# SPALLATION REACTION WITH TIN ISOTOPES

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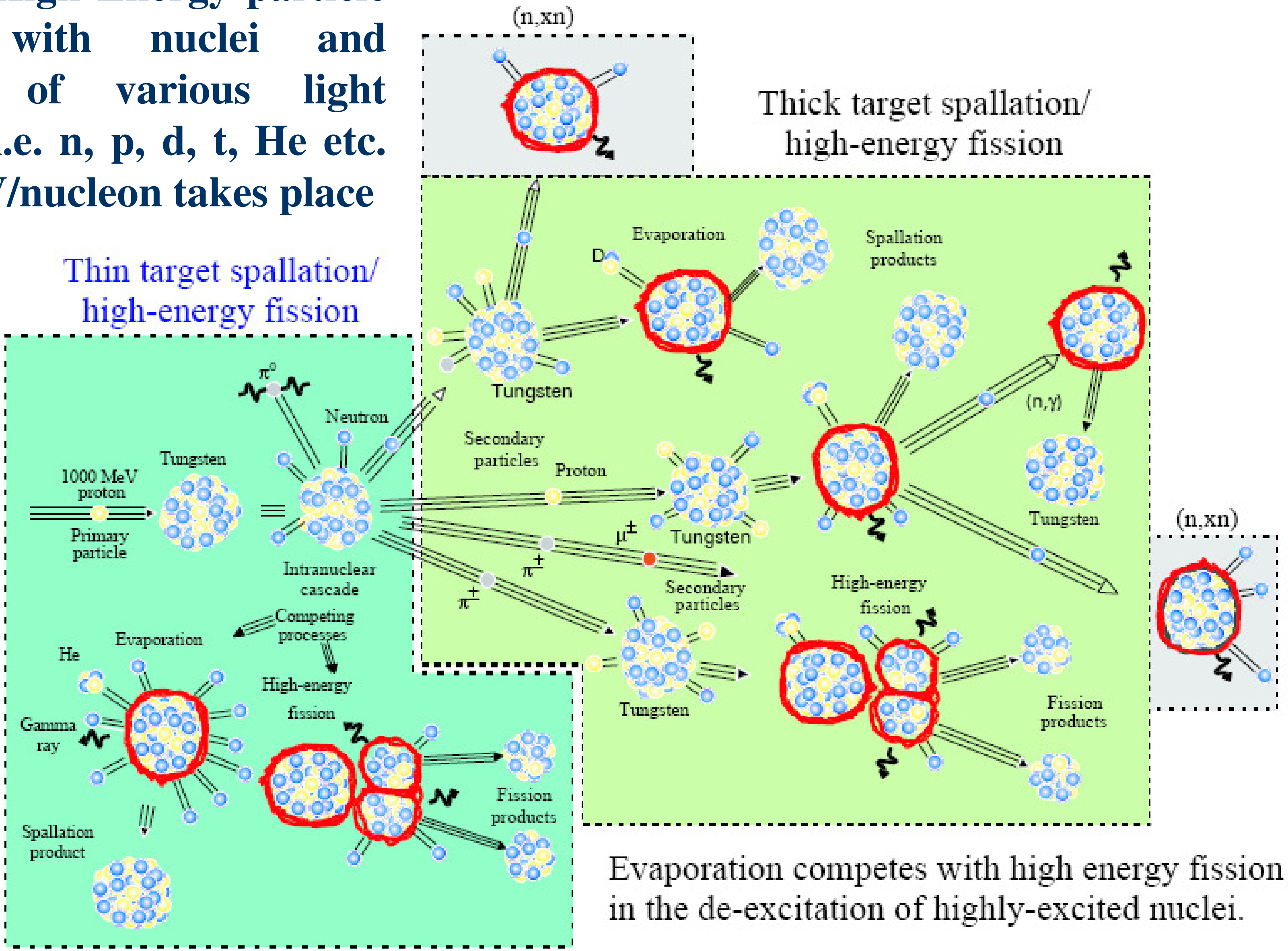
**Liquid Tin as a coolant in the fast reactor systems and as a Spallation target**

# PROPERTIES

| | Tin | LBE | Pb | Bi |
|---|---|---|---|---|
| Melting Point(K) | 505 | 398 | 600 | 544 |
| Boiling Point(K) | 2543 | 1943 | 2022 | 1837 |
| Density(g/cc) | 5.75 -7.29 | 10.5 | 11.35 | 9.75 |
| Surface tension(773 K) (N/m) | 510 | | 431 | |
| Viscosity(873K) (cP x10 $^{2}$) | 1.05 | 1.17 | 1.60 | 1.00 |

# Spallation processes in Thin and Thick target

**Spallation:** High Energy particle collides with nuclei and emission of various light particles i.e. n, p, d, t, He etc. >100 MeV/nucleon takes place




Evaporation competes with high energy fission in the de-excitation of highly-excited nuclei.

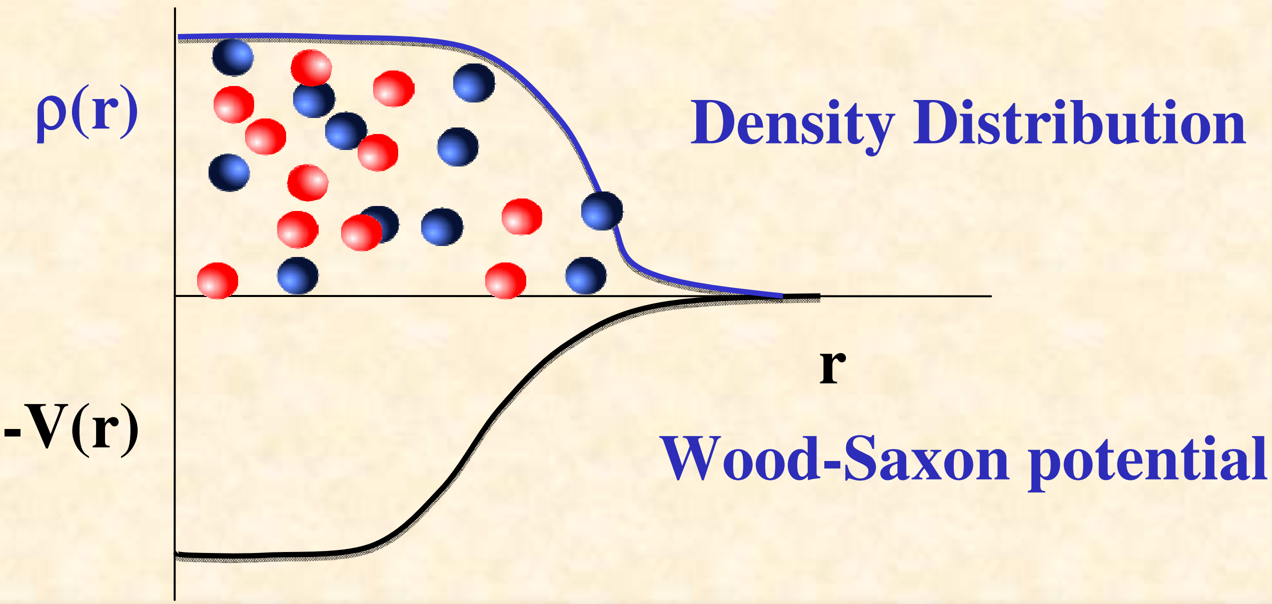
# Intra-Nuclear Cascade model

## What are the inputs we have?

**Projectile:** Charge, mass, energy/momentum

**Target:** Charge, mass, nucleon density distribution

**Each nucleon is assigned position & momentum Using Random Numbers**




$$\begin{cases} \rho(r) = \frac{\rho_0}{1+exp\frac{(r-r_0)}{a}} & \\ \text{where} & r_0 = 1.07A^{1/3}fm \\ a = 0.545fm & \text{For A} > 10 \\ \rho(r) = \rho_0 exp\frac{-r^2}{R^2} & \text{For A} \leq 10 \end{cases}$$

$$\begin{cases} P_F(r) = (\frac{3\pi^2\rho(r)}{2})^{1/3} \\ E_F(r) = \hbar^2\frac{(3\pi^2\rho(r))^{2/3}}{2m_N} \end{cases}$$

$$\begin{cases} V \equiv V_N = E_F + \text{Bindinging energy} \\ V_\pi = 25\text{MeV} \end{cases}$$

## Physics Models

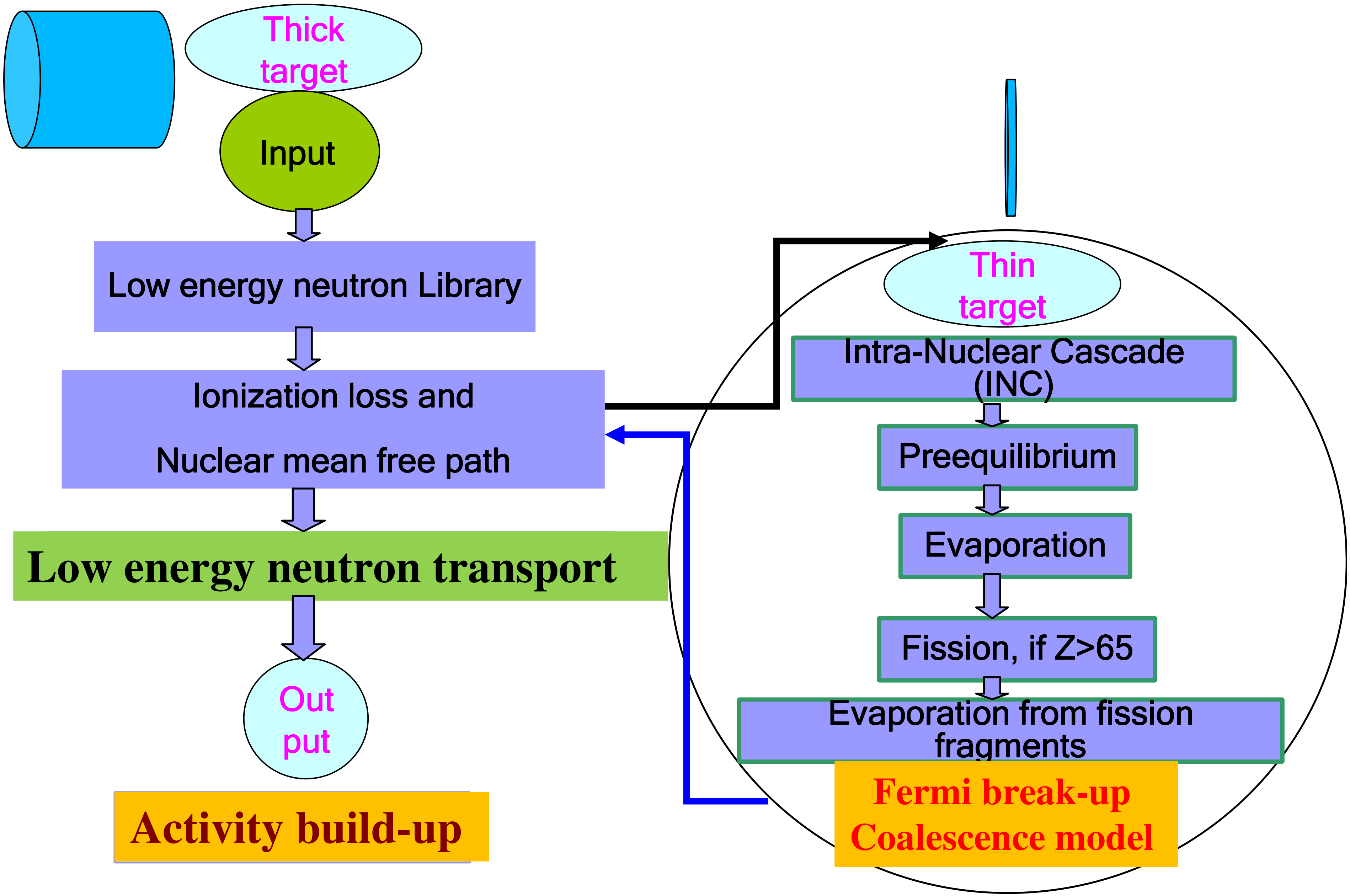
**Intra-nuclear cascade model**

**Pre-equilibrium (exciton model)**

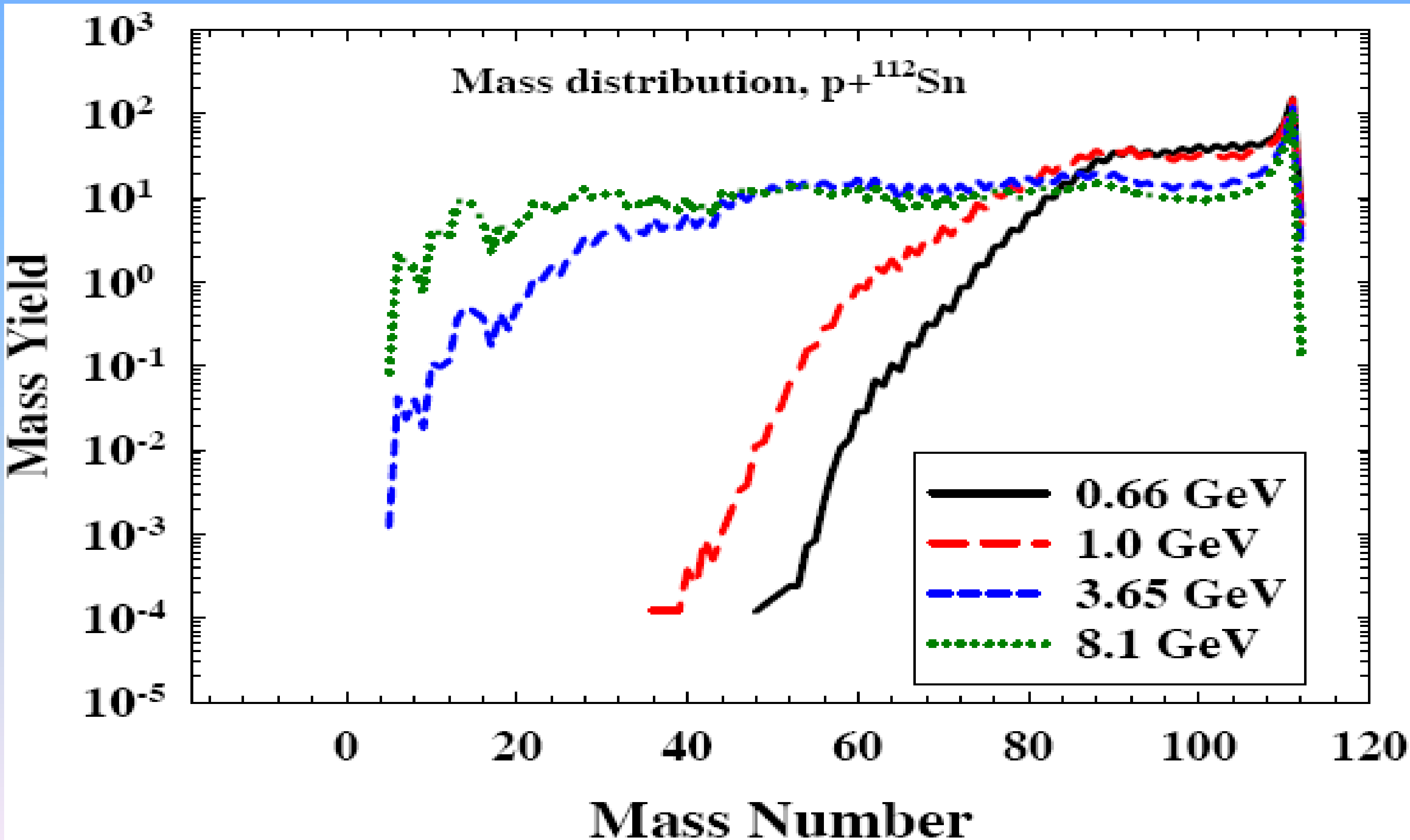
**Evaporation (Generalized Evaporation Model)**

**Fission model (Fong's Model)**

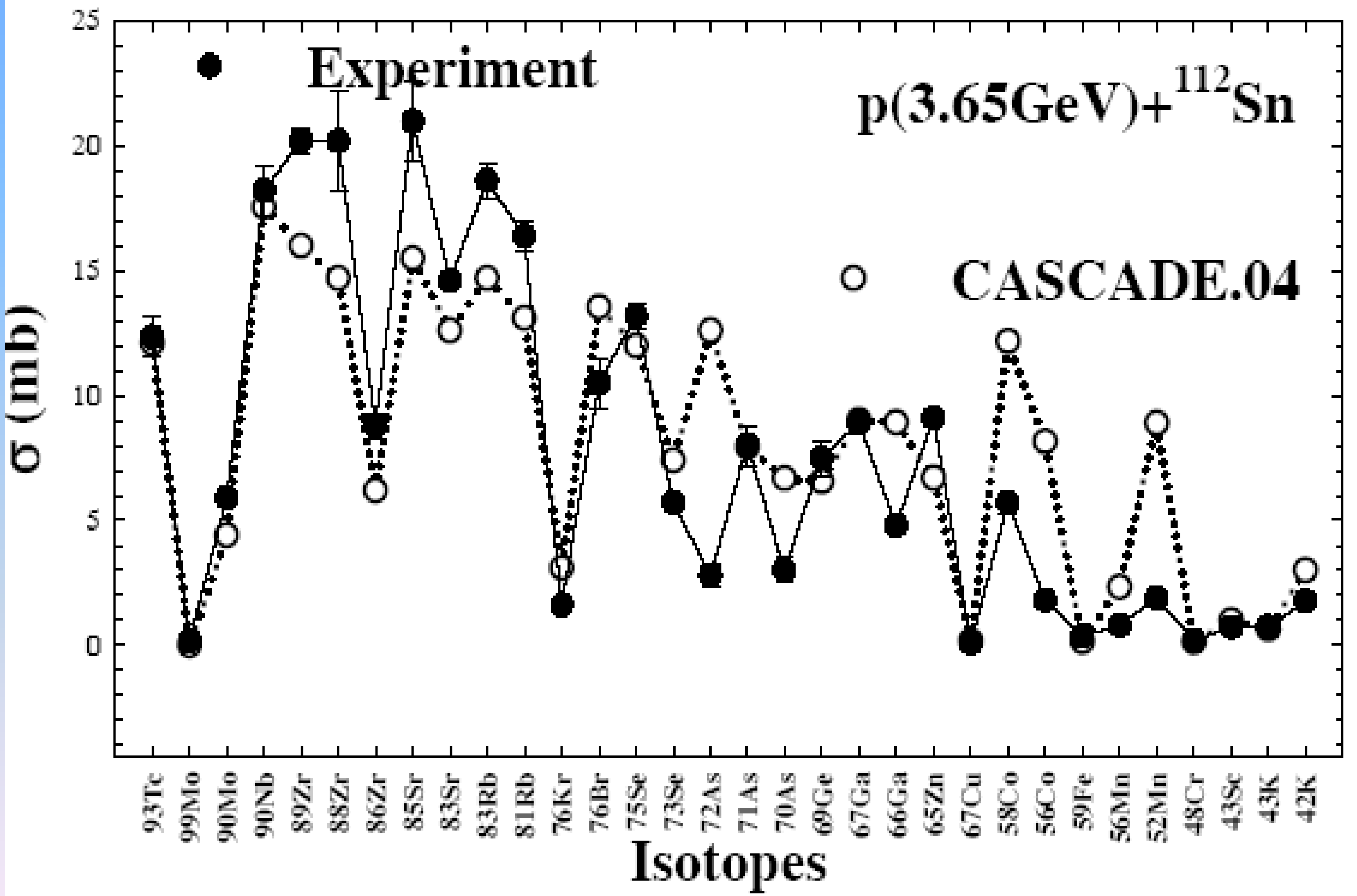
# CASCADE.04 general scheme



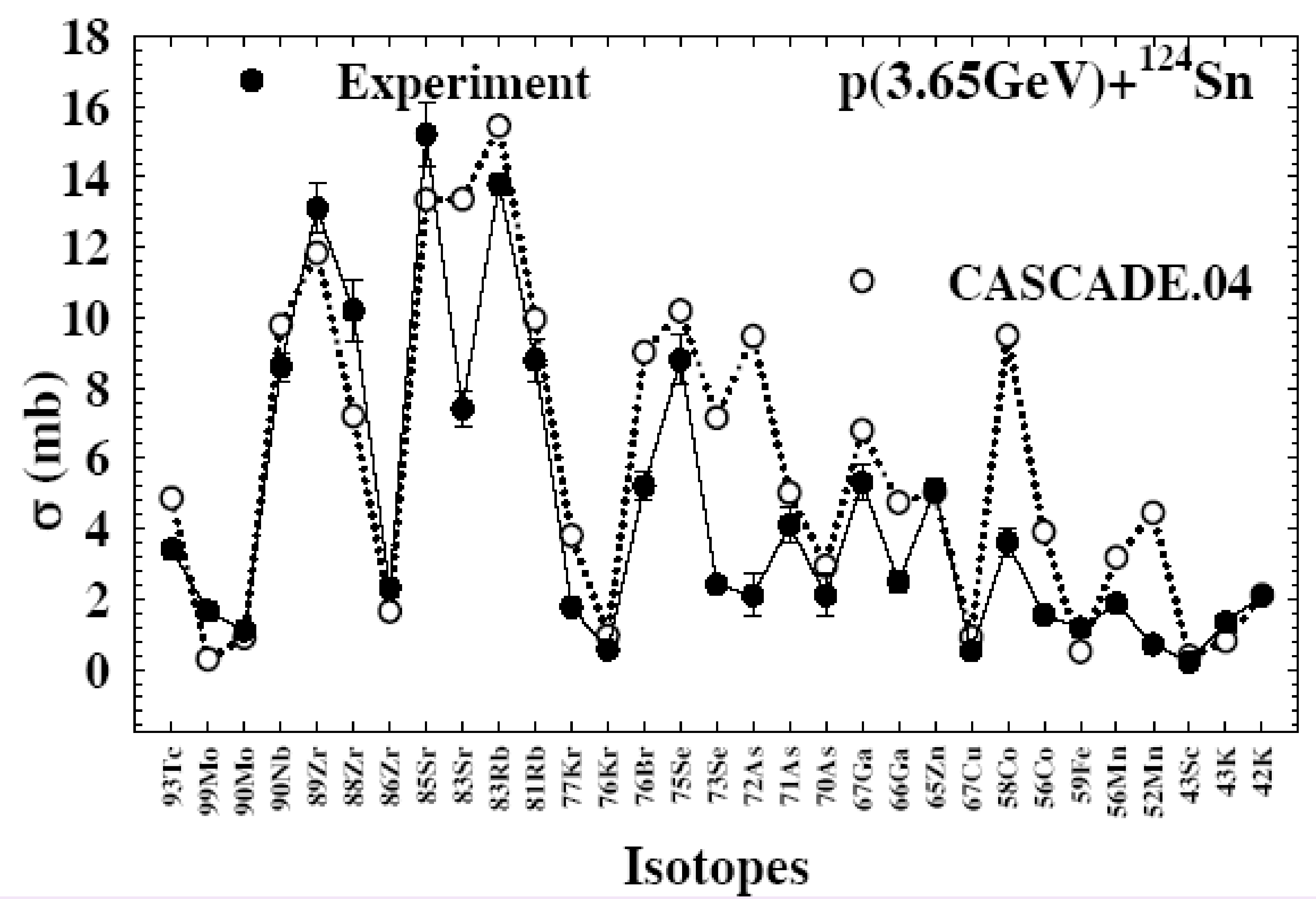
# Mass Distribution of the residues from p + $^{112}$Sn

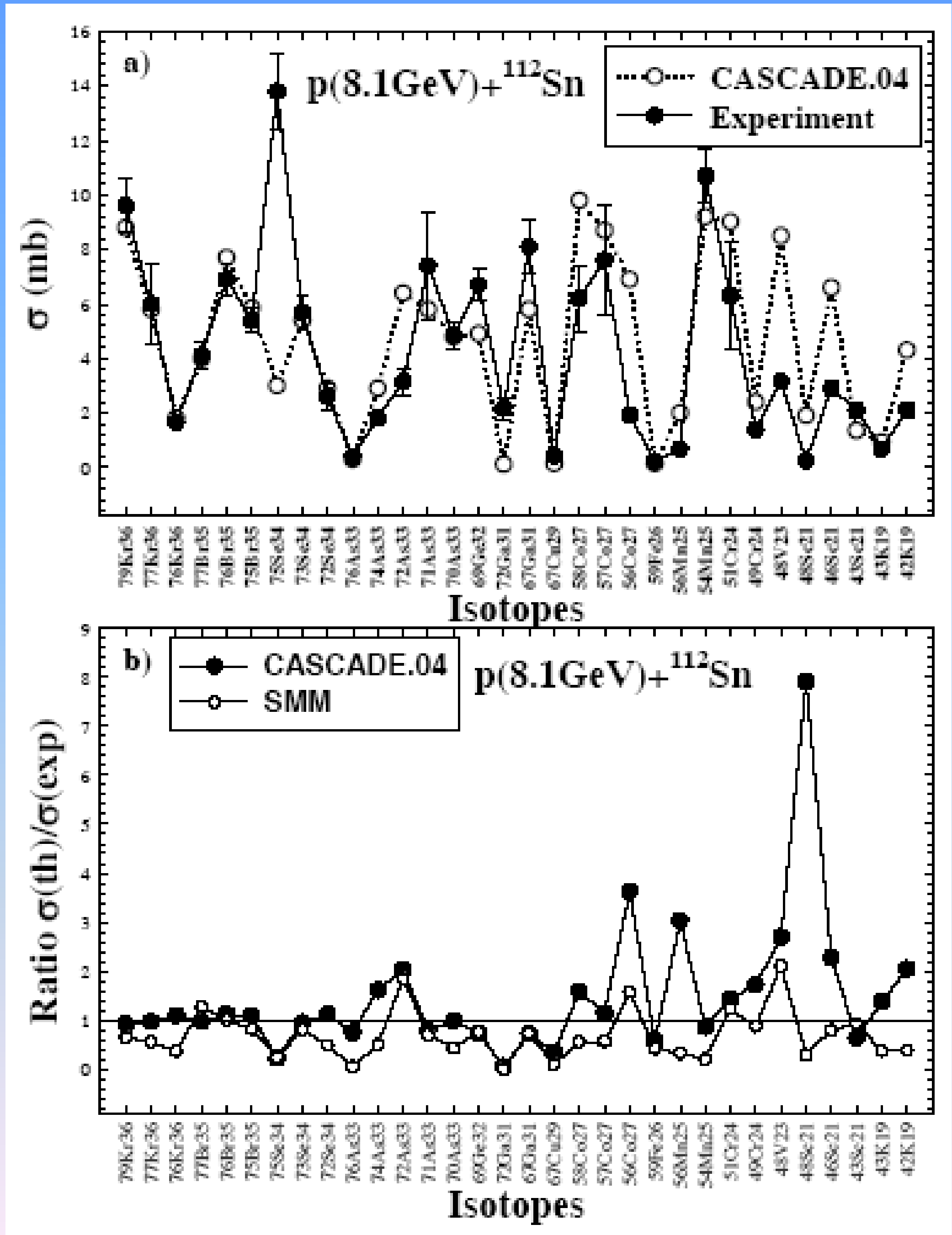


# Cumulative yields of the residues from p + $^{112}Sn$



# Cumulative yields of the residues from p + $^{124}Sn$

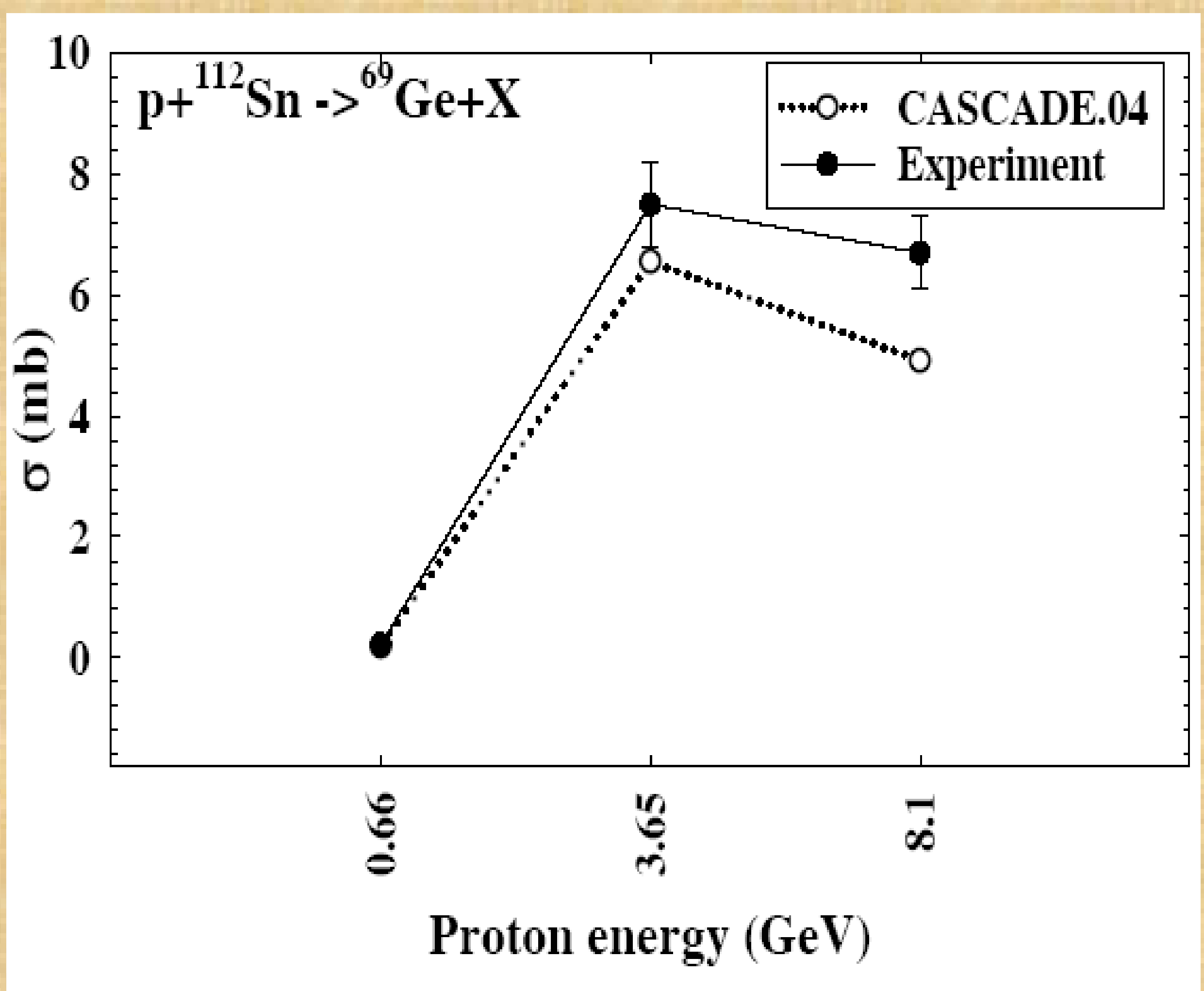





**Cumulative Yields of the Residues from p + $^{112}$Sn**

**Comparison of Cascade.04 And SMM**

# Excitation function for the production of $^{69}Ge$

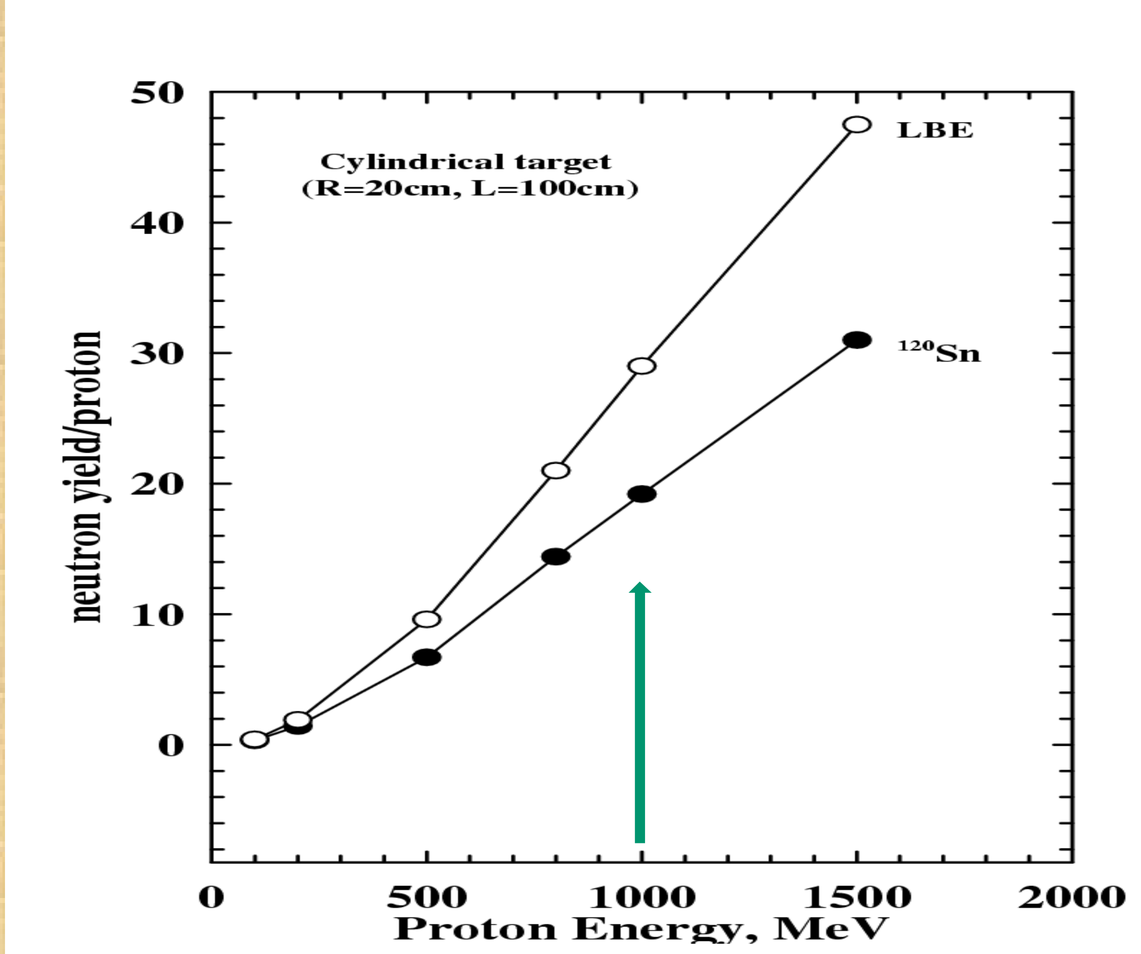


# Neutron yield for LBE and Sn

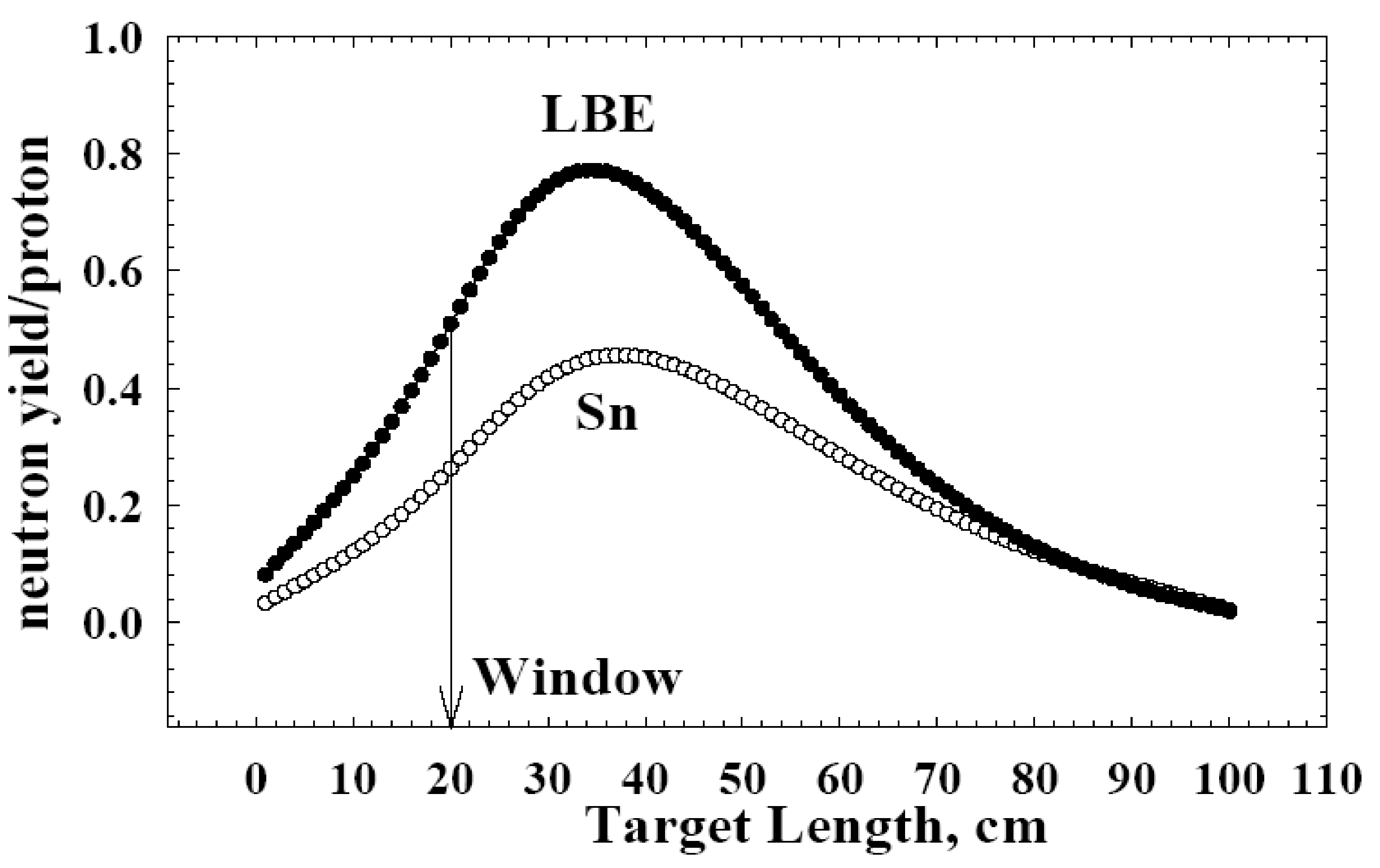
Cylinder

L = 100 cm

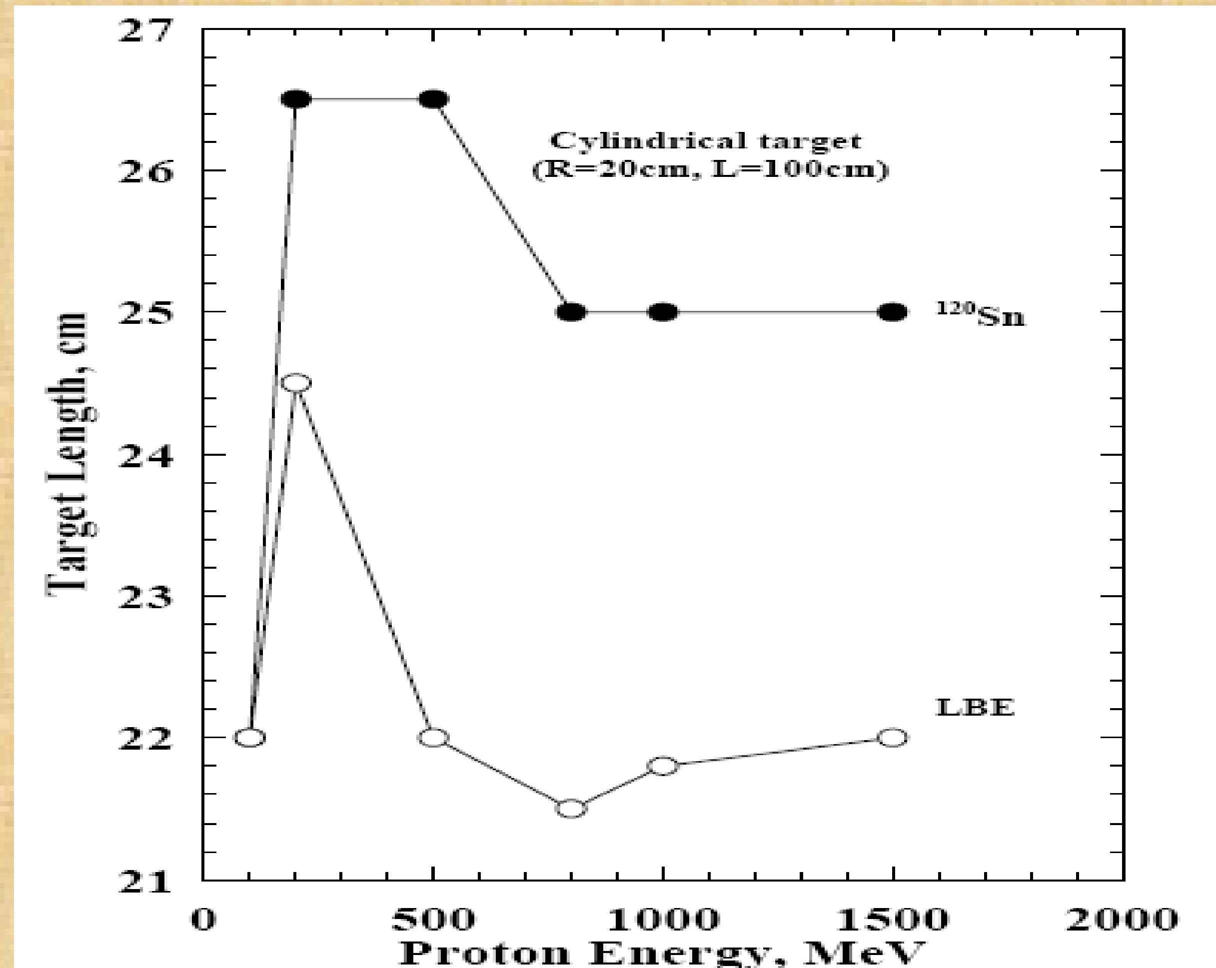
Dia=40 cm



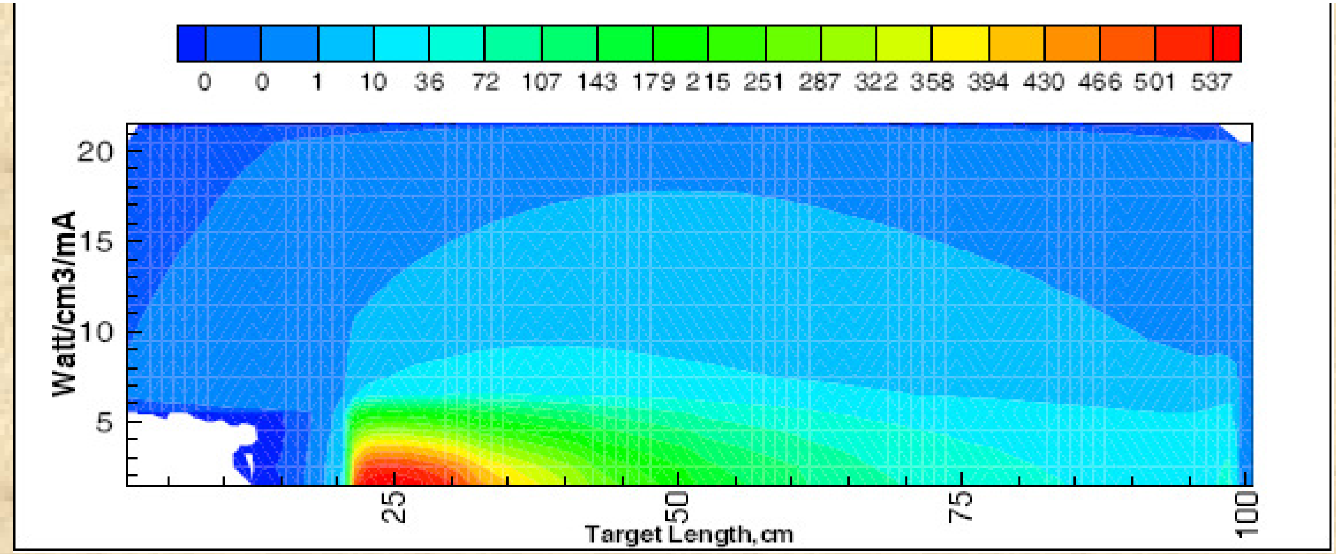
# Neutron yield per cm along the length of target ( 1 GeV p)



# Position of the maximum heat deposition

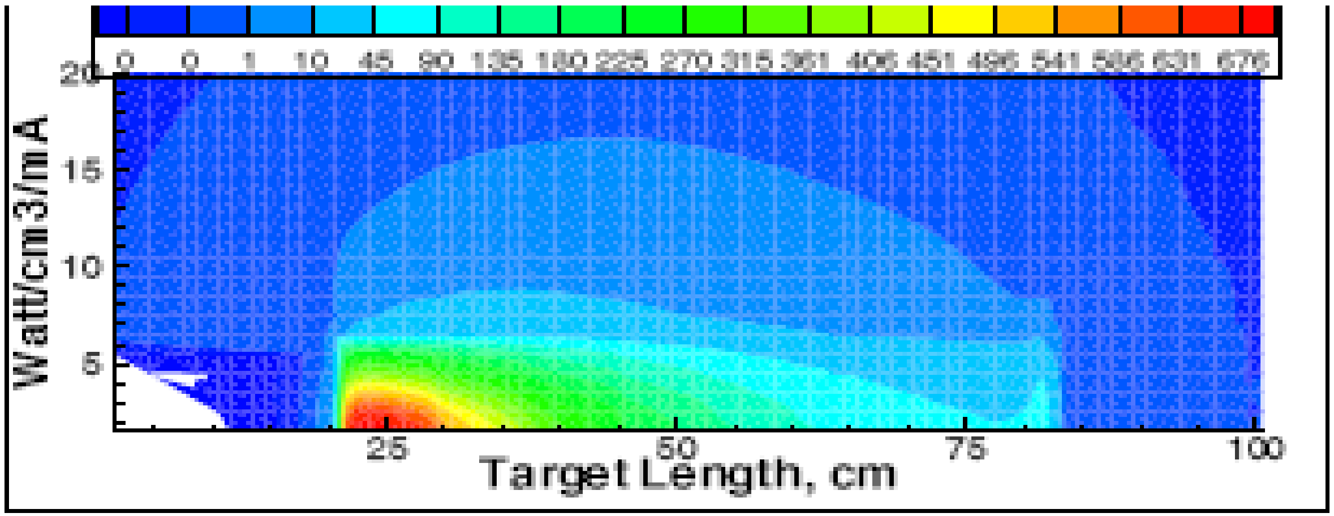


## Heat Density distribution for the cylindrical target (Tin)



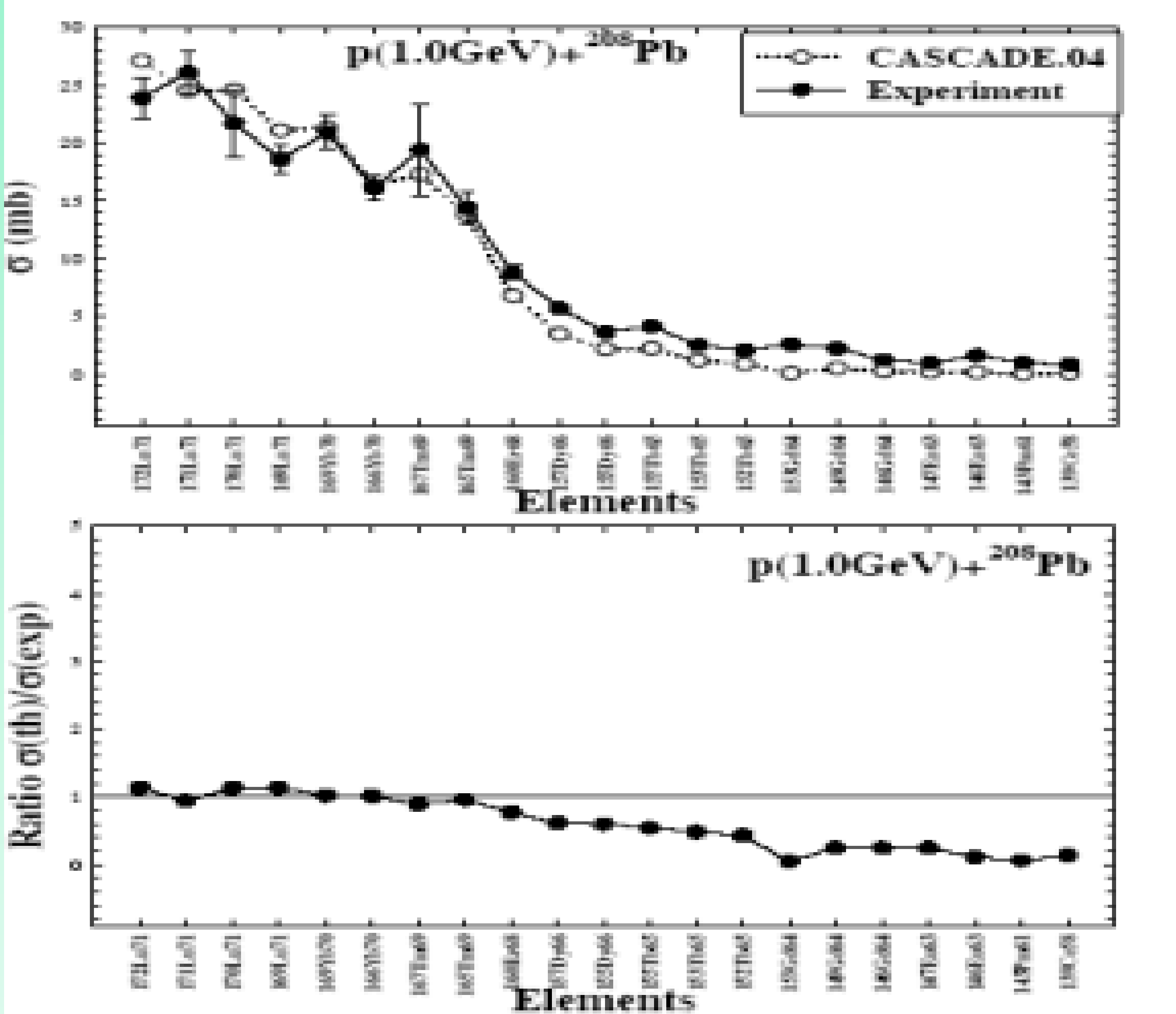

Max 537 watt/cm$^3$ /mA

## Heat Density distribution for the cylindrical target (LBE)

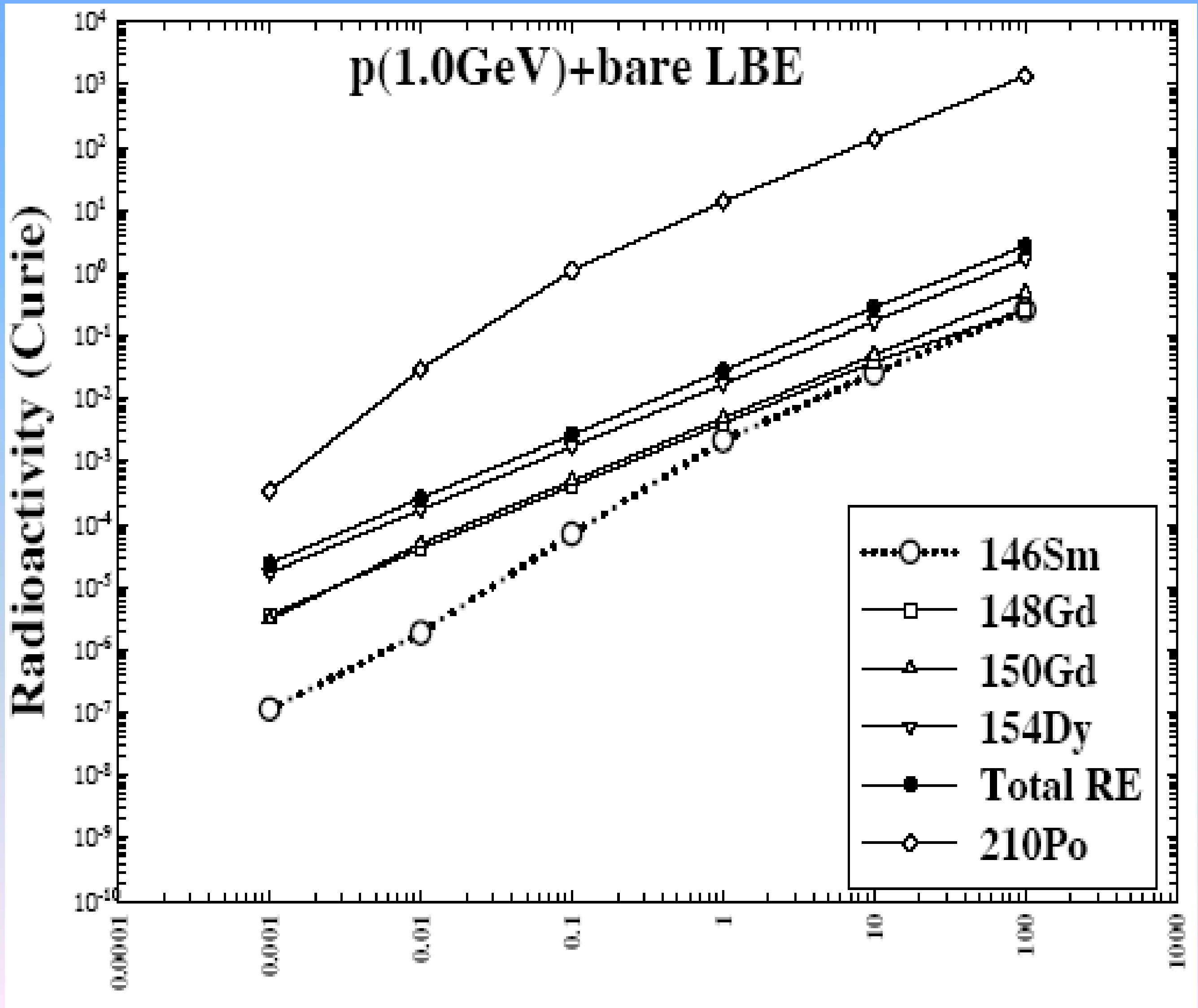



Max 675 watt/cm$^3$/ mA

# Comparison of CASCADE with Data ( p + Pb)



# Production of alpha emitters in p + LBE



# CONCLUSION

**The prediction power of CASCADE.04 is good -**
**Proton spallation data for Tin target well reproduced**

**Tin is a good candidate –**
**devoid of Po and Rare earth alpha emitters**

**Heat and Neutron distributions are more spread over the Target volume in the case of Tin. However, in the case of LBE, distributions are somewhat narrower**

**Issues like corrosion, erosion, DPA etc need to be studied Before final use in systems**