# The secondary target of the hyper atom experiment

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**Panda Coll. Meeting 18/1, GSI, 03/06/17**

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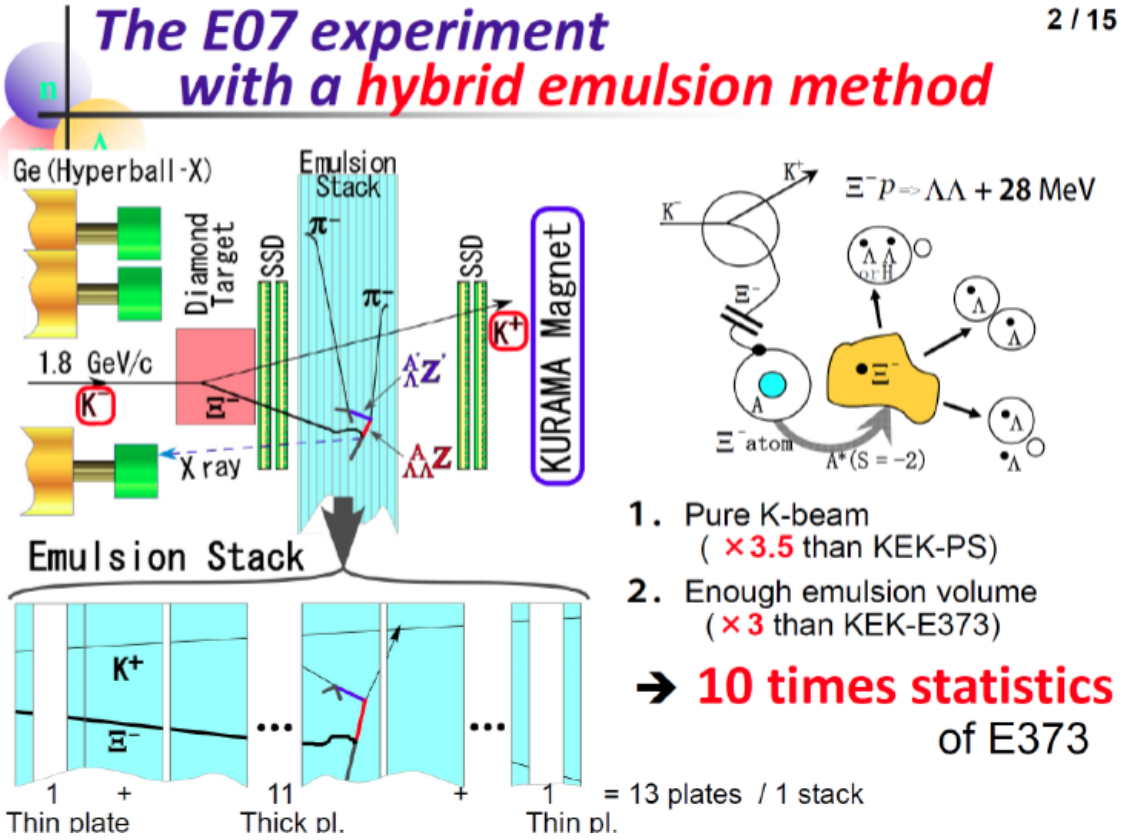
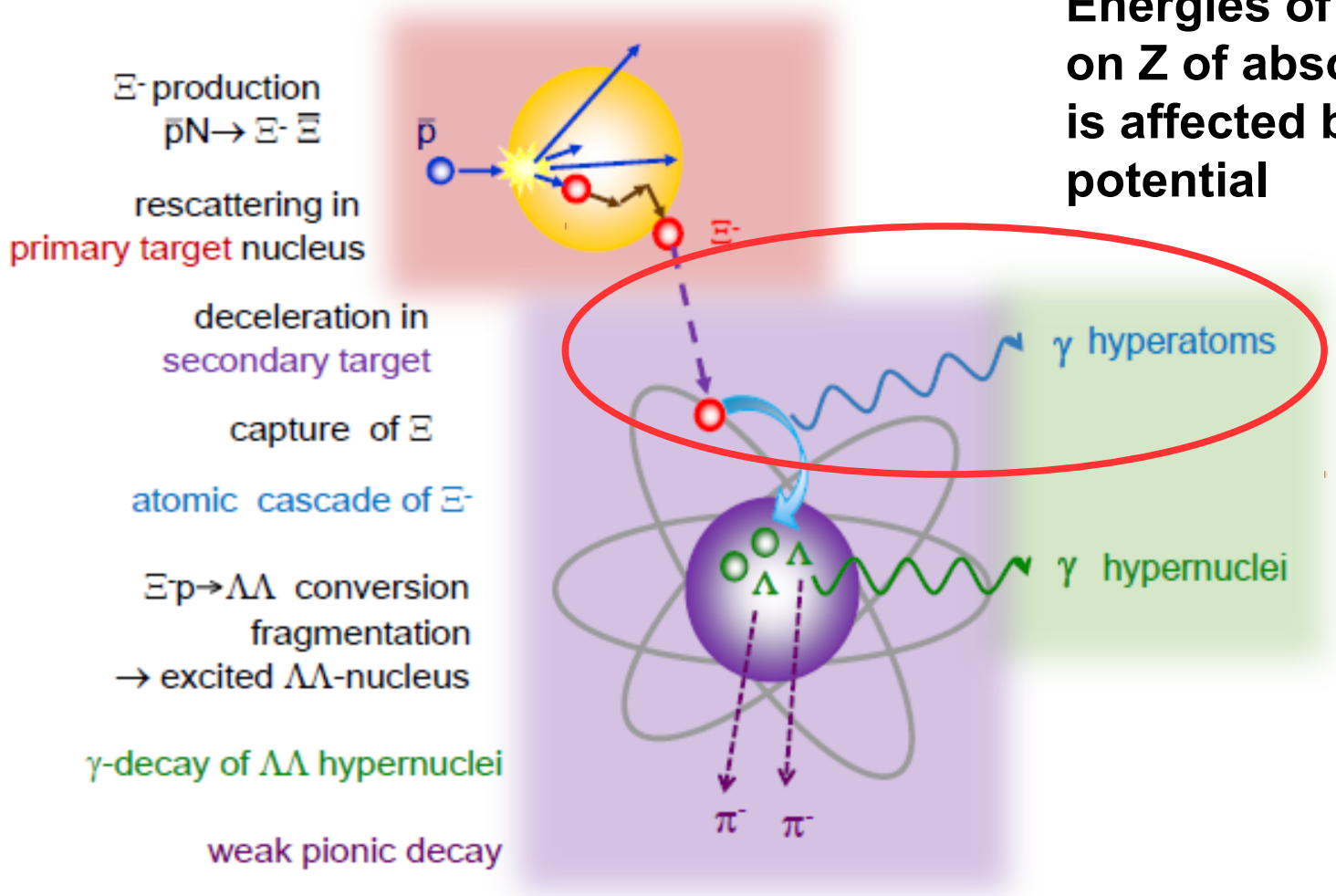
# Experiments at JPARC

- E07 (2017):
  - k⁻ beam
  - Ag and Br (Emulsion)
  - ~40 hyper atoms expected
- E03 (2018/2019):
  - Fe (thick absorber)
  - K⁺ tag
  - ~2500 hyper atoms expected



# Production of hyper atoms at PANDA



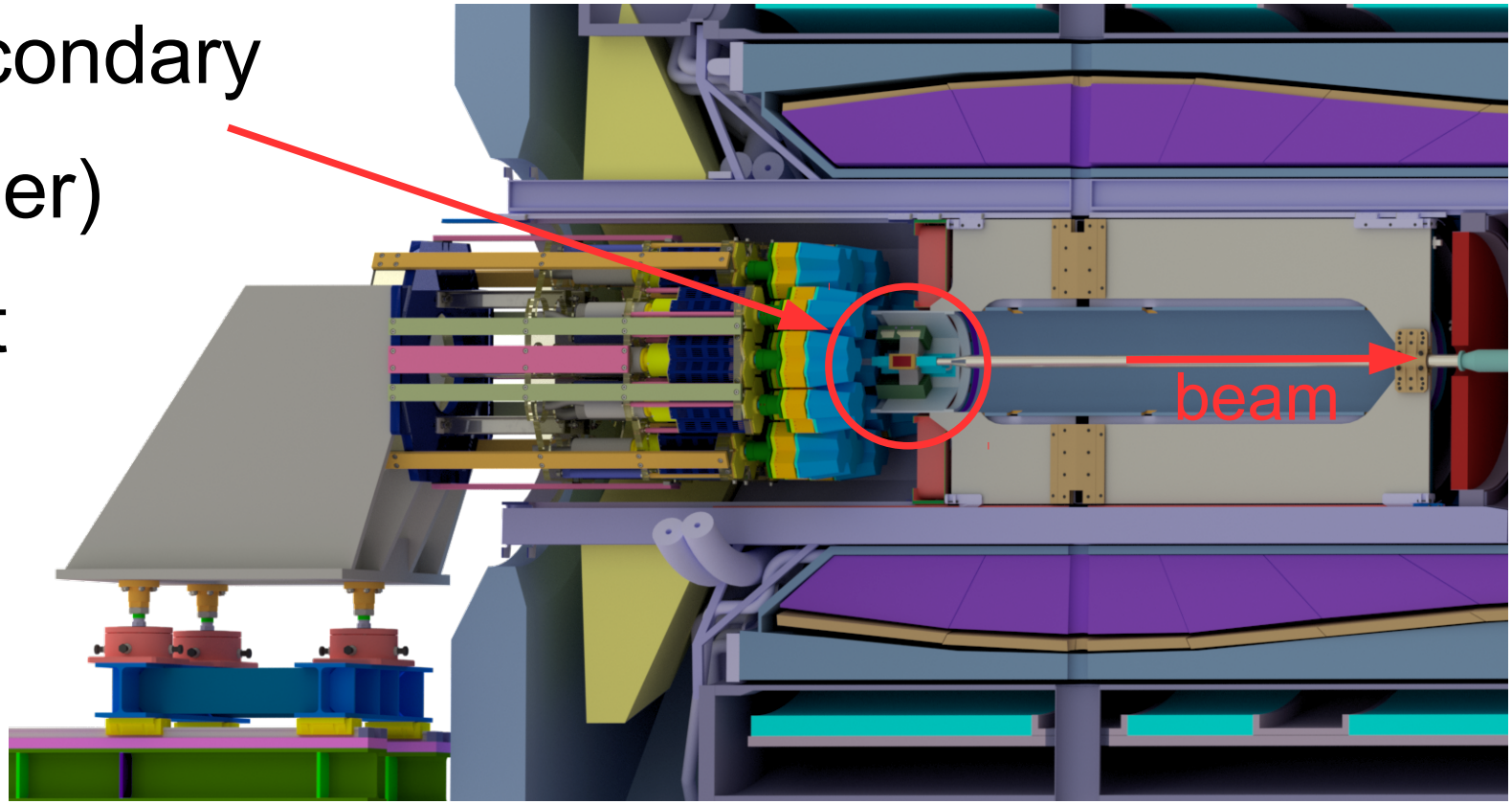

**Energies of X-rays depend on Z of absorber, last X-ray is affected by strong nuclear potential**

< 1 MeV

< 10 MeV

# Setup of the hyper atom experiment

- Measurement of 2 X-rays coincidence
  - Ge detector for small gate
- Dedicated secondary target (absorber)
- Primary target



# Choice of absorber material

- Stable, solid, non magnetic
- Single isotopic

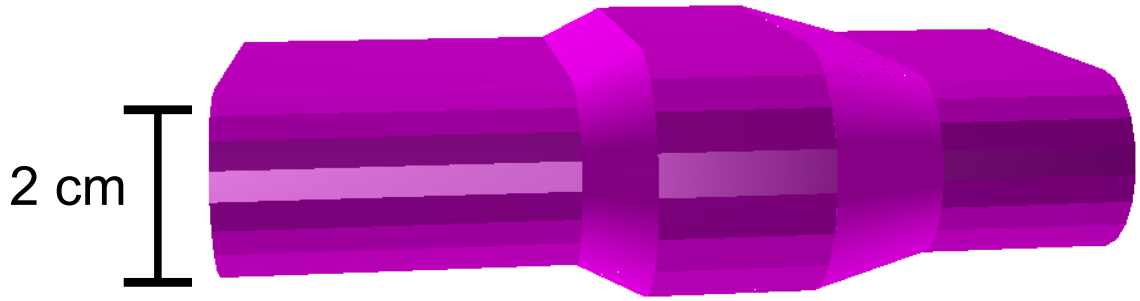
- $f_{fom} = \Xi_{stopping} \cdot \gamma_{Eff,E1} \cdot \gamma_{Eff,E2}$
  - $\Xi_{stopping}$ favors higher density
  - $\gamma_{Eff}$ Z dependance (energy, absorption)
- Measurable strong interaction shift (~1 keV)
- Reasonable width

# Choice of absorber material

| Element | Z | A | density [g/cm^3] | isotopic Abundance [%] | Energy 1 [keV] | Energy 2 [keV] | Shift 2 [keV] | Width 2 [keV] | Yield2 [%] |
|---|---|---|---|---|---|---|---|---|---|
| Al | 13 | 27 | 2.7 | 100.0 | 69.4 | 128.1 | 0.1 | 0.04 | 89.3 |
| Si | 14 | 28 | 2.3 | 92.0 | 80.7 | 148.9 | 0.2 | 0.08 | 87.5 |
| Ti | 22 | 48 | 4.5 | 73.0 | 122.7 | 203.9 | 0.2 | 0.08 | 85.3 |
| V | 23 | 51 | 6.1 | 99.8 | 134.3 | 223.3 | 0.2 | 0.12 | 86.0 |
| Fe | 26 | 56 | 7.9 | 91.8 | 172.2 | 287 | 1.1 | 0.70 | 57.1 |
| Nb | 41 | 93 | 8.6 | 100.0 | 280.9 | 437.5 | 4.3 | 3.61 | 32.2 |
| In | 49 | 115 | 7.3 | 95.0 | 275.8 | 403.6 | 0.9 | 0.50 | 65.0 |
| Ta | 73 | 181 | 16.7 | 99.9 | 325.6 | 440.7 | 0.2 | 0.11 | 88.8 |
| Au | 79 | 197 | 19.3 | 100.0 | 381.7 | 517.1 | 0.7 | 0.43 | 78.4 |
| Pb | 82 | 208 | 11.3 | 52.0 | 411.5 | 558.5 | 1.8 | 1.30 | 56.5 |

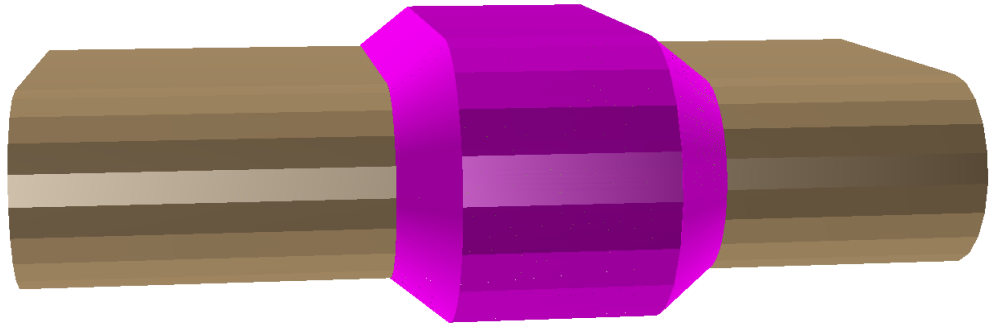
# Optimization of the absorber

- Shape optimized in 3 dimensions
- Stopping optimization
  - $5*10^7$ $\Xi^-$ from GiBUU simulations




Iron target

- $\gamma$ detection optimization
  - Both energies
  - $10^7$ photons (box gen)
  - Shape

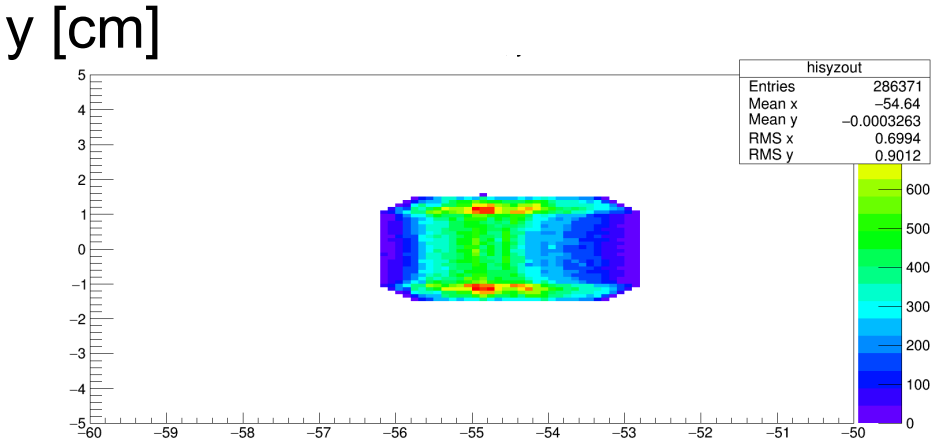


Indium target with titanium foil

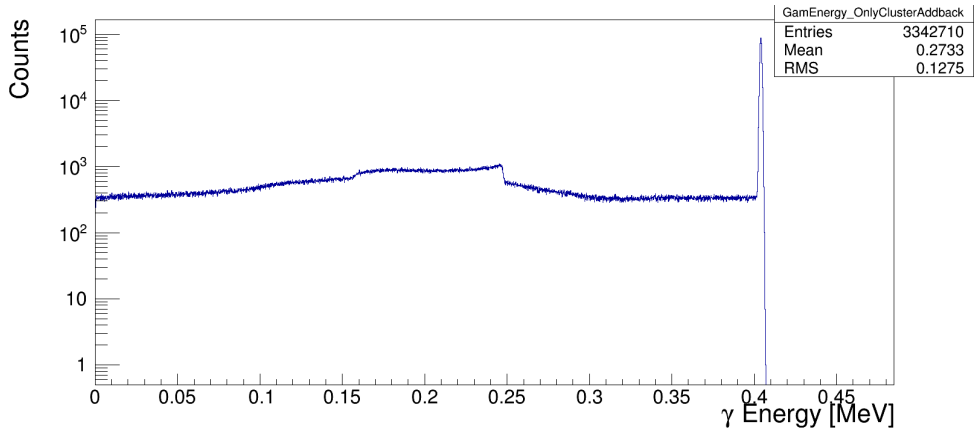
# Optimization: results

| | Fe | In | Pb |
|---|---|---|---|
| $\Xi_{stopping}$ [%] | 0.74 | 0.56 | 0.53 |
| $\gamma_{Eff,E1}$ [%] | 8.38 | 6.42 | 4.45 |
| $\gamma_{Eff,E2}$ [%] | 8.05 | 6.66 | 5.01 |
| **$f_{fom}$ [$10^{-6}$]** | **50.5** | **24.2** | **11.9** |

Larger Z favors smaller target




$\Xi^-$ stopping (indium)




γ efficiency (indium,403.6 keV)

# Counting rates

- 200 $\Xi^-$ /s at PANDA (based on GiBUU)
- 100 days measurement periode
  - > 1.73 *$10^9$ $\Xi^-$ total

| | Fe | In | Pb |
|---|---|---|---|
| $f_{fom}$ [$10^{-6}$] | 50.5 | 24.2 | 11.9 |
| **Yield2** [%] | 57.1 | 65.0 | 56.5 |
| **Iso. abun.** [%] | 91.7 | 95.7 | 52.4 |
| **Coinc.** | **45 693** | **26 019** | **6 081** |

- Resolution: $\Delta E = \sqrt{\frac{Width}{coinc}}$
  - Estimation for In: $Width = \sqrt{2^2 + 0.5^2}\, keV \rightarrow \Delta E \approx 0.01\, keV$
  - Good calibration required (Eu152,Cf252)
  - Activation of Al: online calibration (472.6 keV)
  - Systematics will dominate

# Comparison of isotopes

| | Pb206 | Pb207 | Pb208 |
|---|---|---|---|
| **Iso. abun. [%]** | 24.1 | 22.1 | 52.4 |
| **Energy2 [keV]** | 558.47 | 558.54 | 558.57 |
| **Yield2 [%]** | 57 | 56 | 56.5 |
| **Shift2 [keV]** | 1.72 | 1.78 | 1.79 |
| **Width2 [keV]** | 1.2 | 1.3 | 1.3 |

Isotopes hardly distinguishable

| | Fe | In | Pb |
|---|---|---|---|
| **$f_{fom}$ [$10^{-6}$]** | 50.5 | 24.2 | 11.9 |
| **Yield2 [%]** | 57.1 | 65.0 | 56.5 |
| **Coinc.** | **49 829** | **27 188** | **11 620** |

# Summary

- Hyper atomic experiment is doable
  - Count rates ~ 100 · hyper nuclear exp.
- Various atoms possible
- Indium promising for first experiment

Thanks for your attention

# Backup slides

# Gamma simulation geometry