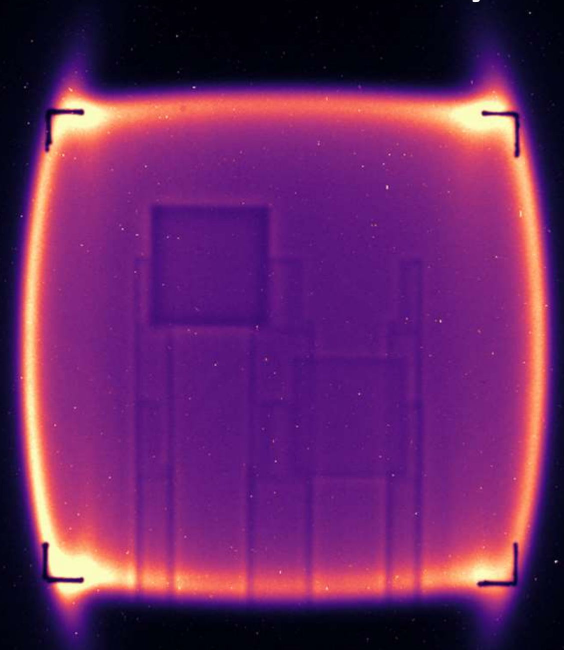
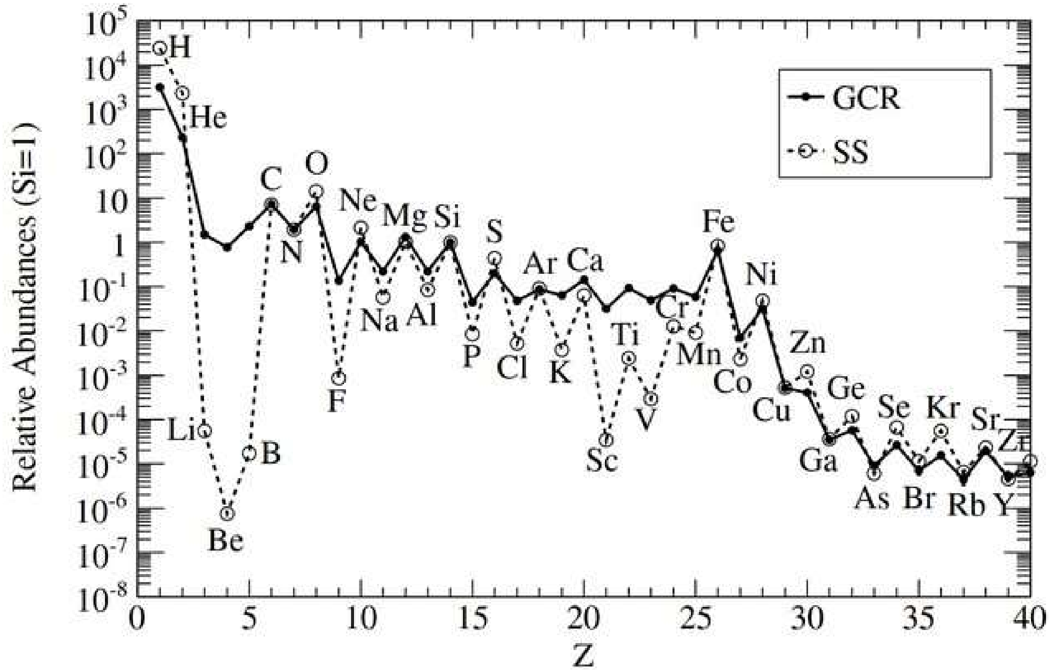
# A few cross-section experiments towards a clearer view of our Galaxy

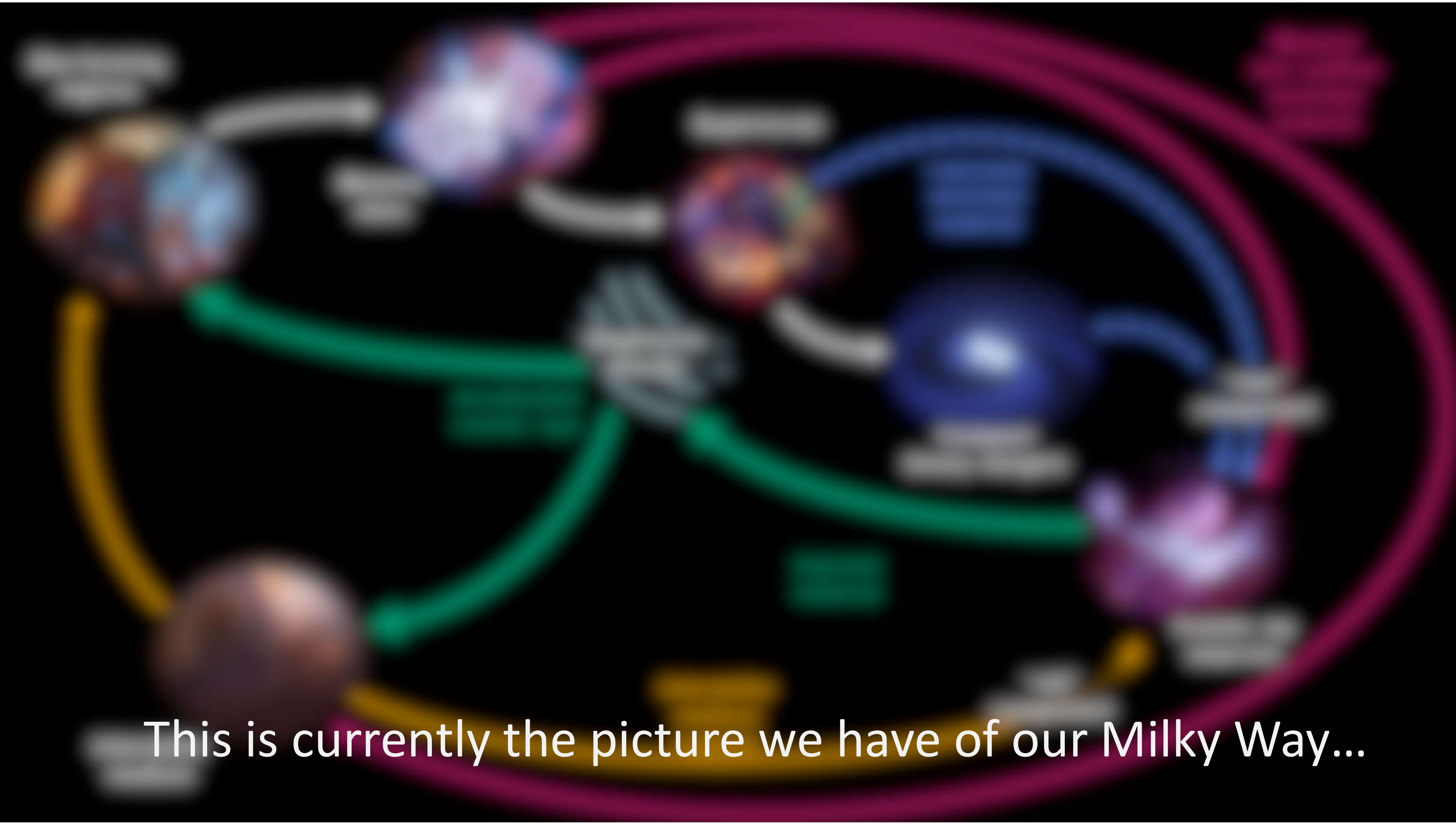


Priyarshini Ghosh, NASA Goddard Space Flight Center
Igor Moskalenko, Stanford
John Krizmanic, NASA Goddard
Patrick Peplowski, Johns Hopkins
Mauricio Unzueta, Berkeley Lab

# Advances in our knowledge of the Galaxy

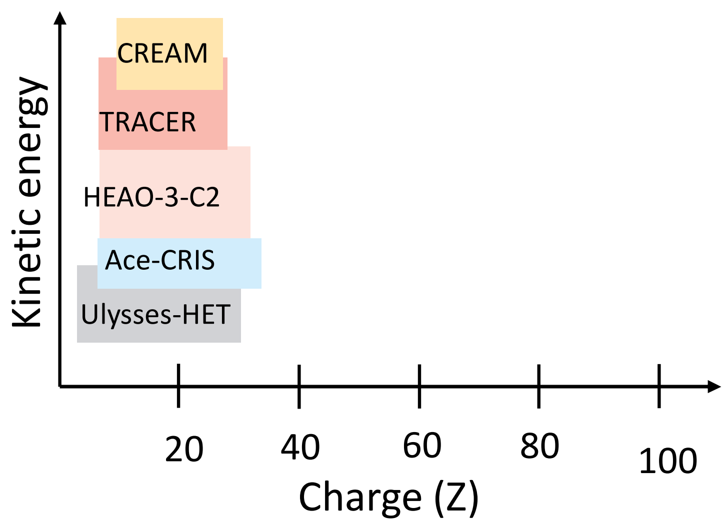



Ref: Rauch 2009, Murphy 2016,
Lodders 2003, Sanuki 2000,
Aguilar 2011



This is currently the picture we have of our Milky Way…

# How will TIGERISS help further our knowledge?




TIGERISS will address scarcity of UHGCR data:

- Combining Silicon Strip Detectors and Cerenkov detectors
- Single-element resolution
- Uncertainty: 0.2 charge units
- Wide range: B to Pb
- No Normalization Required
- No atmosphere corrections-lesser systematic uncertainty

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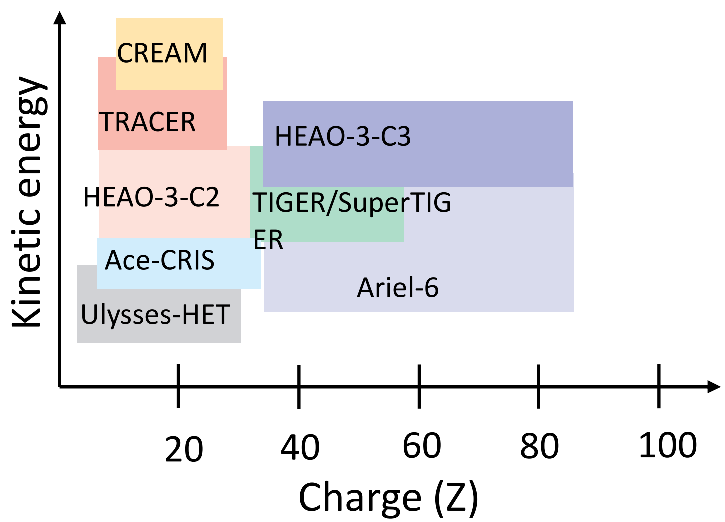


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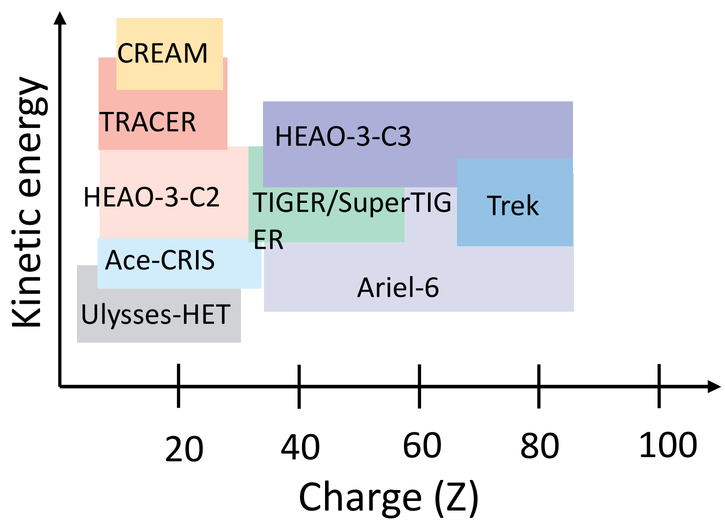


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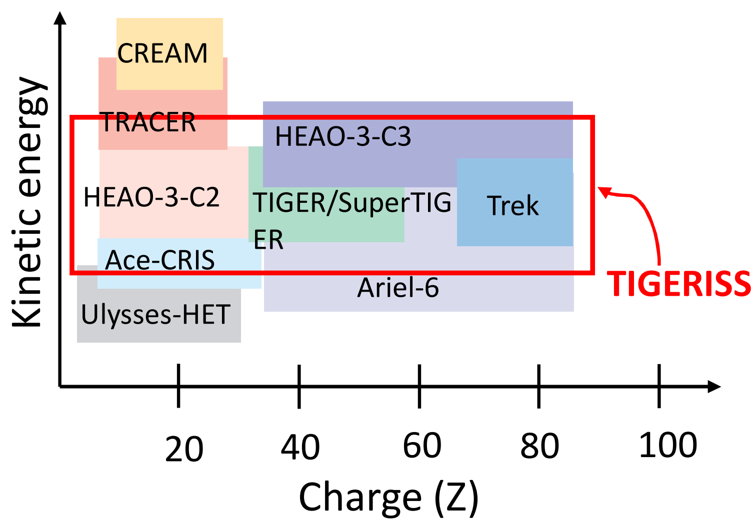


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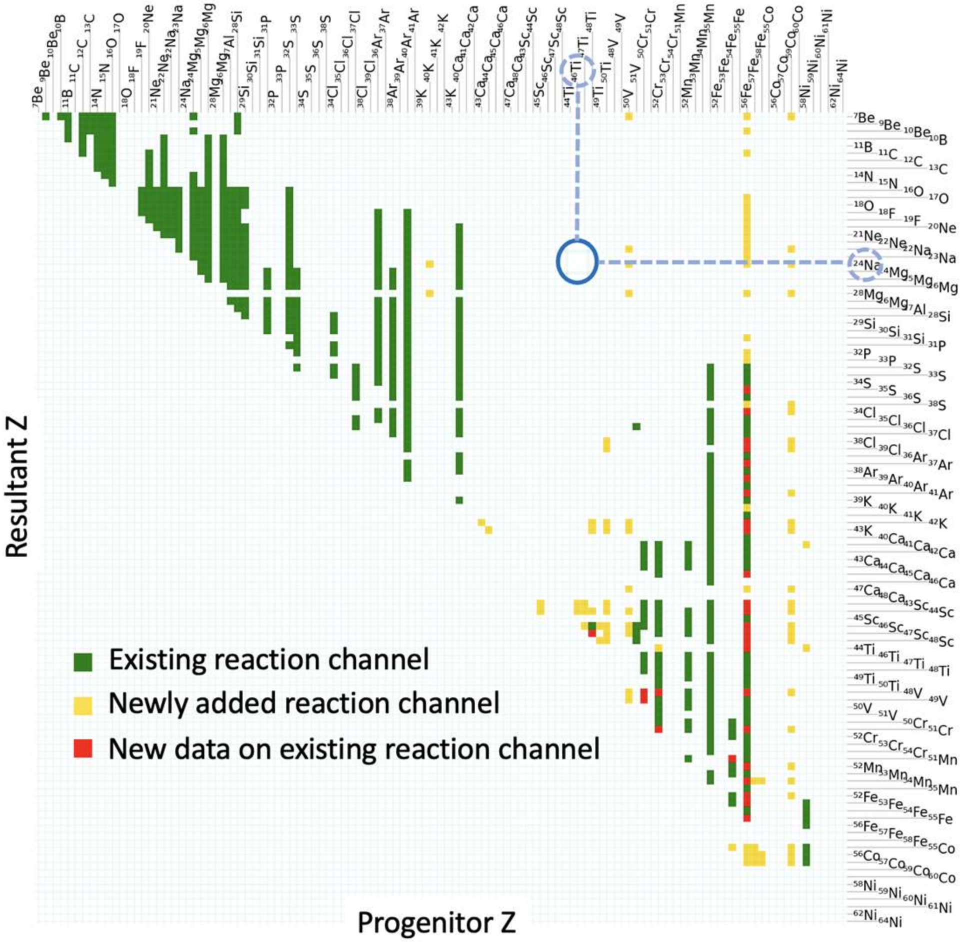
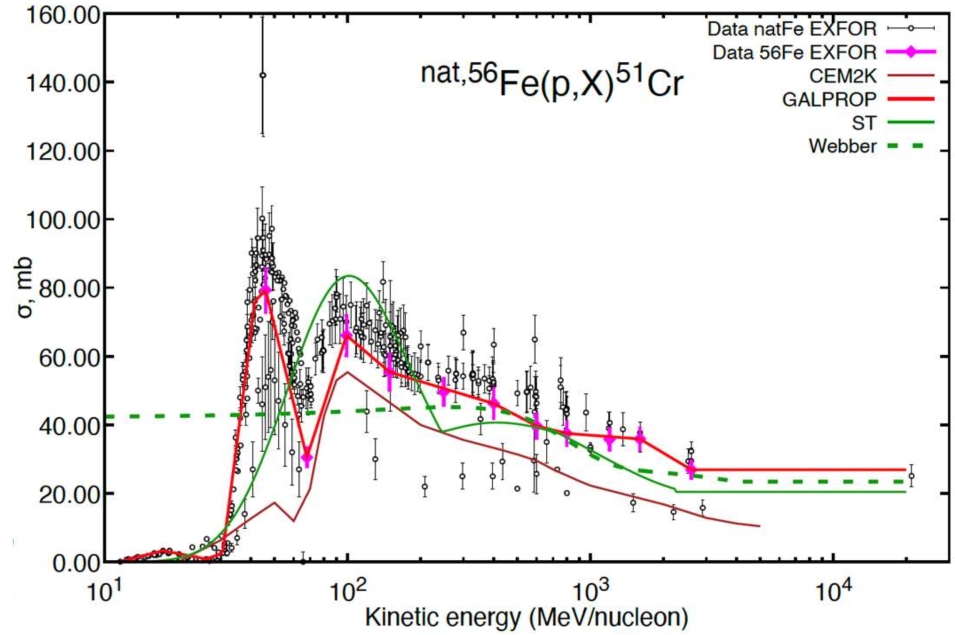
# GALPROP cross-sec library:




*Available data for $^{nat}Fe(p,X)^{51}Cr$ shows the need for isotopic measurements:*

1) *scatter of data (black circles) by different groups is large*
2) *data for $^{56}Fe$ isotope (magenta diamonds) differ from $^{nat}Fe$ data*
3) *Webber (green dashes) and Silberberg-Tsao (green line) systematics and the CEM2K code do not reproduce the data*

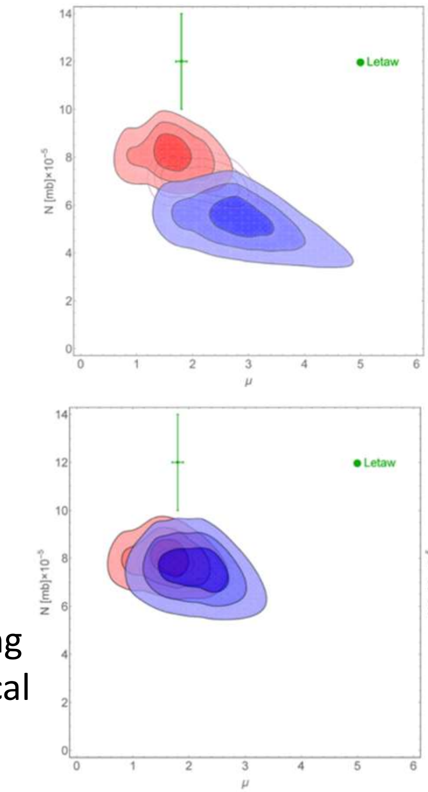
# TIGERISS measurements needed

| Target | Astrophysically-important reactions and their current needs |
|---|---|
| ${}^{nat}Ba$ | ${}^{nat}Ba(p,X)$ charge- and mass-changing cross section data available for very low energies only (<70 MeV), higher energies required [6] |
| ${}^{nat}Sn$ | ${}^{124}Sn(p,n){}^{124}Sb$ data available for very low energies only (<18 MeV) [7] |
| ${}^{nat}Os$, ${}^{nat}Pt$ | No data |
| ${}^{nat}Pb$ | [8] is the only known source that reports mass-changing cross sections, but only at one energy point (1A GeV) of ${}^{208}Pb$. More data are required. |
| ${}^{nat}Ca$ | ${}^{40}Ca \rightarrow {}^{37}Ar$ (decays to ${}^{37}Cl$): Low energy data <50 MeV/n and 6 contradicting data points in the range 100-800 MeV/n. The data points differ by factors of 2-5. The ratio ${}^{36}Cl/{}^{37}Cl$ is used as radioactive clock for medium-mass CR nuclei. ${}^{40}Ca \rightarrow {}^{36}Cl$: just 3 data points, while cross section is large (30-180 mb). ${}^{40}Ca \rightarrow {}^{39}Ca$ (decays to ${}^{39}K$): just 3 points. |
| ${}^{nat}Ni$ | ${}^{nat}Ni(p,X)$ data important to Psyche as well |
| ${}^{52}Cr$ | Major contributor to ${}^{51}Cr$, which decays to ${}^{51}V$. ${}^{52}Cr$ also contributes to radioactive isotopes of Sc, which decay to ${}^{46}Ti$, ${}^{47}Ti$, ${}^{48}Ti$, and to ${}^{45}Sc$ (stable). Sc, Ti, V are mostly secondary and the ratios Sc/Fe, V/Fe are of the fundamental importance for understanding of propagation of heavy GCRs. |
| ${}^{124}Xe$ | Current data are all <50 MeV/n, higher energies needed |
| ${}^{28}Si$ | Current data exists mostly for ${}^{nat}Si$. From ${}^{28}Si$ beam, we can get cross sections for isotopes of Li, Be, B, C, N, O, Ne, Na, Mg, Al |
| ${}^{56}Fe$ | Current data exists mostly for ${}^{nat}Fe$. Need cross sections for ${}^{56}Fe$ beam |

} s-process

} r-process

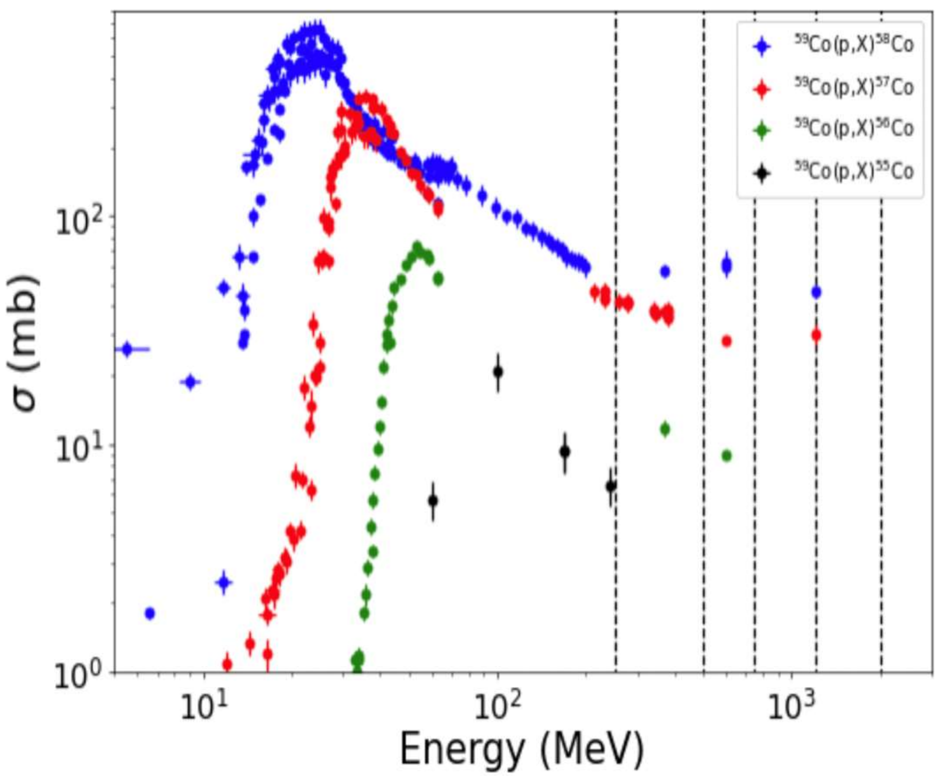
} Constraining astrophysical models, relevant to planetary surface composition

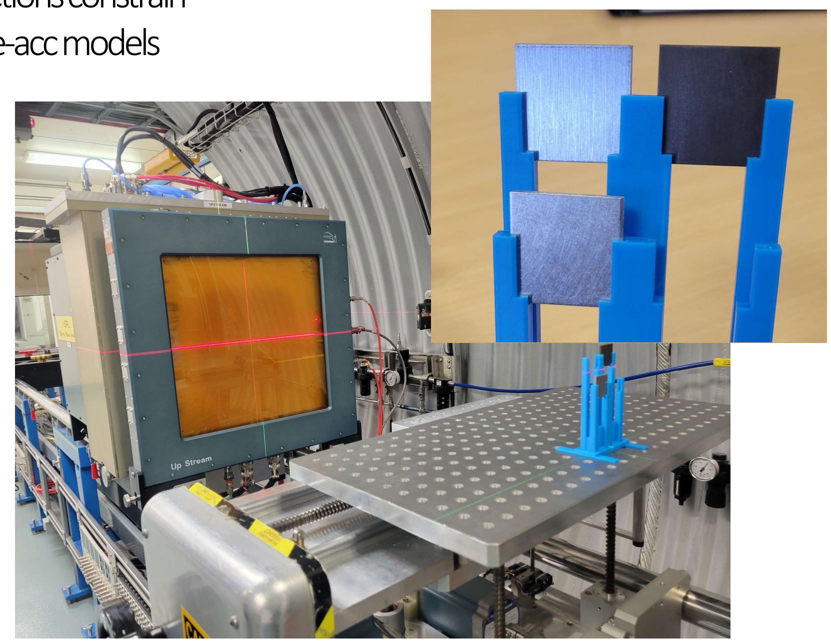



*Contour plots of an $\chi 2$ fit for the disk model (red is ${}^{51}V/{}^{51}Cr$ , blue is ${}^{49}Ti/{}^{49}V$). The green point denotes the electron attachment cross section. The discrepancy between the ${}^{51}V/{}^{51}Cr$ and ${}^{49}Ti/{}^{49}V$ fits (left) is cured by a 15% reduction in ${}^{49}Ti$ production cross section {source: Benyamin 2011, Kelly Lave 2003]*

# Experiment #1: Sub-Fe region isotopes

- Co: constrain astrophysical re-acc models
- Al: Instrument background removal
- Mn: scarce data at high energies
- Cr: Cr (p,x) reactions constrain astrophysical re-acc models

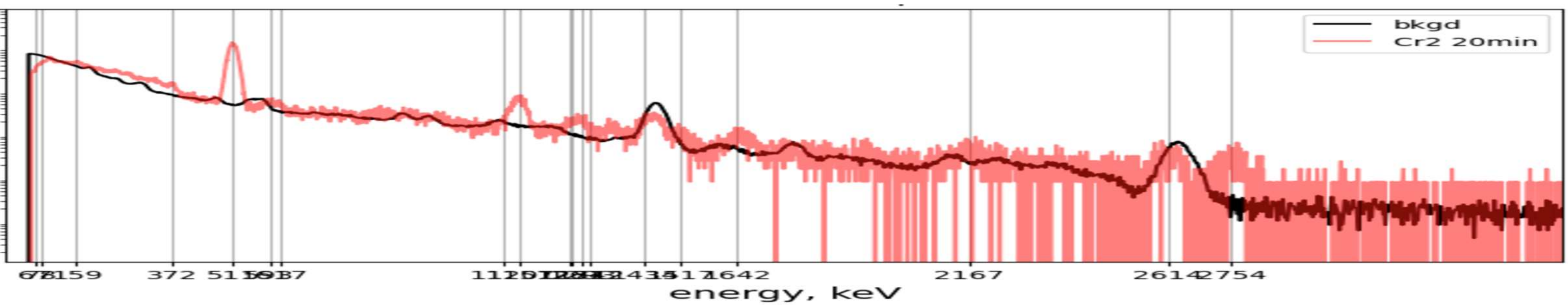


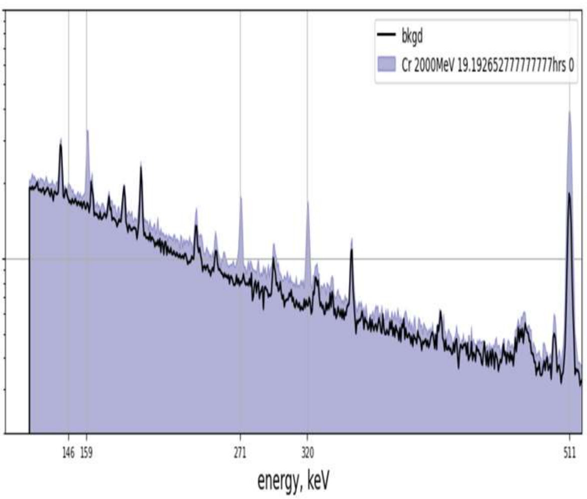



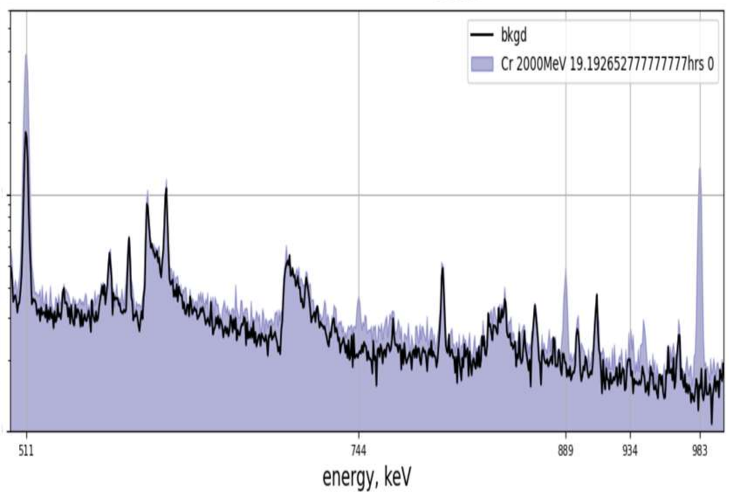
Reducing uncertainties in measurement at NSRL:

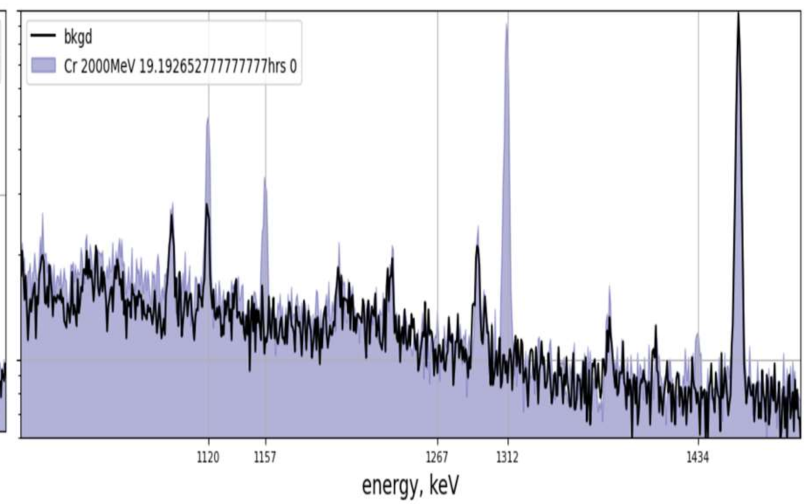
- High proton flux in short time ($10^8$ p/cm$^2$ <30 mins), large beam area: **multiple targets at once**
- Thin targets, high purity: **contributions of secondary products to nuclide production minimal, and thick target corrections will not be required**.
- Measurements over entire energy range on single experimental setup: **removing significant systematic uncertainty typically associated with multiple experiments with differing systematic uncertainties**
- P- beam flux is measured in-situ with precision of 3.6%, **reducing one large systematic uncertainty in activation cross-section**
- Proposed target measurements will use high-precision γ-ray spectrometers whose detection efficiency is calibrated using NIST-tracible sources **having 3% precision or better**
- Using large data sets, **statistical uncertainties will be negligible**
- Target irradiations are planned to provide ample activation, with sufficiently long integration times.
- Because measurements can be repeated, decay curves are measured and **provide validation** of the expected isotopes and accurate background estimates.
- Taken together, we expect to provide **total uncertainties of 7-10%,** as demonstrated by measurements of $^{nat}Cu(p,X)$ reaction cross sections

# Source of uncertainty to be reduced:



# Experiment #2: NA61

| Run A: Li-O | | Run B: Na-Si | |
|---|---|---|---|
| reaction | $N_{int}$ | reaction | $N_{int}$ |
| $^{16}O+p$ | 60k | $^{28}Si+p$ | 50k |
| $^{12}C+p$ | 50k | $^{24}Mg+p$ | 50k |
| $^{11}B+p$ | 10k | $^{20}Ne+p$ | 50k |
| $^{15}N+p$ | 10k | $^{22}Ne+p$ | 20k |
| $^{14}N+p$ | 10k | $^{27}Al+p$ | 10k |
| $^{10}B+p$ | 5k | $^{26}Mg+p$ | 10k |
| $^{13}C+p$ | 5k | $^{23}Na+p$ | 10k |
| $^{7}Li+p$ | 5k | $^{25}Mg+p$ | 10k |
| | | $^{21}Ne+p$ | 10k |
| | | $^{32}S+p$ | 5k |
| | | $^{29}Si+p$ | 5k |

$\Sigma N_{int} = 3.8 \times 10^5$

Michael Unger's talk from yesterday!

# Experiment #3: $^{52}Cr$

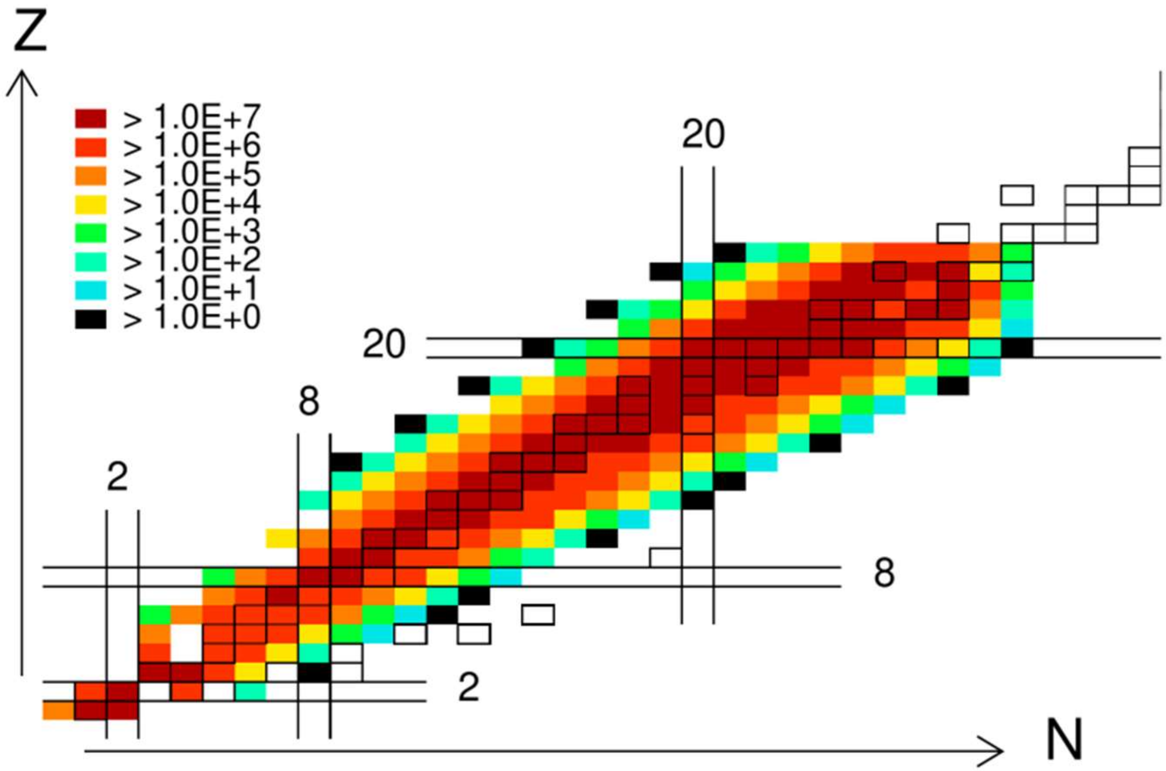
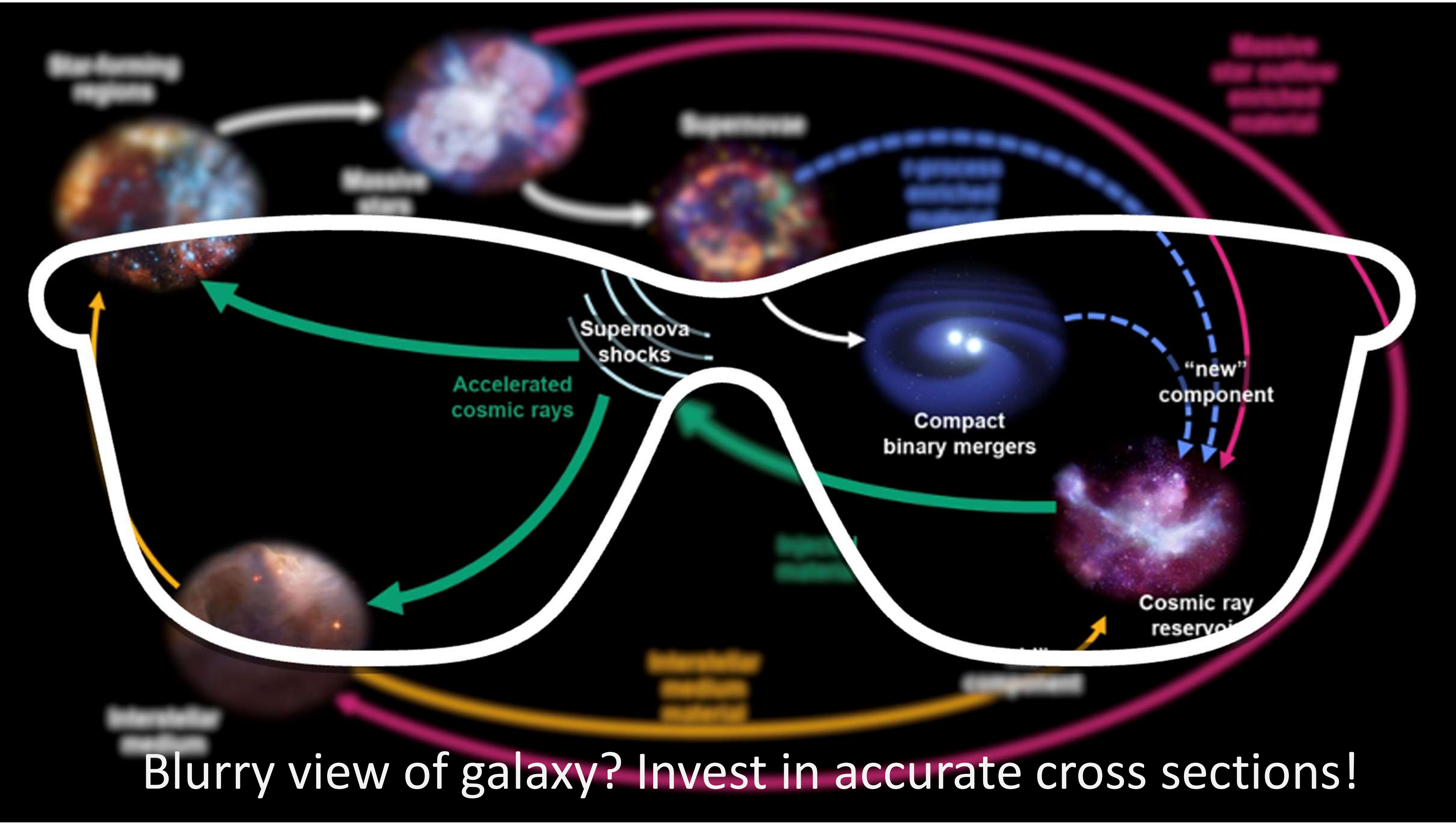



Figure 2: Expected total number of events measured in the proposed experiment




Blurry view of galaxy? Invest in accurate cross sections!