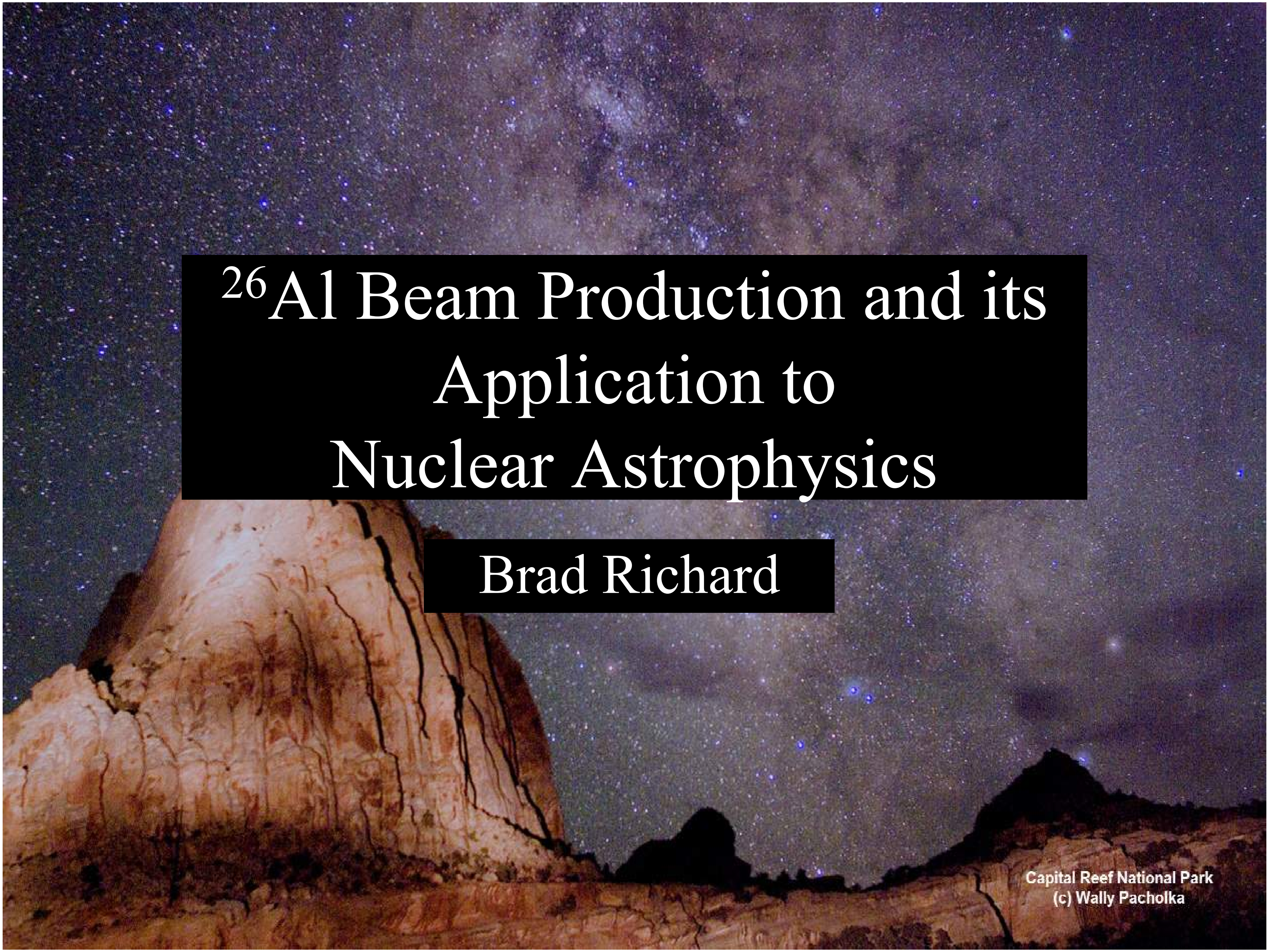
^{26}Al Beam Production and its Application to Nuclear Astrophysics

Brad Richard



^{26}Al

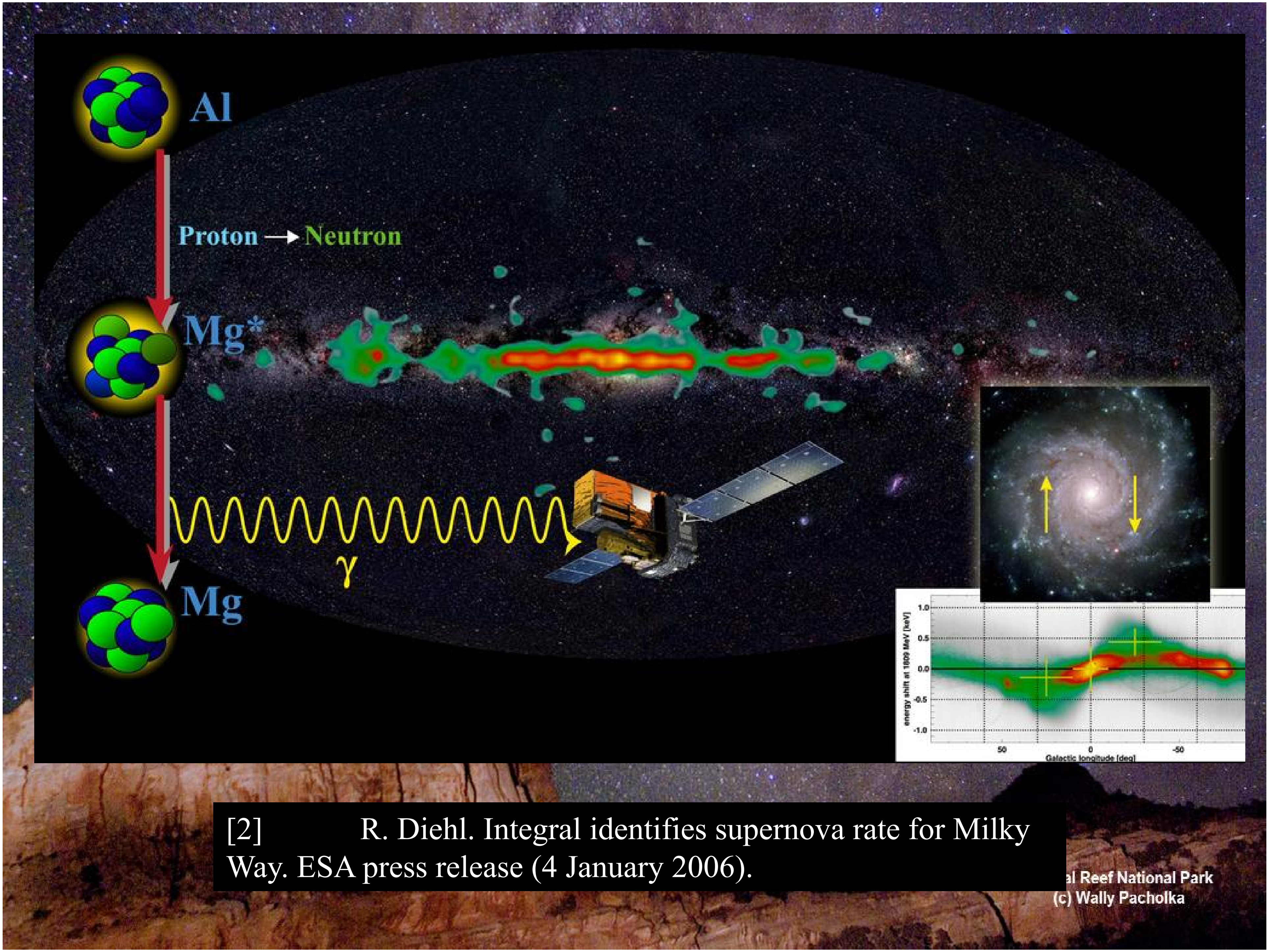
Significance to Nuclear Astrophysics

- Produced during advanced stages of stellar evolution
- Unique 1.8MeV gamma emission during decay to ^{26}Mg
- One facet of the ongoing nucleosynthesis occurring in the Galactic disk

<u>Half-life</u>	<u>Galaxy's Age</u>
~ 7×10^5 yrs	~ 13×10^9 yrs

- Insights into unexplored areas of the galaxy and discovery of phenomena such as gamma ray bursts
  - Developments in satellite telescopes has greatly advanced the ability to study such phenomena. [1]

[1] C. M. Deibel et al., Phys. Rev. C80, 035806 (2009).



[2] R. Diehl. Integral identifies supernova rate for Milky Way. ESA press release (4 January 2006).

Study ^{26}Al?

- Helps understand ongoing nucleosynthesis in the galaxy and the advanced stages of stellar evolution
  - Main source of Galactic ^{26}Al [3]
  - Greater understanding of the nuclear paths involved in the production and destruction of ^{26}Al
- Study $^{26}Al(n, p)^{26}Mg$ reaction

[3] S. E. Woosley and T. A. Weaver, Astrophys. Journal, 238: 1017-1025, (June 1980).

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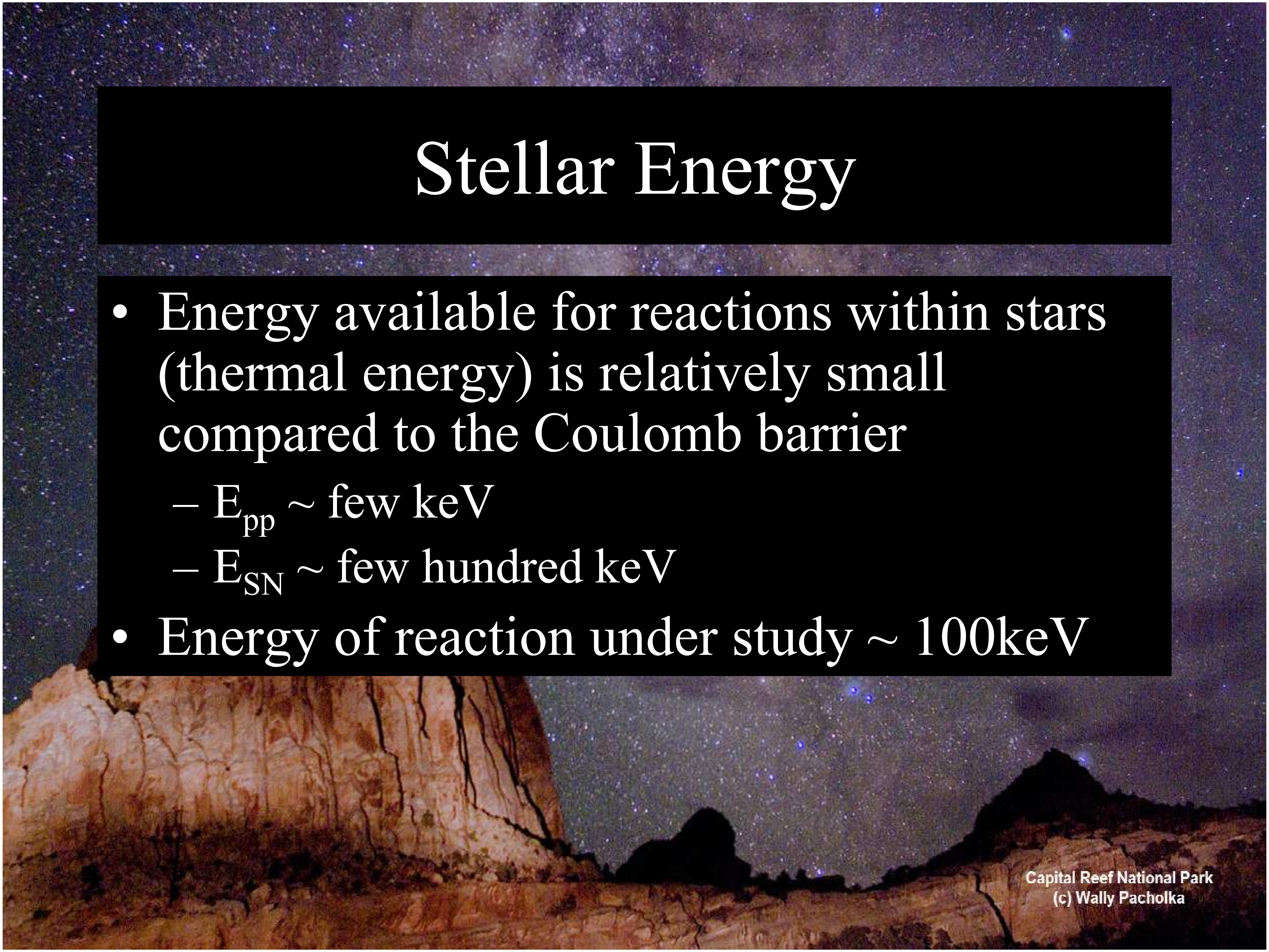
Stellar Energy

- Energy available for reactions within stars (thermal energy) is relatively small compared to the Coulomb barrier
  - E_{pp} ~ few keV
  - E_{SN} ~ few hundred keV
- Energy of reaction under study ~ 100keV

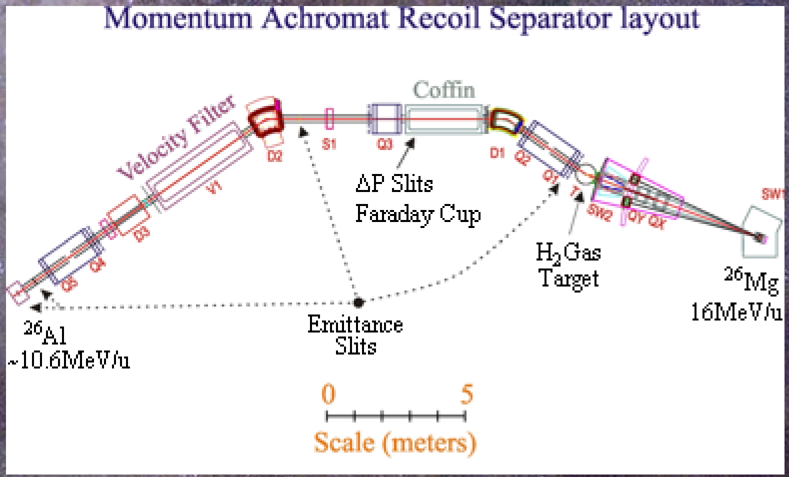


^{26}Al(n, p)^{26}Mg at Astrophysical Energies (E ~ few hundred keV)

- ^{26}Al is a radioactive beam and must be produced in a lab
- Astrophysical energy (Kt ~ 100keV) is very low compared to our reaction energy (lab)
- Neutron interaction (neutron source required)

MARS

- ^{26}Al production – inverse kinematics (heavy ion beam on light target)
- MARS filter out the unwanted products
  - Momentum achromat – magnetic rigidity
  - Recoil separator – q/m



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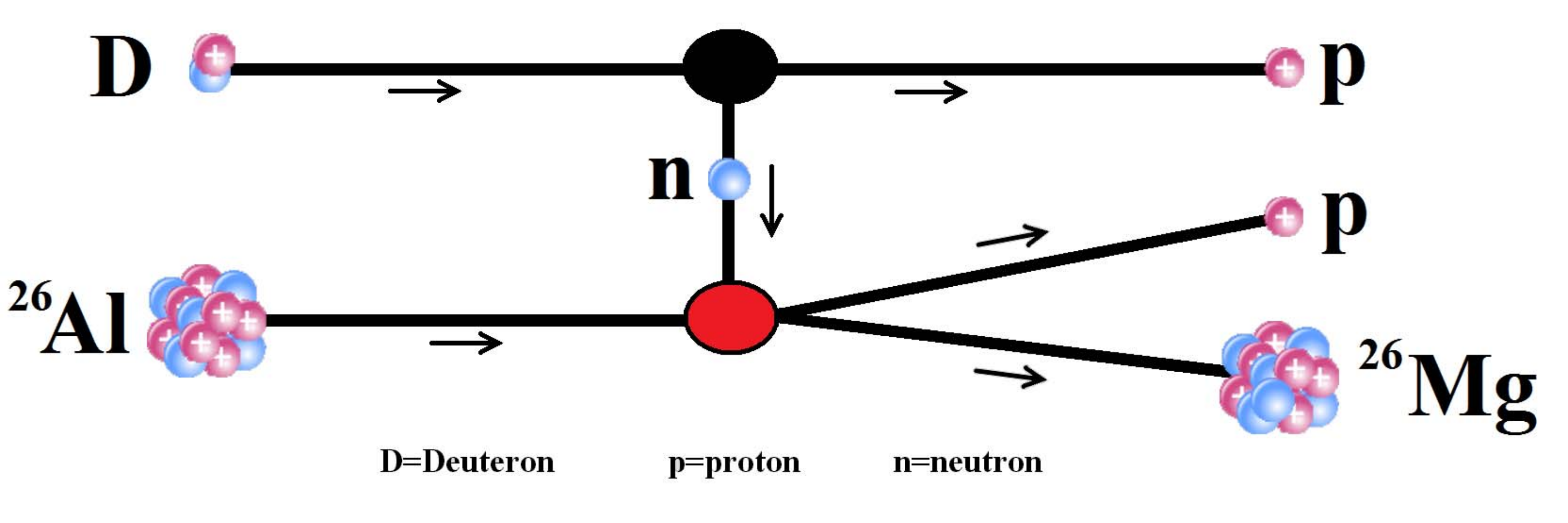


- THM – indirect method
- Must satisfy:

[4] $E_{qf} = E_{Al\text{-}n} - B_{np}$ (Quasi-free reaction)

  - E_{qf} = is the relative energy of the ^{26}Al and the neutron
  - $E_{Al\text{-}n}$ = is the beam energy in the CoM of the two body reaction
  - B_{np} = is the binding energy of the neutron in the deuteron

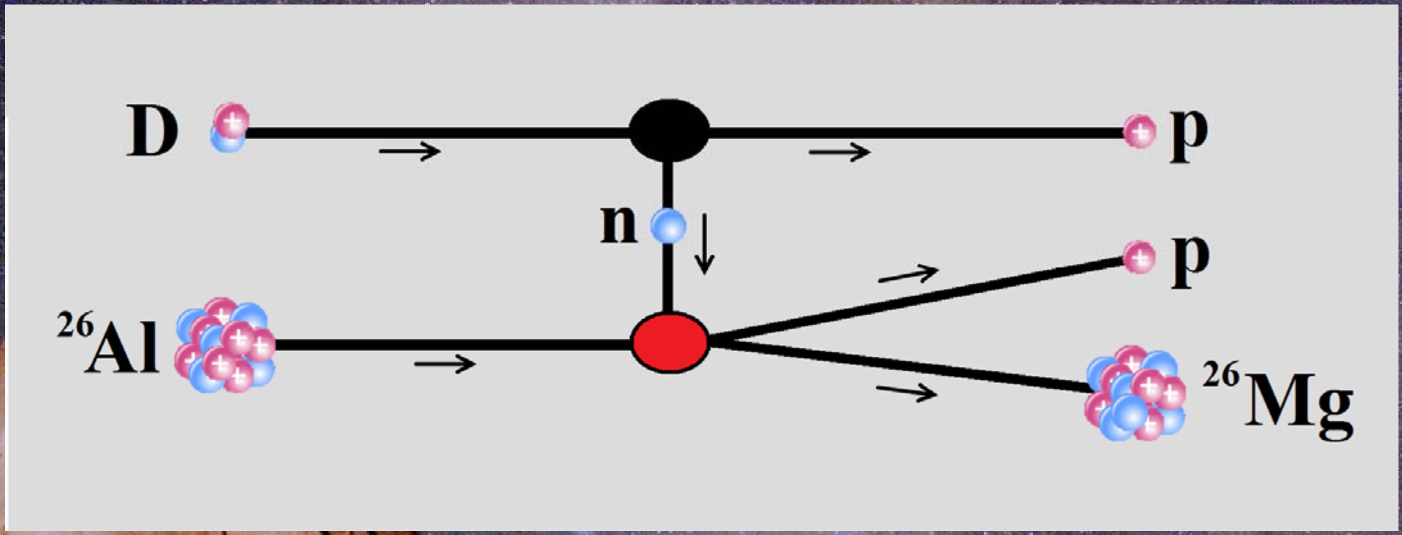
0 (relatively very small) = $E_{Al\text{-}n}$ - 2.25MeV

→ Converted to laboratory frame of reference

$E_{Al\text{-}n}$ = **60MeV**

[4] M. La Cognata et al., Phys. Rev. C 72, 065802 (2005).

Virtual Neutron Beam



Spectator – proton of the deuteron

Reactants – ^{26}Al and neutron

Products – ^{26}Mg and another proton

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Experiment Overview

- Multiple methods of production
- Isolate isotope (MARS)
- Beam degradation
- Trojan Horse Method a possibility?
  – Energy
  – Angular straggling

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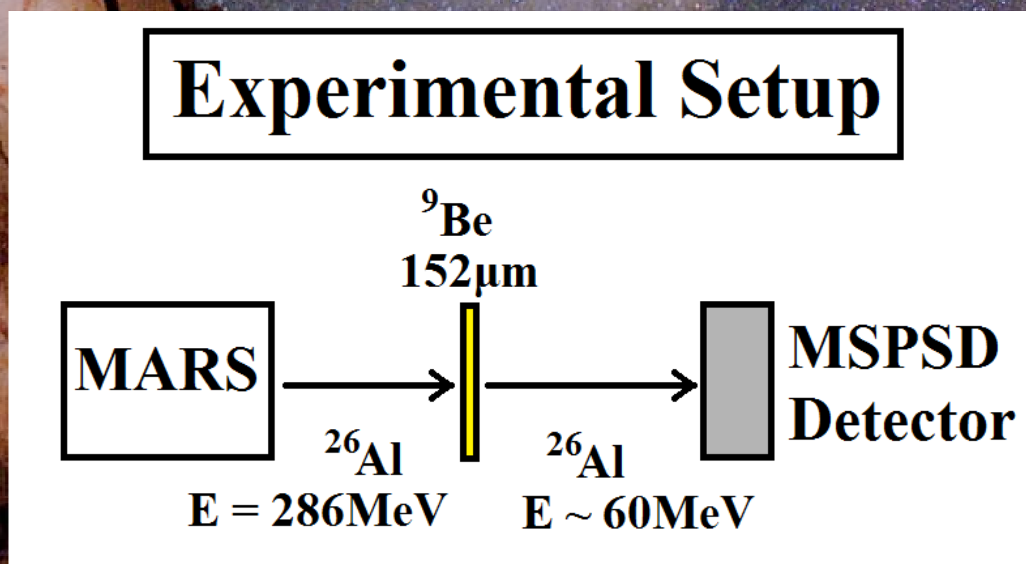
Aim of Experiment

- Produce ^{26}Al beam
- Degrade it to energy suitable for THM application (E ~ 60MeV)



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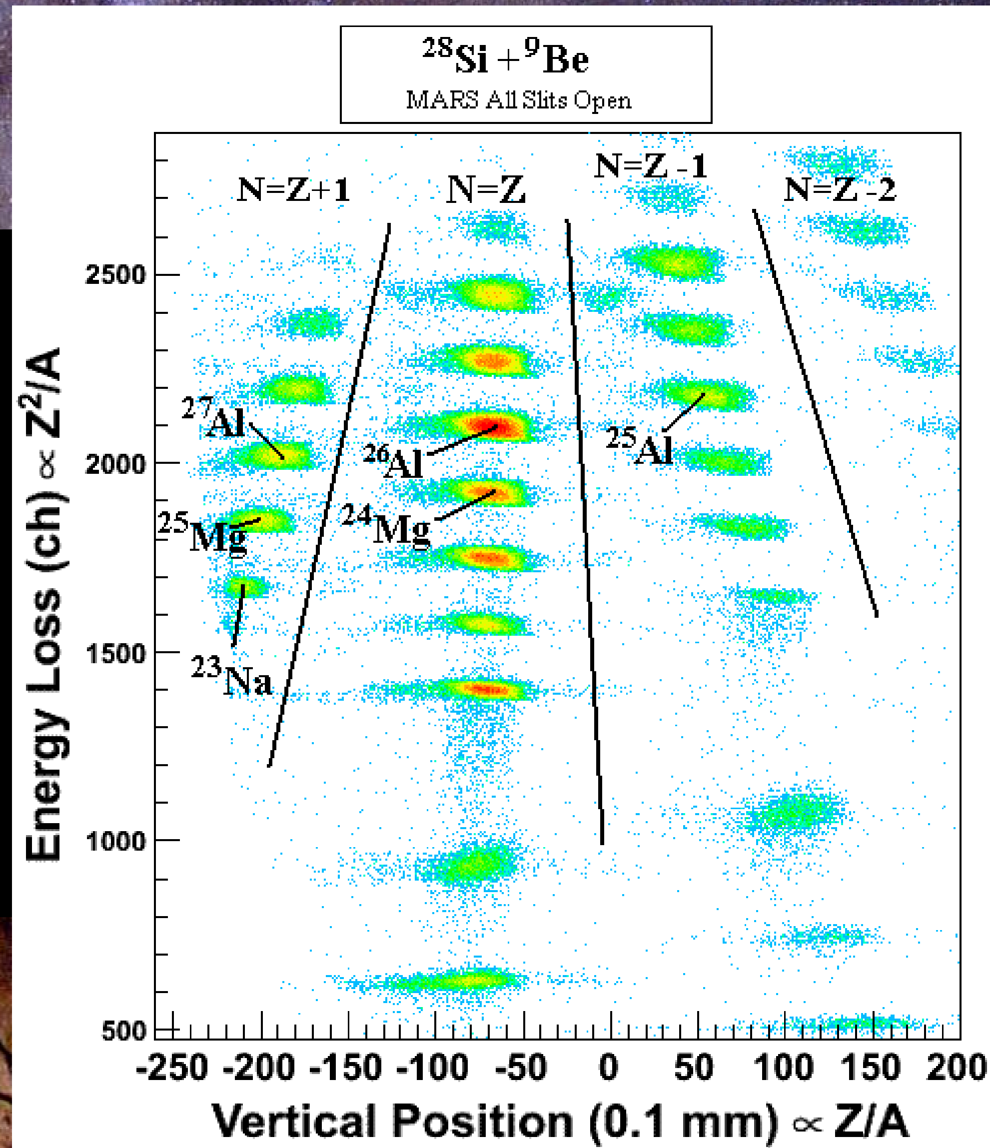
Detectors

- Target detector – MSPSD (multi-strip position sensitive detector)

- $^{28}Si + {}^{9}Be$ (more complicated)
- MARS all slits open
- Many ions present (not as pure)



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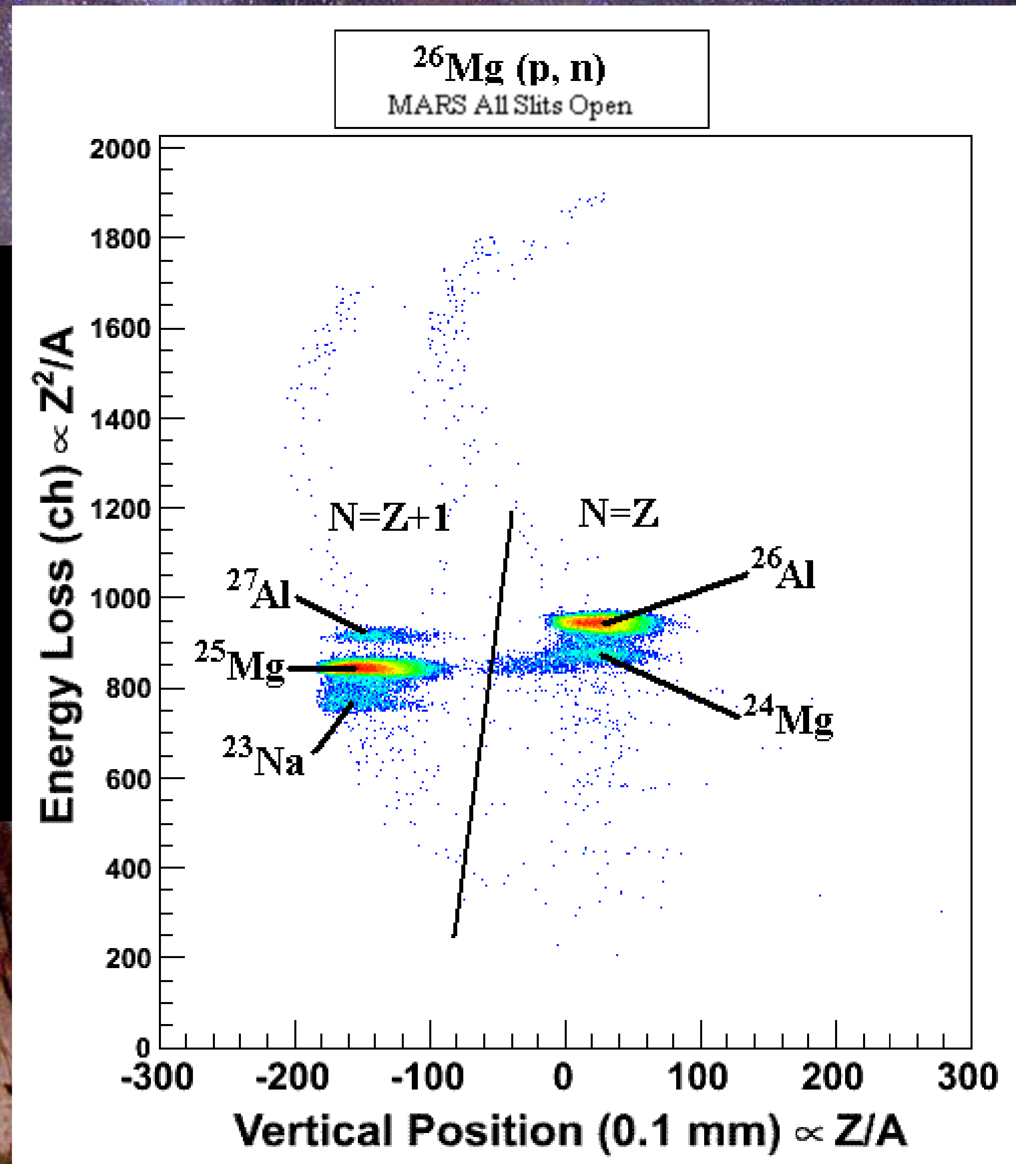
- ^{26}Mg (p, n)
- MARS all slits open
- Fewer ions present



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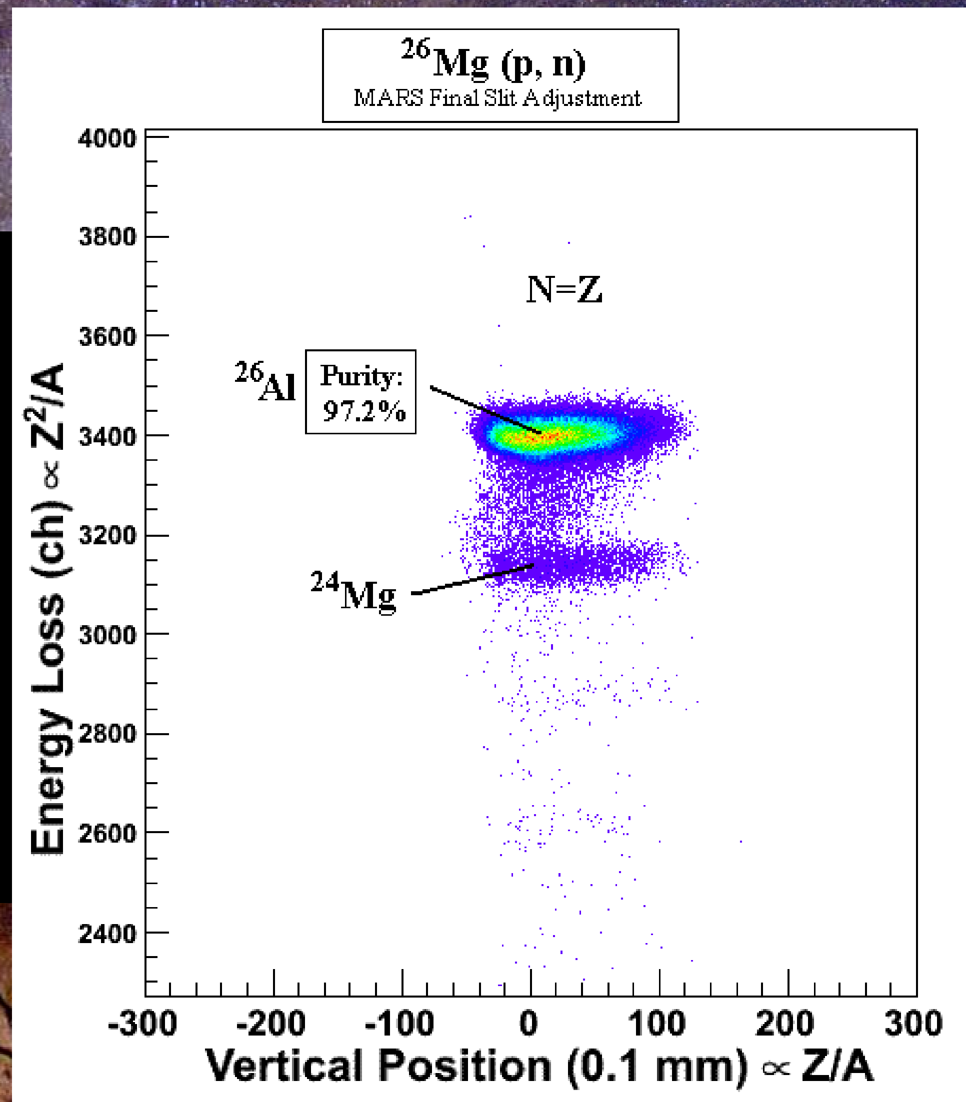
- ^{26}Mg (p, n)
- MARS final slit adjustment
- ^{24}Mg only impurity
- > 97% purity
- 3×10^5 pps intensity



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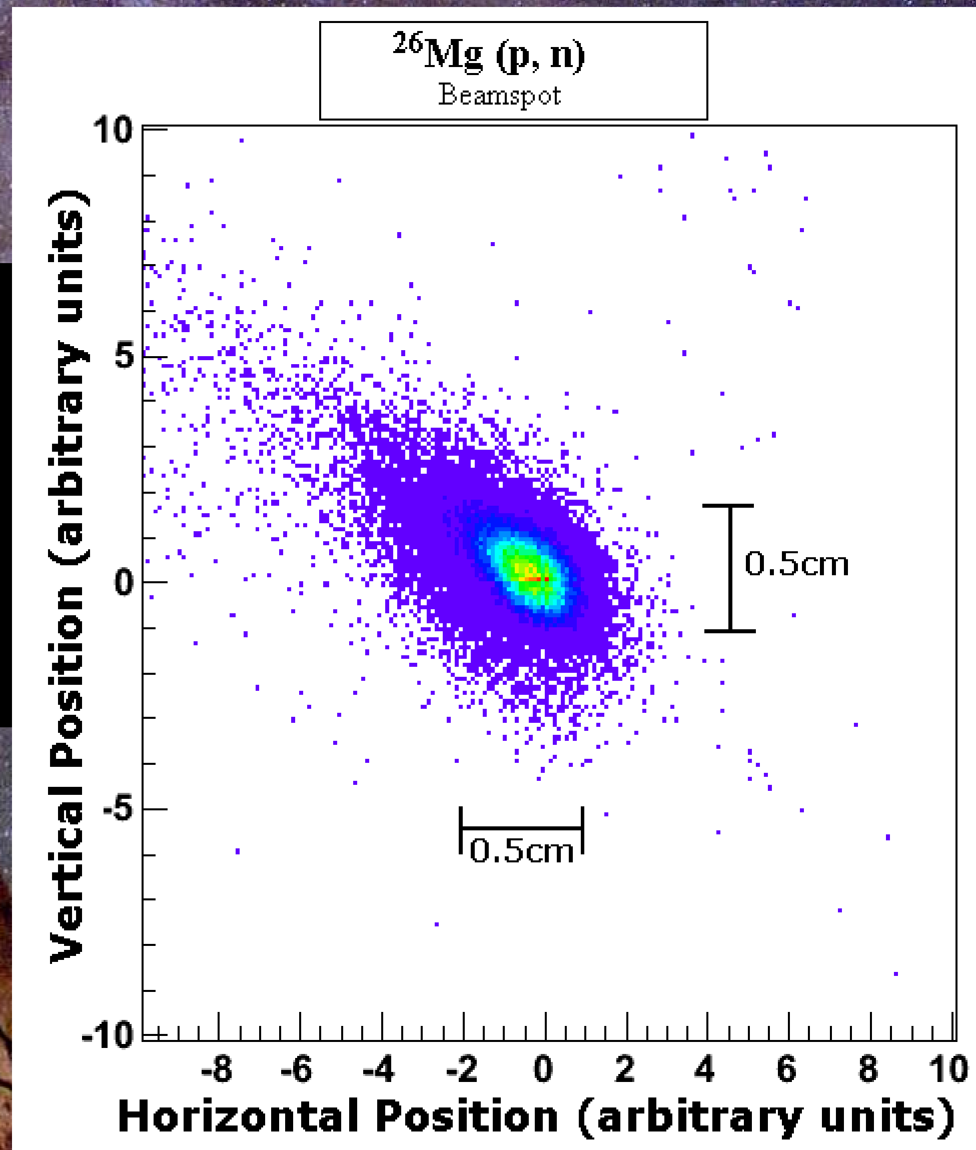
Degradation Calculations

Initial Energy (MeV / nucleon)	Initial Energy (MeV)	Material	Thickness (micron)	Energy Remaining (MeV / nucleon)	Energy Loss (MeV)	Energy Remaining (MeV)	Angle (mrad)
11	286	Carbon	120	2.61	218	68	7.07
			125	2.02	233	53	7.16
		Aluminum	120	2.79	213	73	10.55
			125	2.25	227	59	10.69
		Beryllium	155	2.98	208	78	5.83
			160	2.55	220	66	5.88
			165	2.09	231	55	5.93
		Gold	40	2.22	228	58	31.53

Calculations were made utilizing LISE++ Physical Calculator

Actual degrader – 152 micron Be foil

- ^{26}Mg (p, n)
- Beamspot after energy degradation
- 0.5cm x 0.5cm



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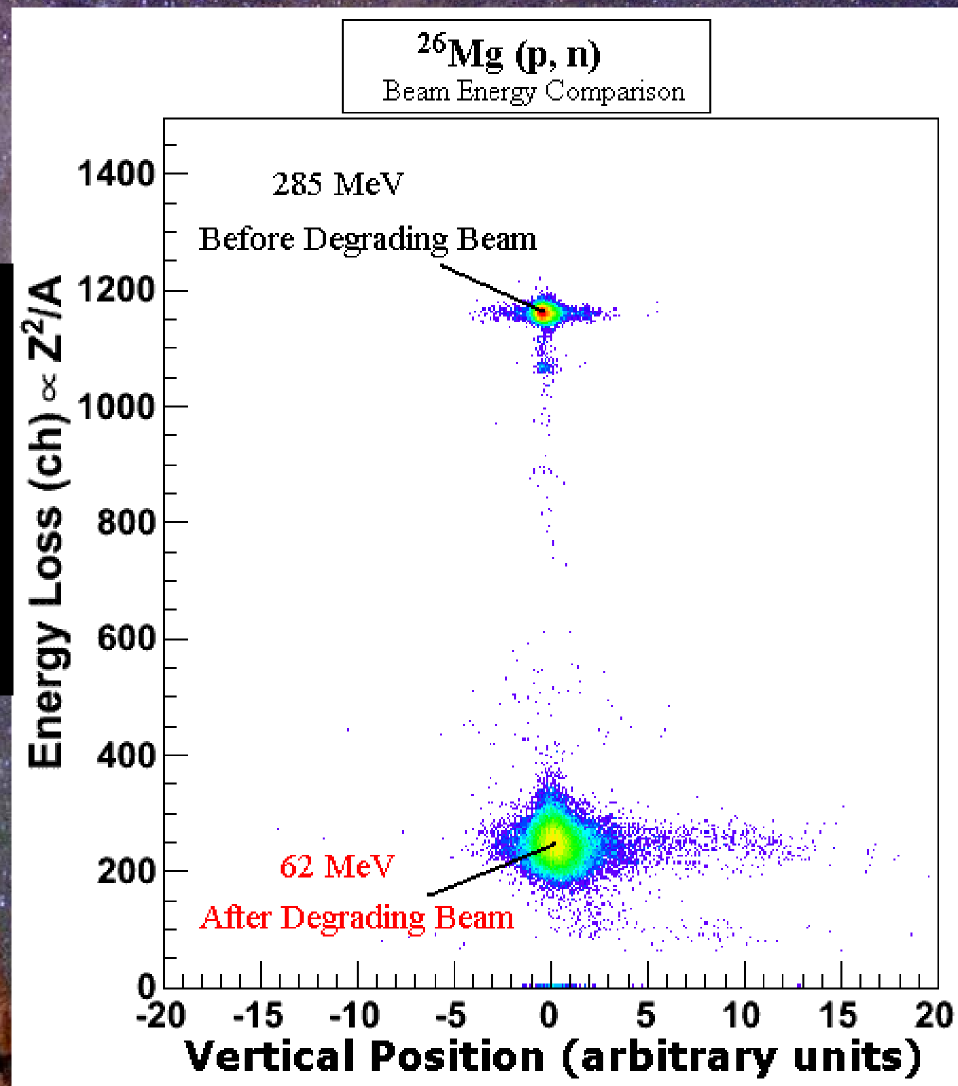
- 26Mg (p, n)
- Energy comparison, before/after degradation



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Experiment Degradation

- 152µm Beryllium foil

- No intensity loss

Method?

- 0.5cm x 0.5cm beamspot
- Energy resolution needs
- ~ 60MeV

- >97% Pure

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Conclusion

- Secondary Beam
  - Intense ($3x10^5$pps) and pure >97%
  - 11MeV/u (286MeV)
- Degradation
  - ~ 60MeV
  - No intensity loss
  - Beamspot 0.5cm x 0.5cm
- My contribution
  - Determination of proper degrader
  - Detector Energy Calibration
  - Spectra - Isotope identification

Acknowledgements

- Dr. Robert Tribble, Dr. Livius Trache, Dr. Gianluca Pizzone, and Dr. Brian Roeder
- Dr. Sherry Yennello
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Energy Calibration / Ion Identification

- Locate N=Z line
- Identify channel numbers of ions
- Using Bρ use LISE++ to calculate energy for each ion
- Coordinate Energy for several ions with an energy level from the spectra (channel)
- Plot energy (x) vs. channel (y) and fit a trendline
- Check by testing with other ions and correlation