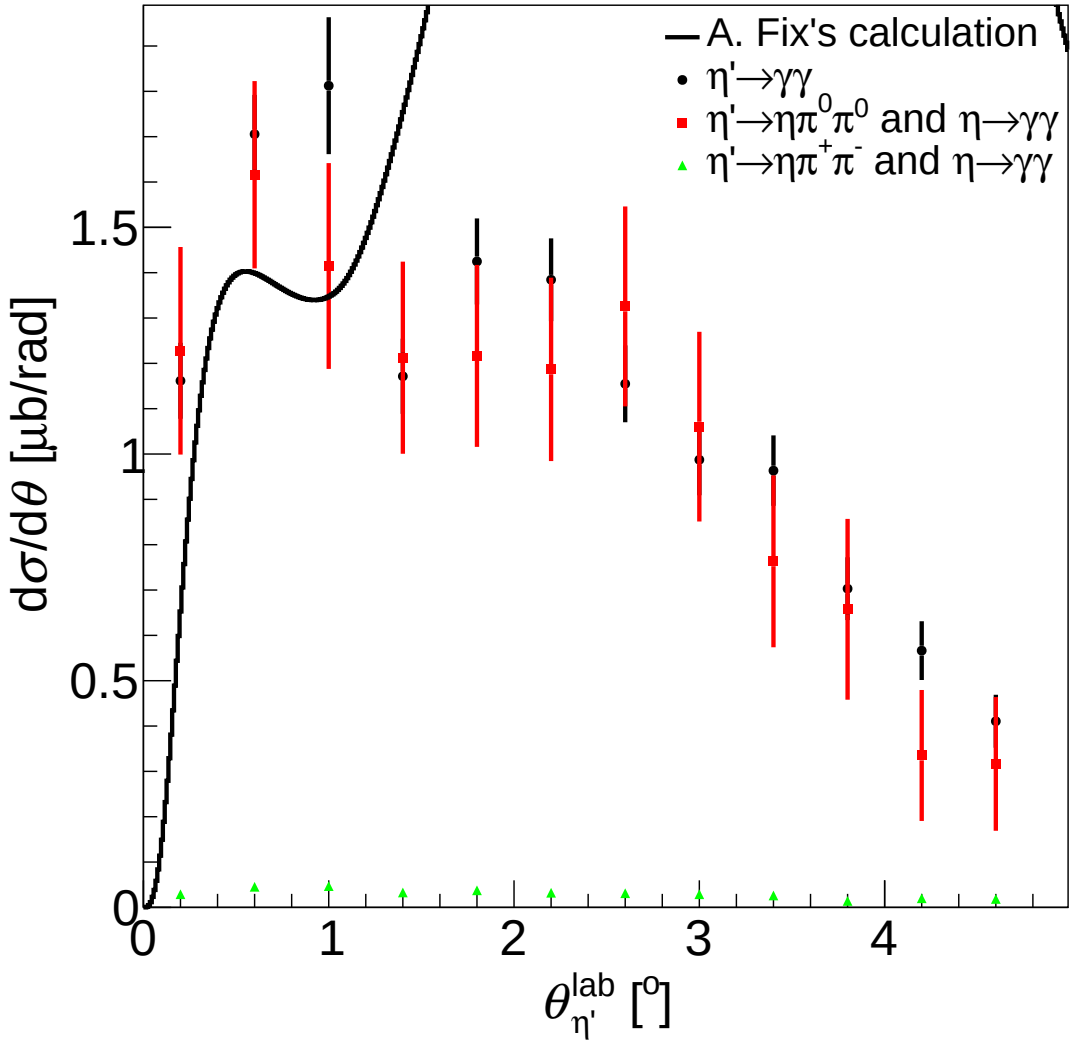
Crude fit used to extract yields



Yields can be improved by a factor 3-4 with an optimal selection criteria

Differential cross-sections

For all three decays



- Fair agreement for the neutral decays
- Expect statistical error on Γ to be between 15 and 25%

Conclusion

Very preliminary differential cross-sections extracted

- Fair agreements between neutral decays with a selection criteria not optimized
- Issues with charge decay is not yet understood
- Statistical error on Γ expected to be between 15 to 25% with optimal selection criteria
- New skims will be produced in the coming days

A new measurements with a statiscal error of 4% and systematic error of 3% appears possible in HallD with

- $\mathrm{E}_{\mathrm{e}^-}^{\mathrm{beam}} = 12$ GeV improves FOM by $\sim 20\%$ wrt 2021-11
- FCAL2 acceptance/trigger and resolution improves FOM by ??% wrt 2021-11
- $\sim$?? PAC days with a carbon target