

Institute of Physics (IOP)  
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Glasgow, Scotland, April 4 - 7, 2011

## NUCLEAR DATA FOR SPACE RADIATION

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April 6, 2011



## Space Radiation:

### GALACTIC COSMIC RAYS (GCR)

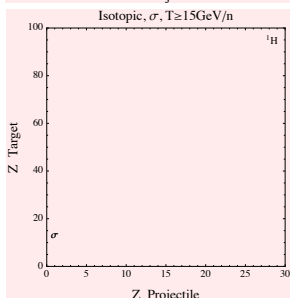
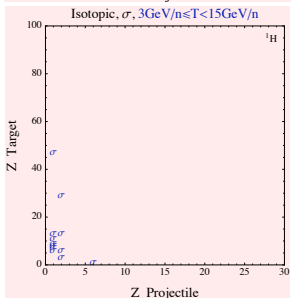
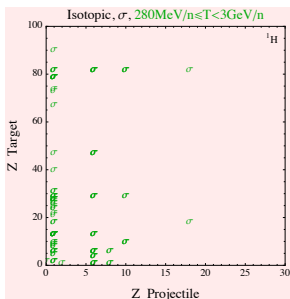
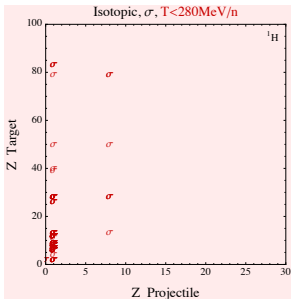
- Protons  $\rightarrow$  Fe nuclei  $\sim$  100 MeV/n – 50 GeV/n
- Peaks: H, He, C, O, Si, Fe
  
- Important for long duration space flight
- Radiation Dose: GCR nuclei (cross sections input)
- Need to understand all nuclear interactions (theory)
- Validation: Need data for nuclear interactions (experiment)
- Talk will discuss nuclear database relevant for space radiation



- Database: ~ 50,000 entries
  - ZP, AP, TP, ZT, AT, ZF, AF
  - Cross section type
    - total, differential, charge changing, elemental, isotopic ...
  - Bibliography
- Energy regions:
  - **Below pion threshold:**  $T < 280 \text{ MeV/n}$
  - **Low:**  $280 \text{ MeV/n} \leq T < 3 \text{ GeV/n}$
  - **Medium:**  $3 \text{ GeV/n} \leq T < 15 \text{ GeV/n}$
  - **High:**  $T \geq 15 \text{ GeV/n}$
- Fragments:
  - Have data for all fragments
  - H, He fragments - TODAY ONLY
    - very abundant, highly penetrating, significant fraction of dose



1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



$^1\text{H}$   $\sigma$

Missing:

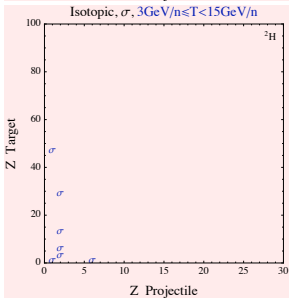
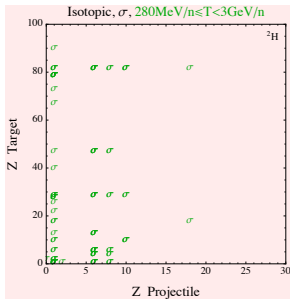
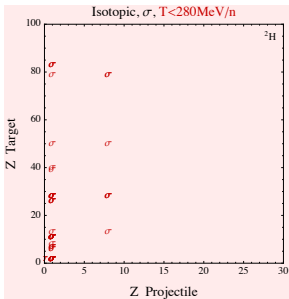
He, C, O(light), Si, Fe

He, Si, Fe

C, O, Si, Fe



1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



$^2\text{H}$   $\sigma$

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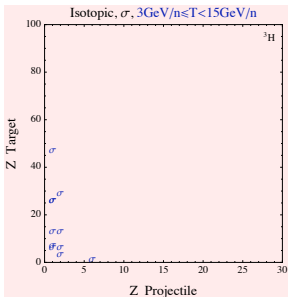
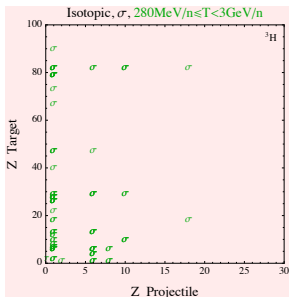
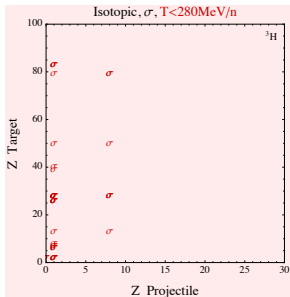
He, C, O(light), Si, Fe

He, Si, Fe

C, O, Si, Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



${}^3\text{H}$   $\sigma$

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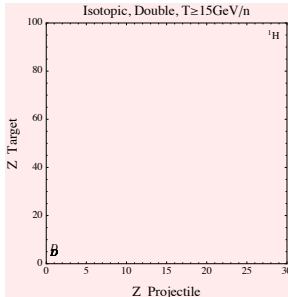
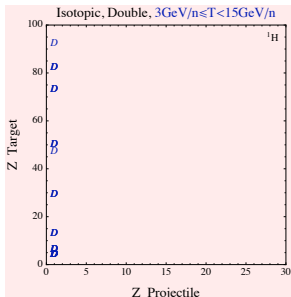
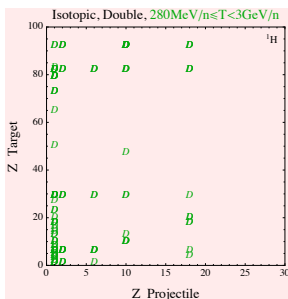
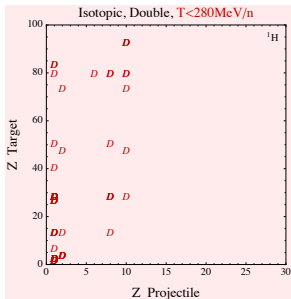
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He, Si, Fe

C, O, Si, Fe



1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



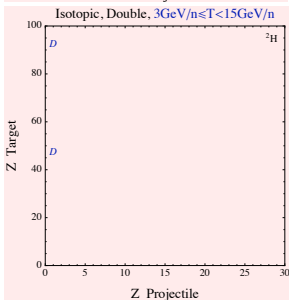
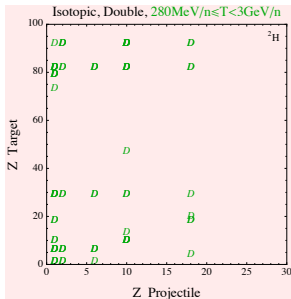
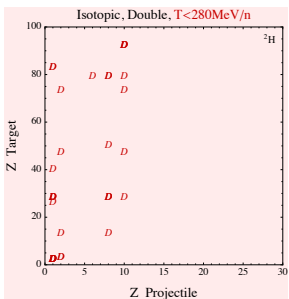
$^1\text{H}$  Double differential

Reasonable representation

Missing:  
 C, O (light), Si, Fe  
 Fe  
 He, C, O, Si, Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



$^2\text{H}$  Double differential

Reasonable representation

Missing:

C, O(light), Si, Fe

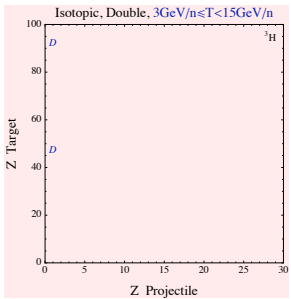
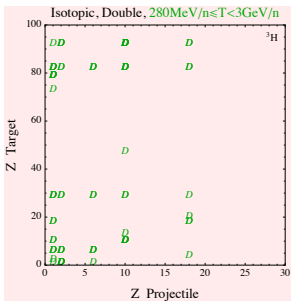
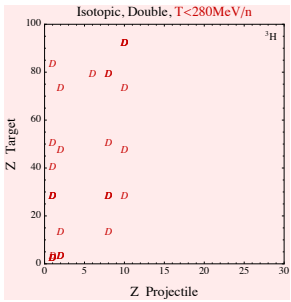
Fe

He, C, O, Si, Fe





1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



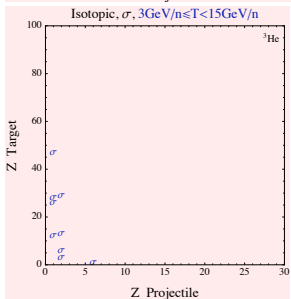
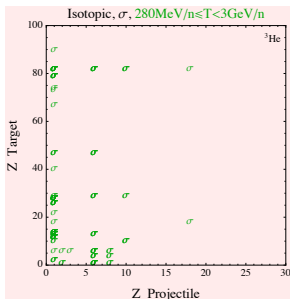
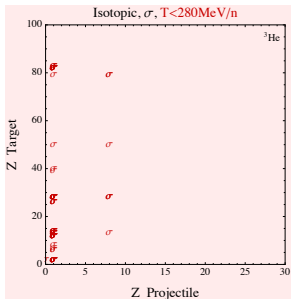
<sup>3</sup>H Double differential

Reasonable representation

Missing:  
 C, O(light), Si, Fe  
 Fe  
 He, C, O, Si, Fe



1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



$^3\text{He}$   $\sigma$

Missing:

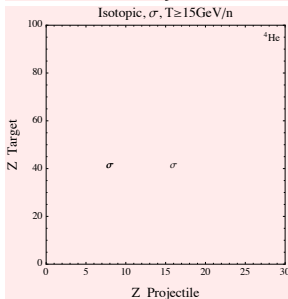
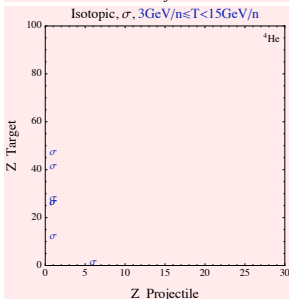
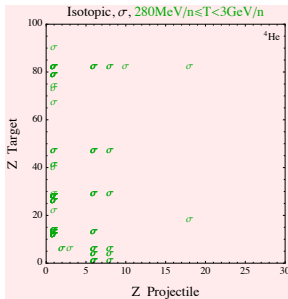
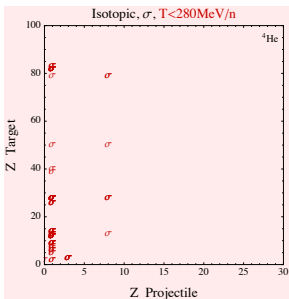
He, C, O(light), Si, Fe

Si, Fe

C, O, Si, Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



$^4\text{He}$   $\sigma$

Missing:

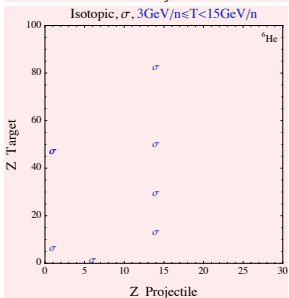
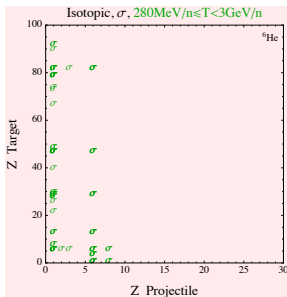
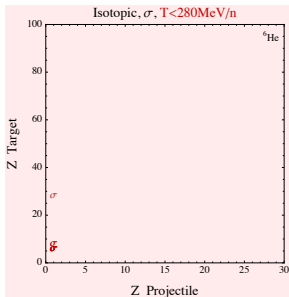
C, O(light), Si, Fe

Si, Fe

C, O, Si, Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



${}^6\text{He}$   $\sigma$

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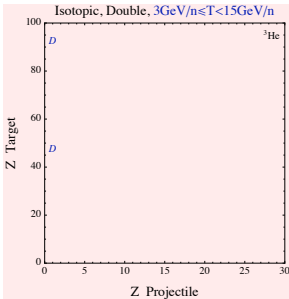
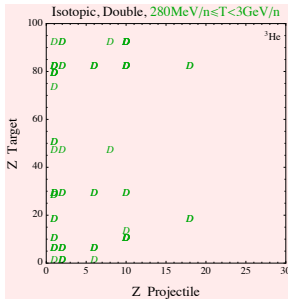
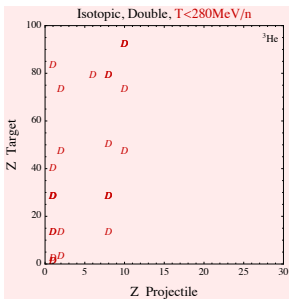
C, O, Si, Fe

Si, Fe

C, O, Si(H), Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



$^3\text{He}$  Double differential

Missing:

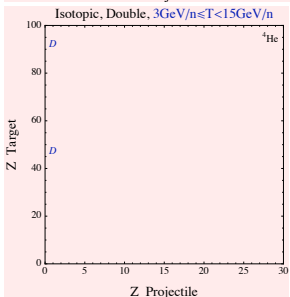
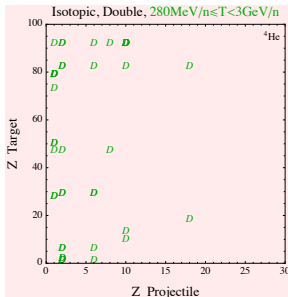
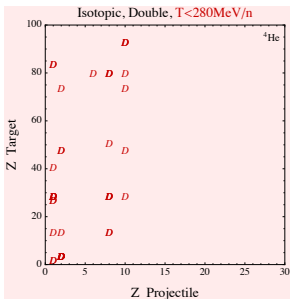
C, O(light), Si, Fe

Si, Fe

He, C, O, Si, Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



$^4\text{He}$  Double differential

Missing:

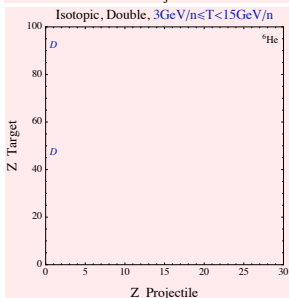
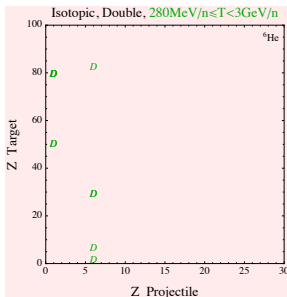
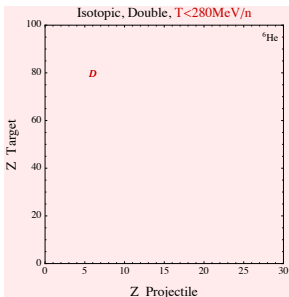
C, O(light), Si, Fe

Si, Fe

C, O, Si, Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS



<sup>6</sup>He Double differential

Missing:

C, O, Si, Fe

O, Si, Fe

C, O, Si, Fe



# 1. INTRODUCTION 3. H 4. HE 5. CONCLUSIONS

- Surprisingly large amount of missing experimental data
- Lack of theoretical model validation
- The following table shows experiment recommendations:

Cross section	Fragment	$< \pi$ projectile	Low energy projectile	Medium energy projectile
$\sigma$	$^{1,2,3}\text{H}$	He, C, O(light), Si, Fe	He, Si, Fe	C, O, Si, Fe
$dEd\Omega$	$^{1,2,3}\text{H}$	C, O(light), Si, Fe	Fe	He, C, O, Si, Fe
$\sigma$	$^3\text{He}$	He, C, O(light), Si, Fe	Si, Fe	C, O, Si, Fe
	$^4\text{He}$	C, O(light), Si, Fe	Si, Fe	C, O, Si, Fe
	$^6\text{He}$	C, O, Si, Fe	Si, Fe	C, O, Si(H), Fe
$dEd\Omega$	$^{3,4}\text{He}$	C, O(light), Si, Fe	Si, Fe	He, C, O, Si, Fe
	$^6\text{He}$	C, O, Si, Fe	O, Si, Fe	C, O, Si, Fe





# THE END

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