

ERNA:

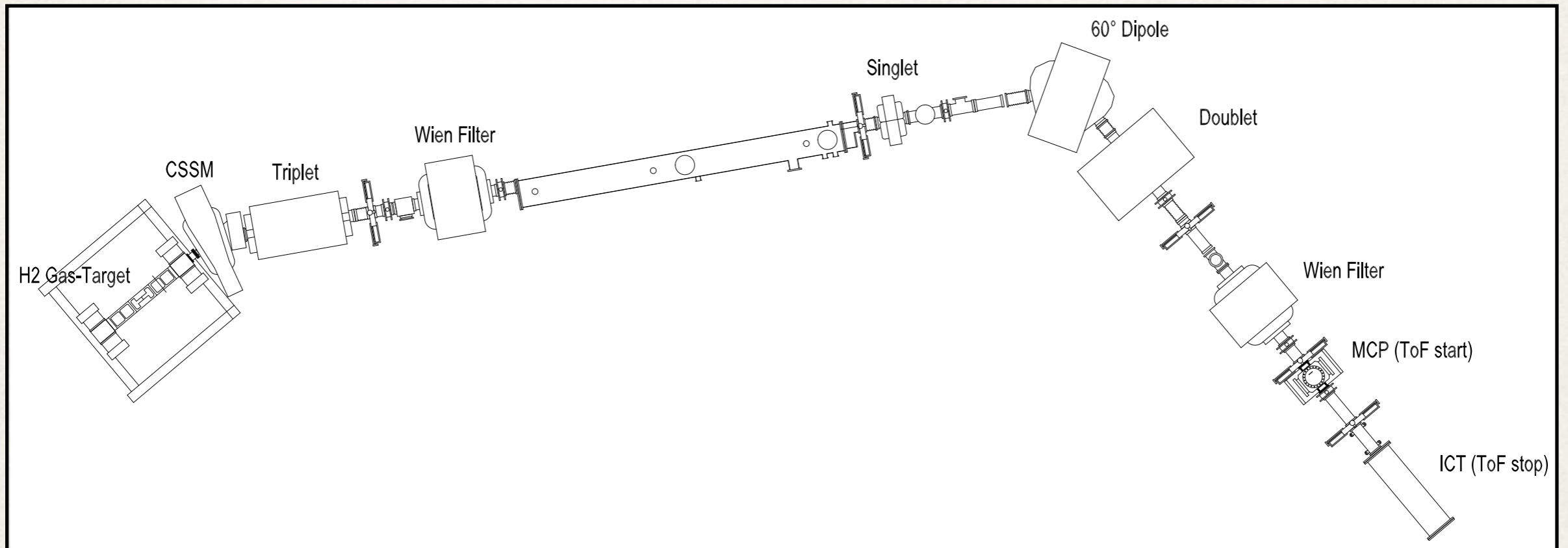
present status and perspectives

A. Di Leva

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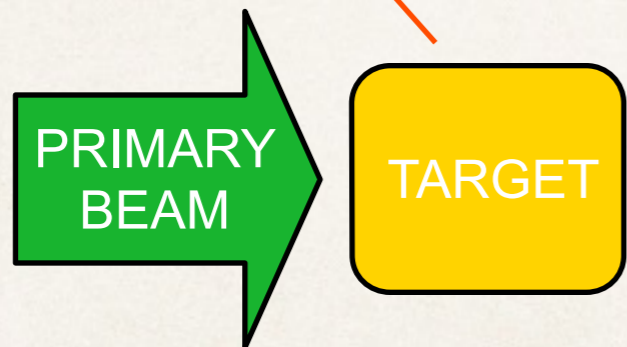
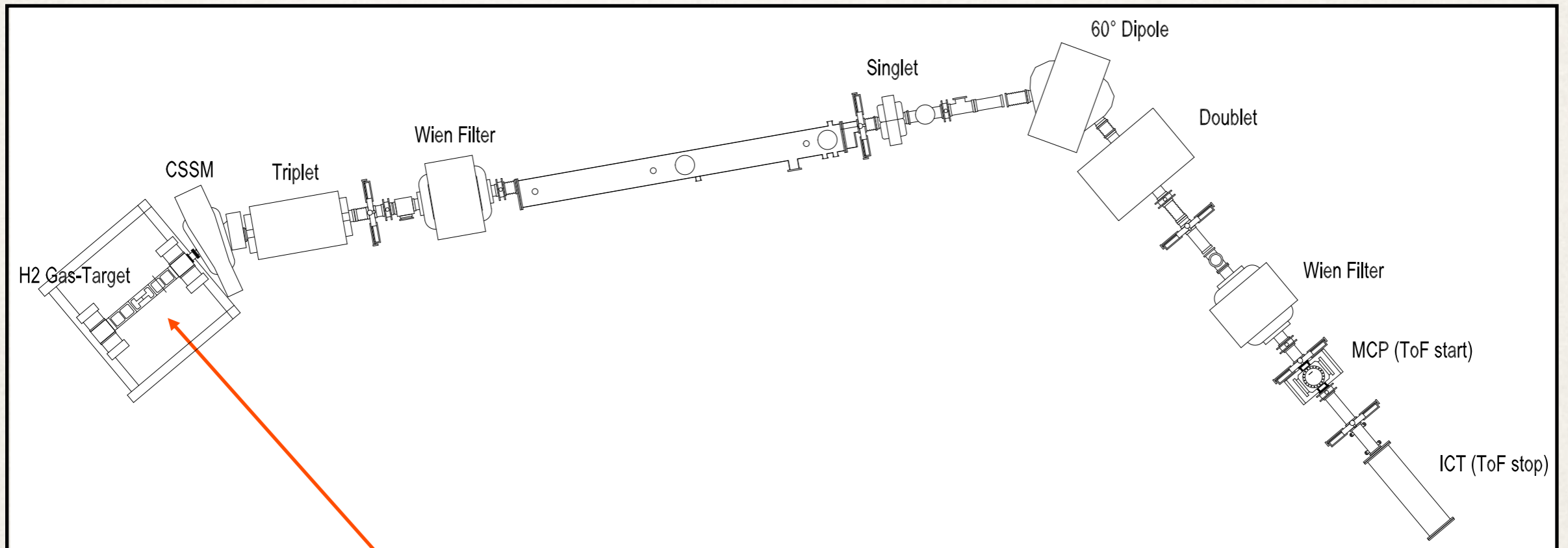
*Padova, 29 Aprile 2015*

# Recoil Mass Separator ERNA

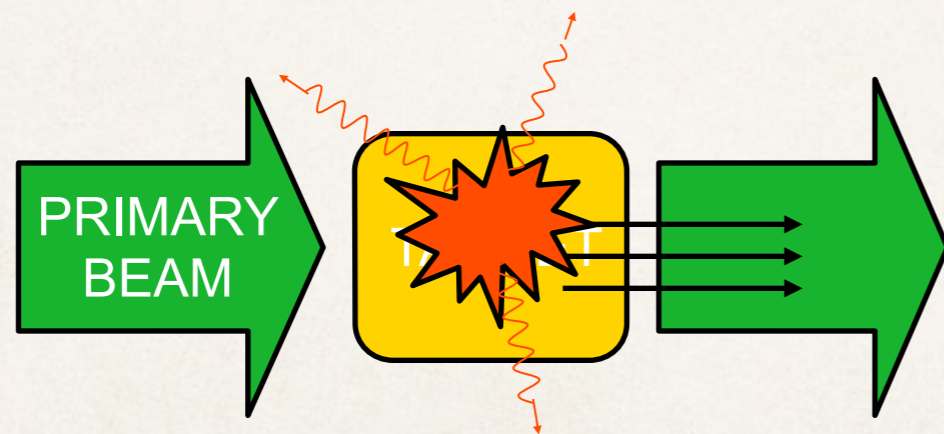
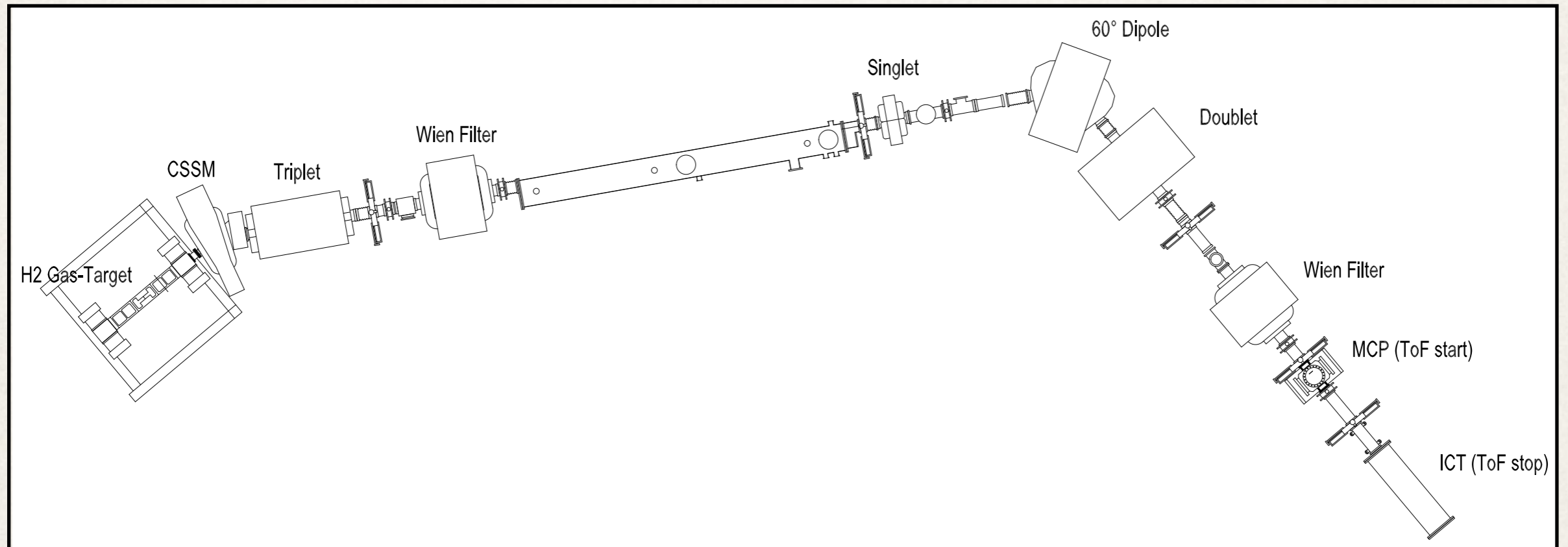




# Recoil Mass Separator ERNA

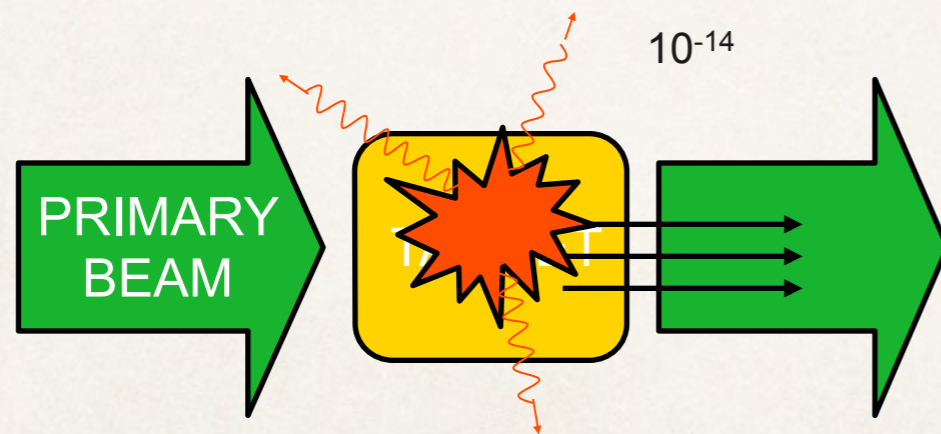
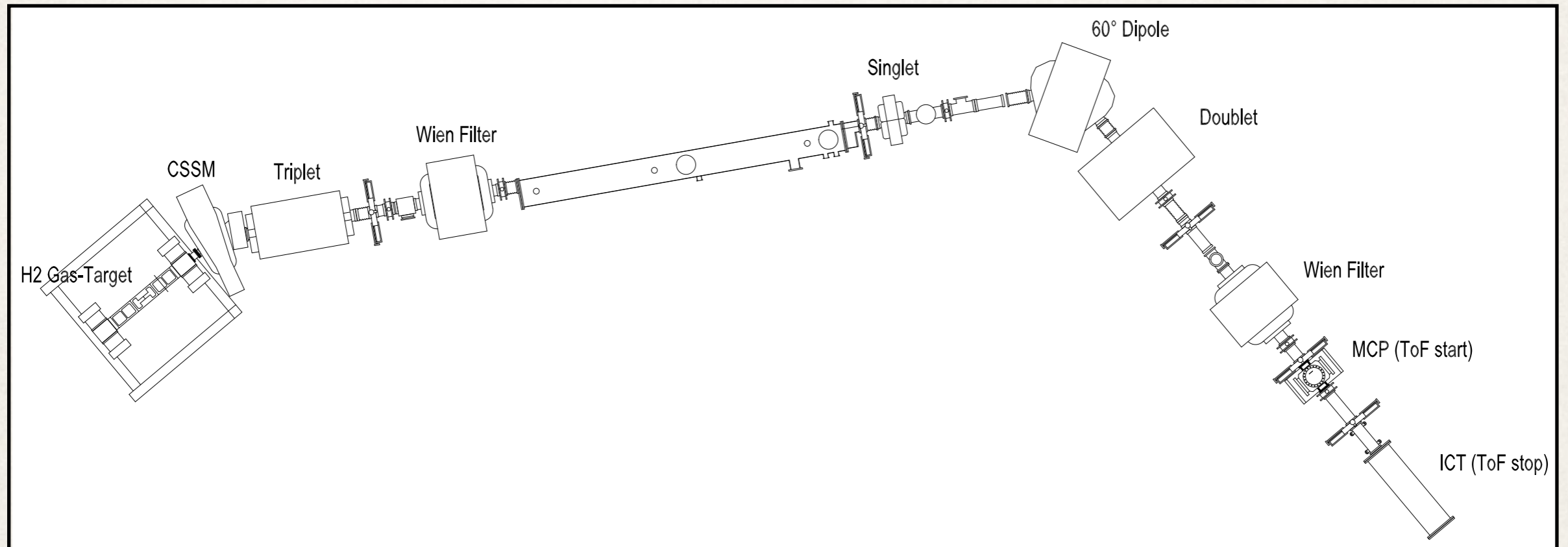


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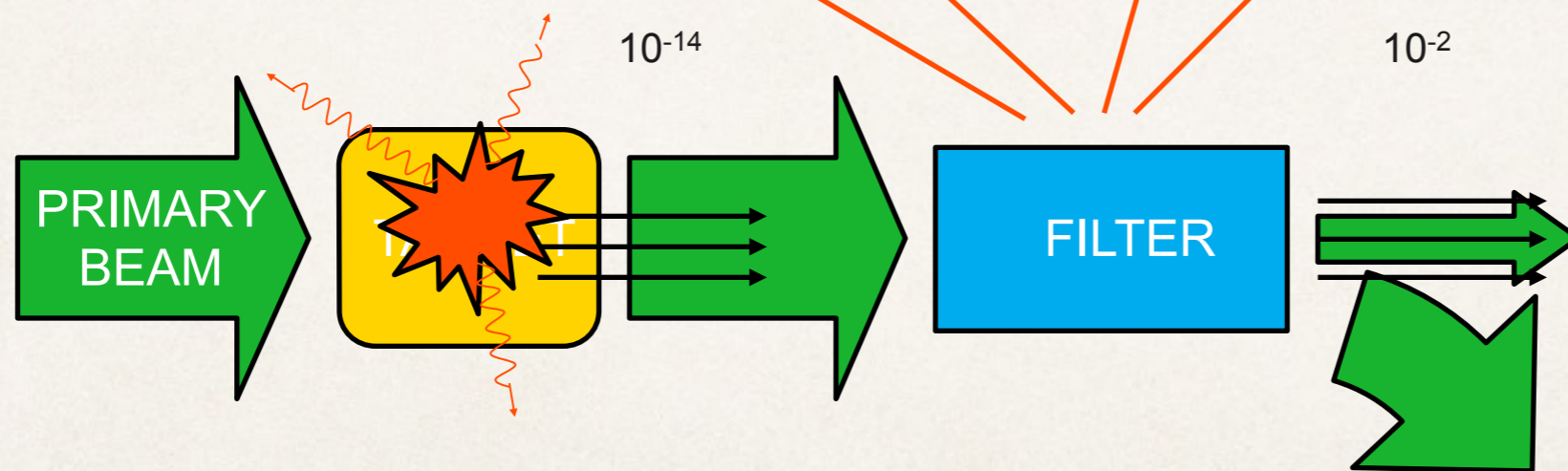
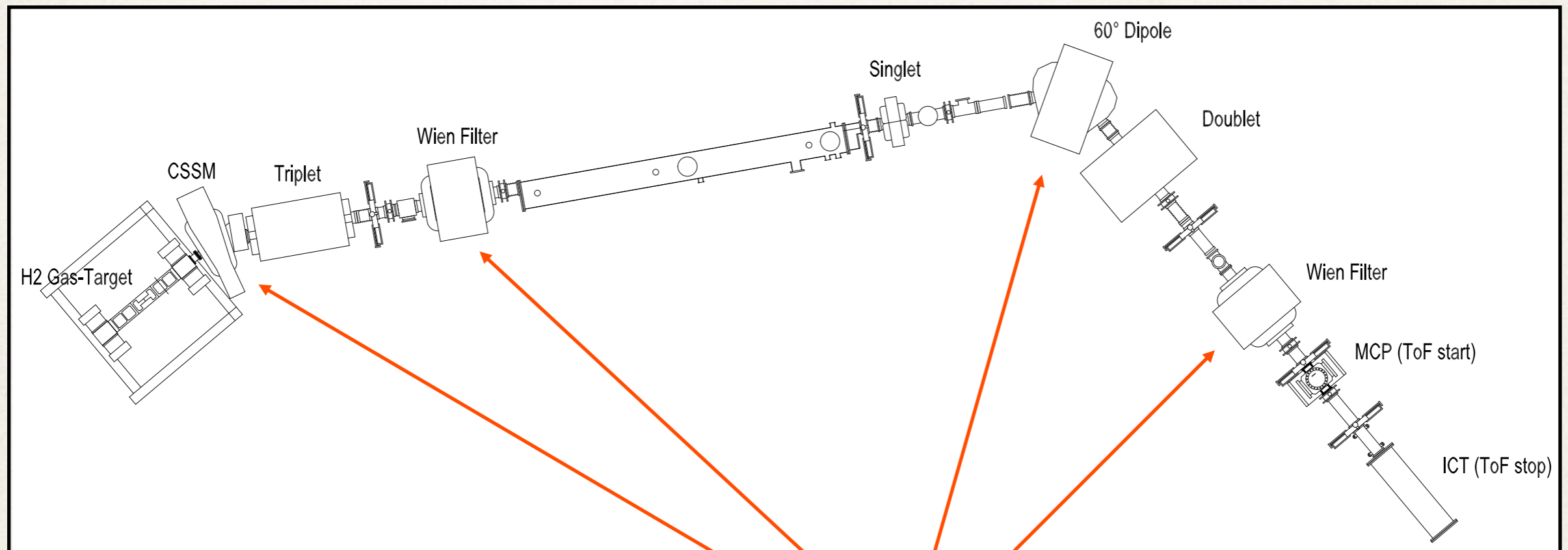




# Recoil Mass Separator ERNA

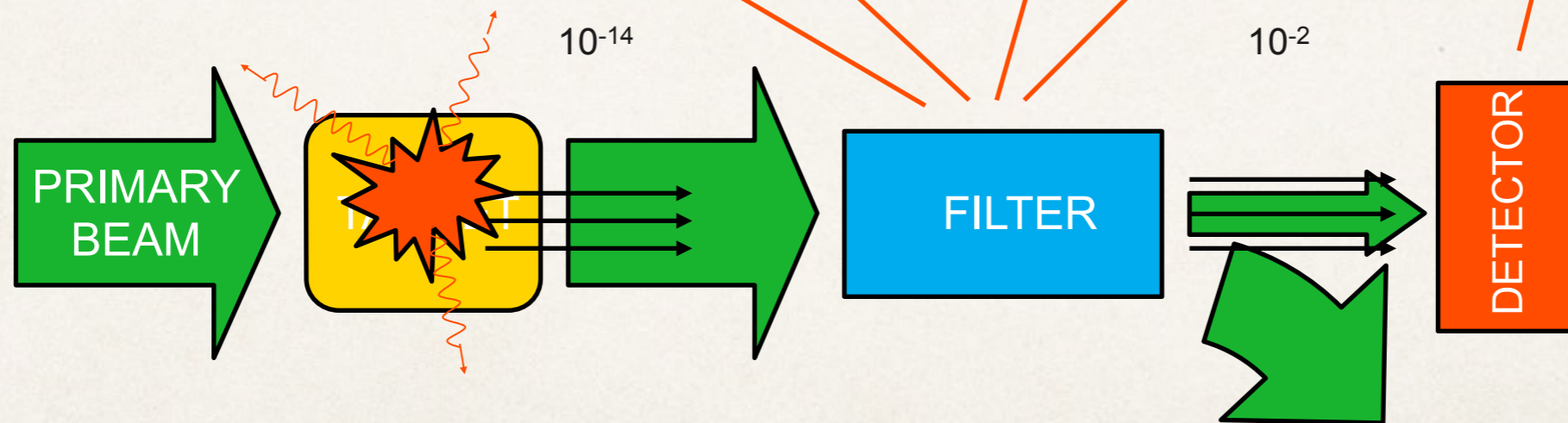
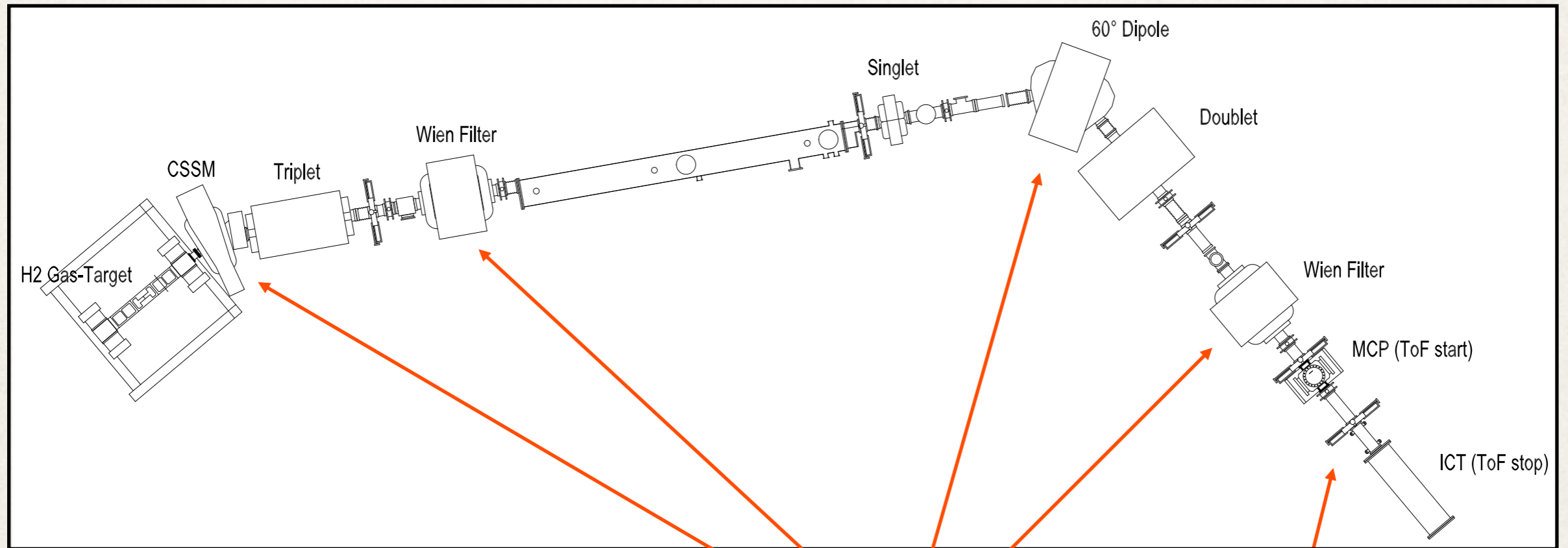


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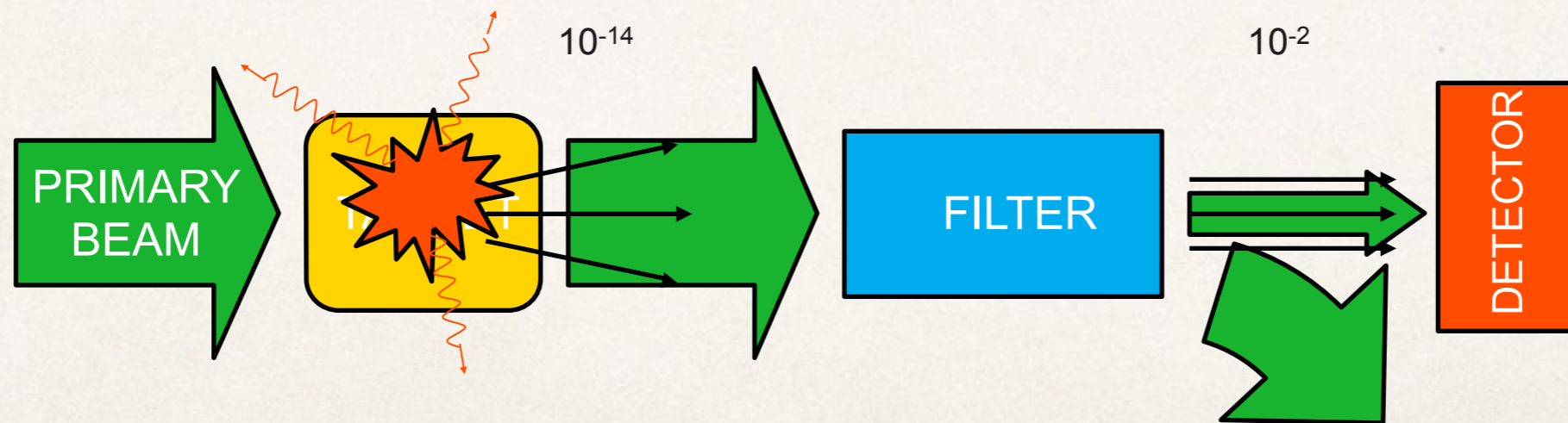
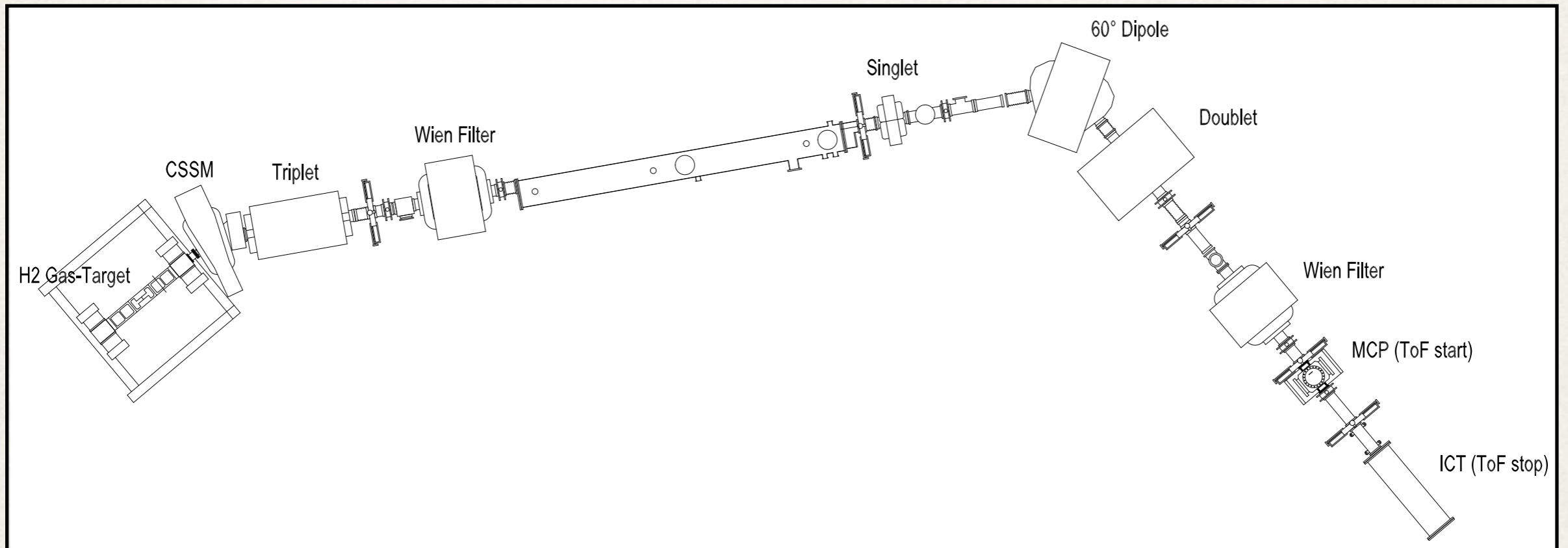




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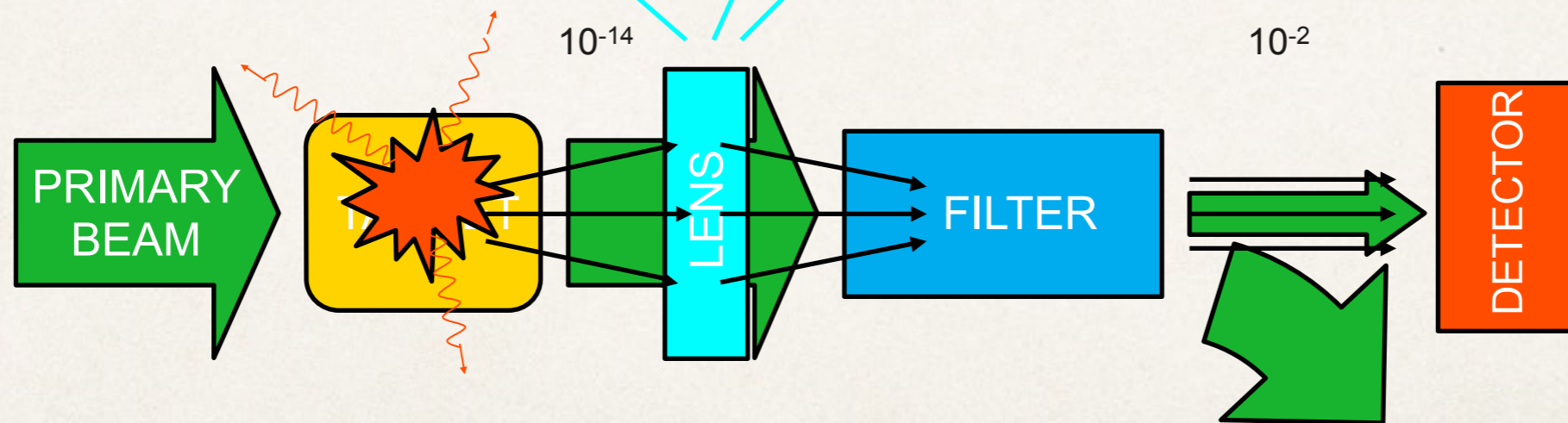
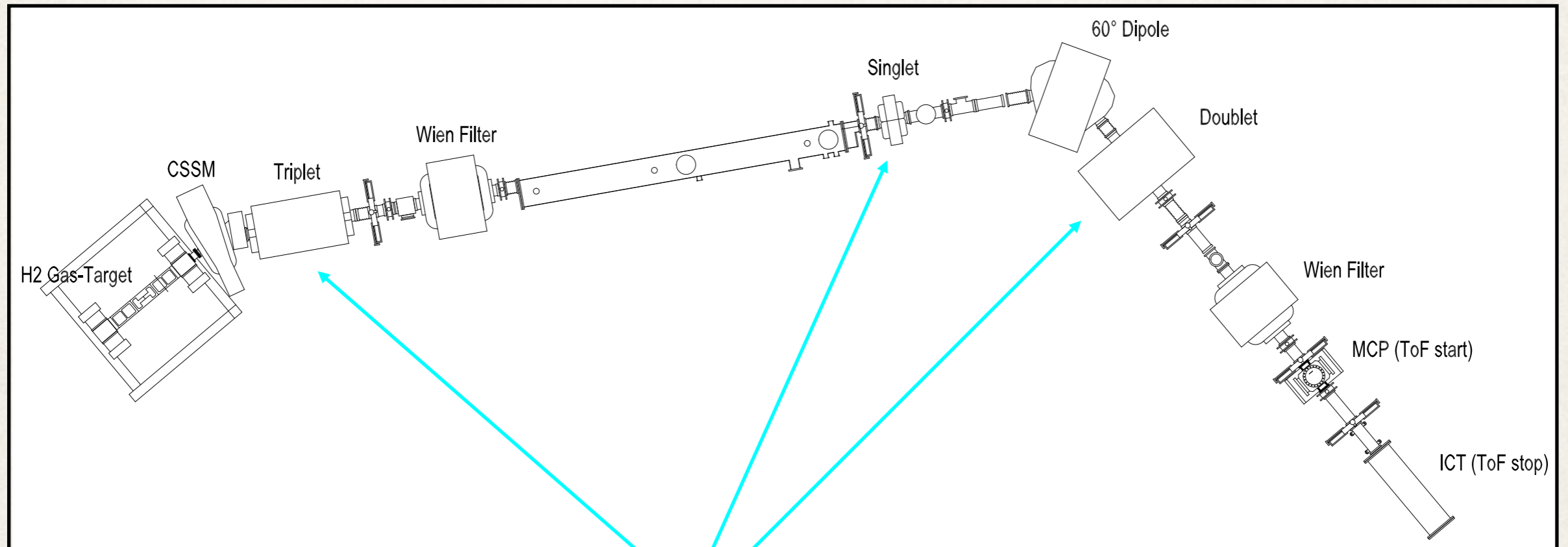


# Recoil Mass Separator ERNA

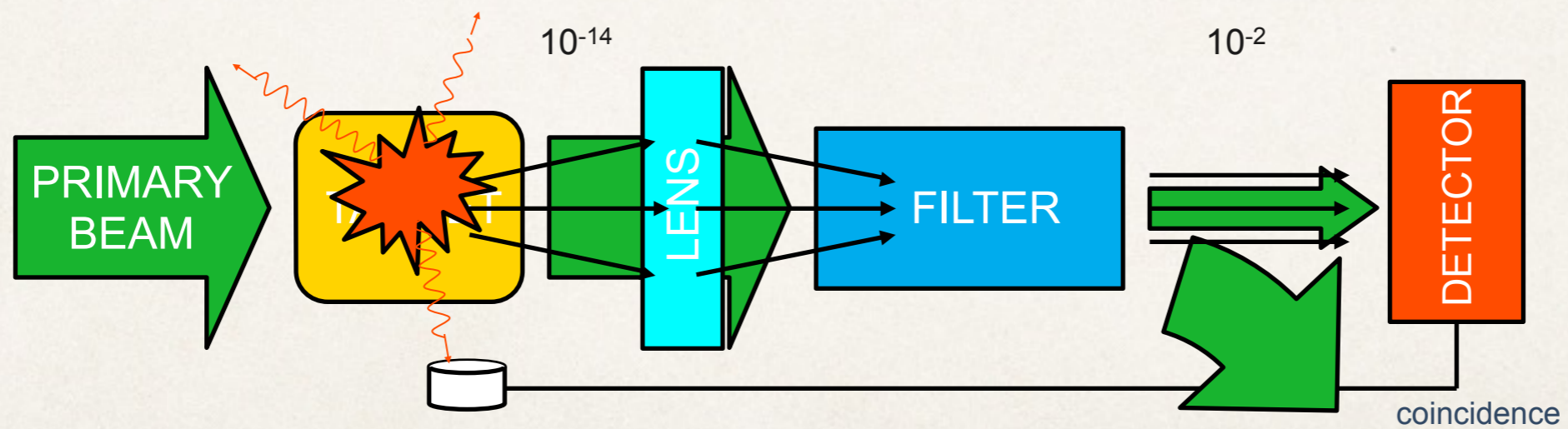
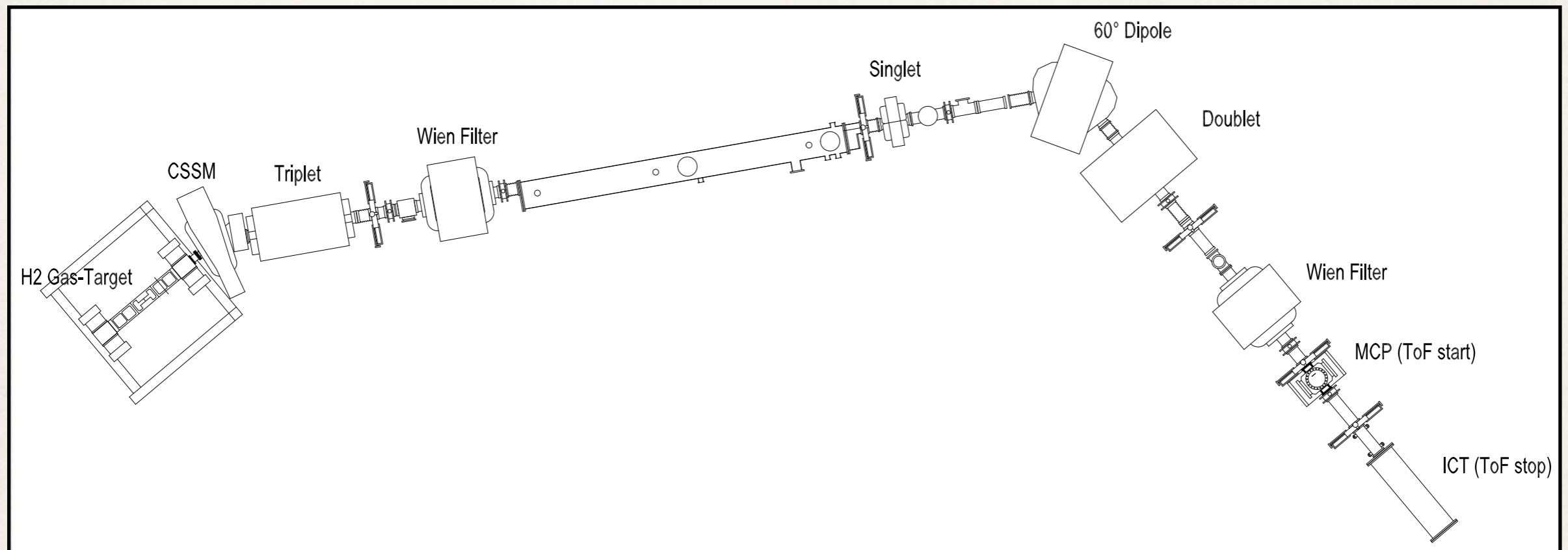




# Recoil Mass Separator ERNA

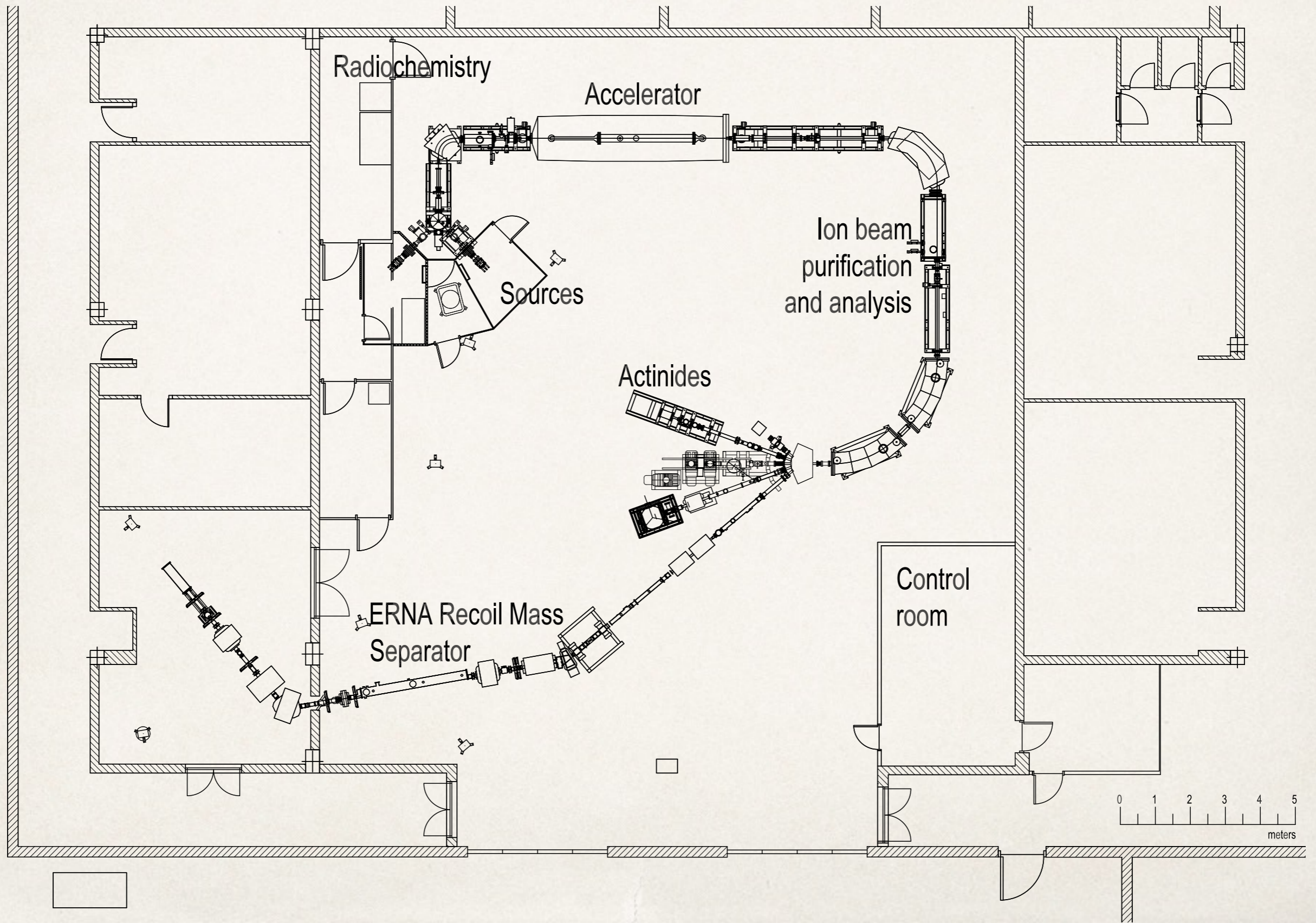


# Recoil Mass Separator ERNA



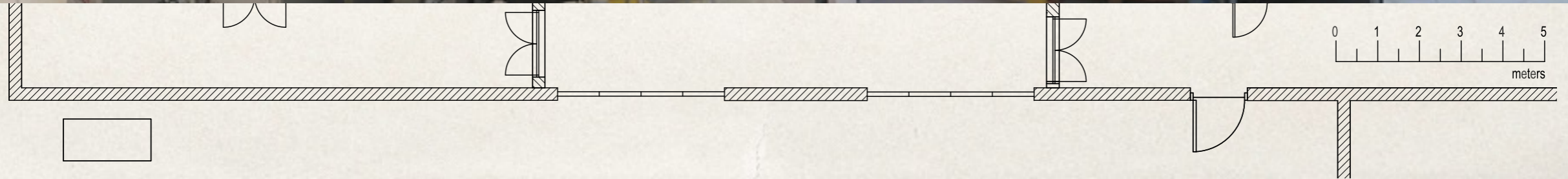
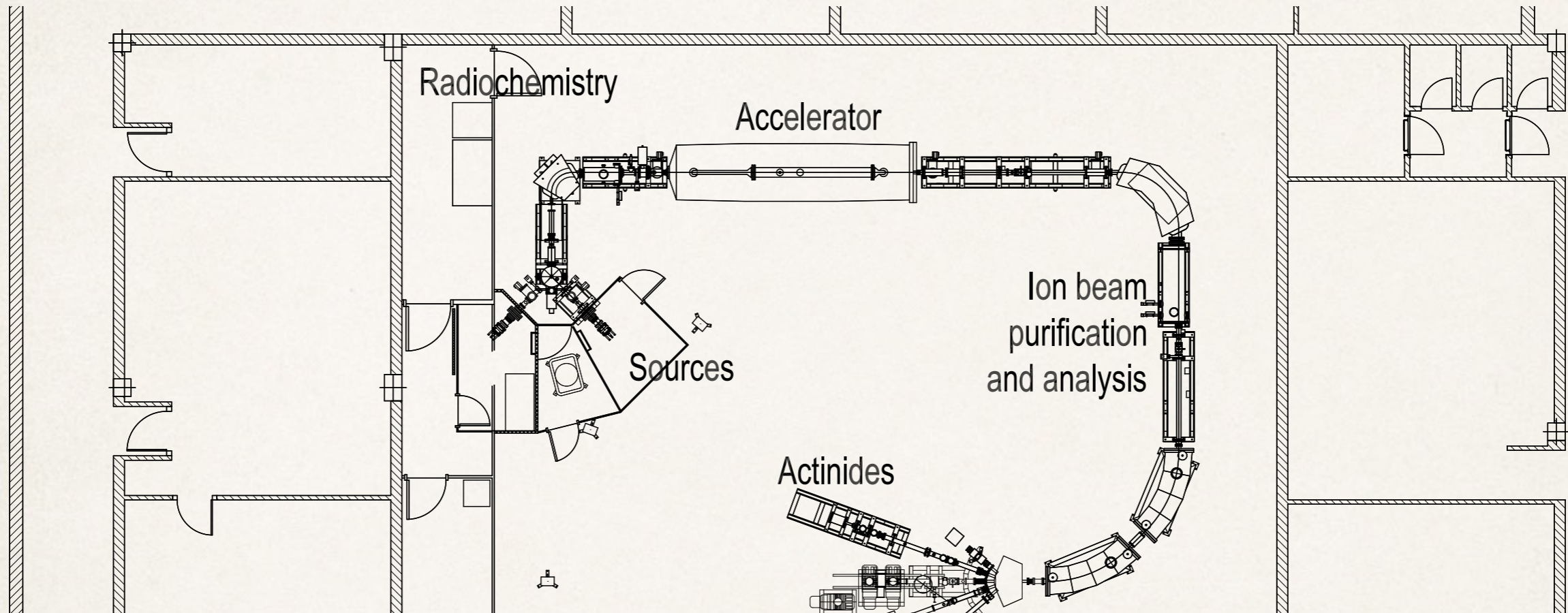


# ERNA at CIRCE





# ERNA at CIRCE





# ERNA experimental program

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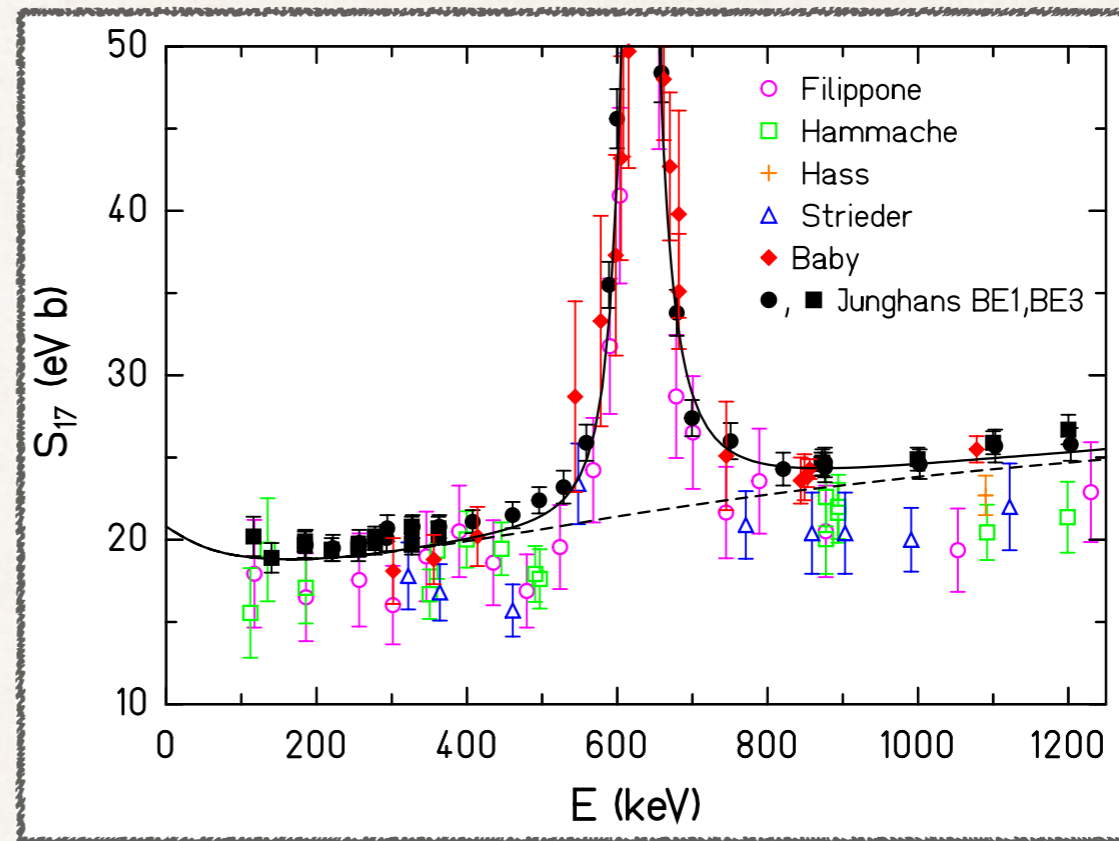
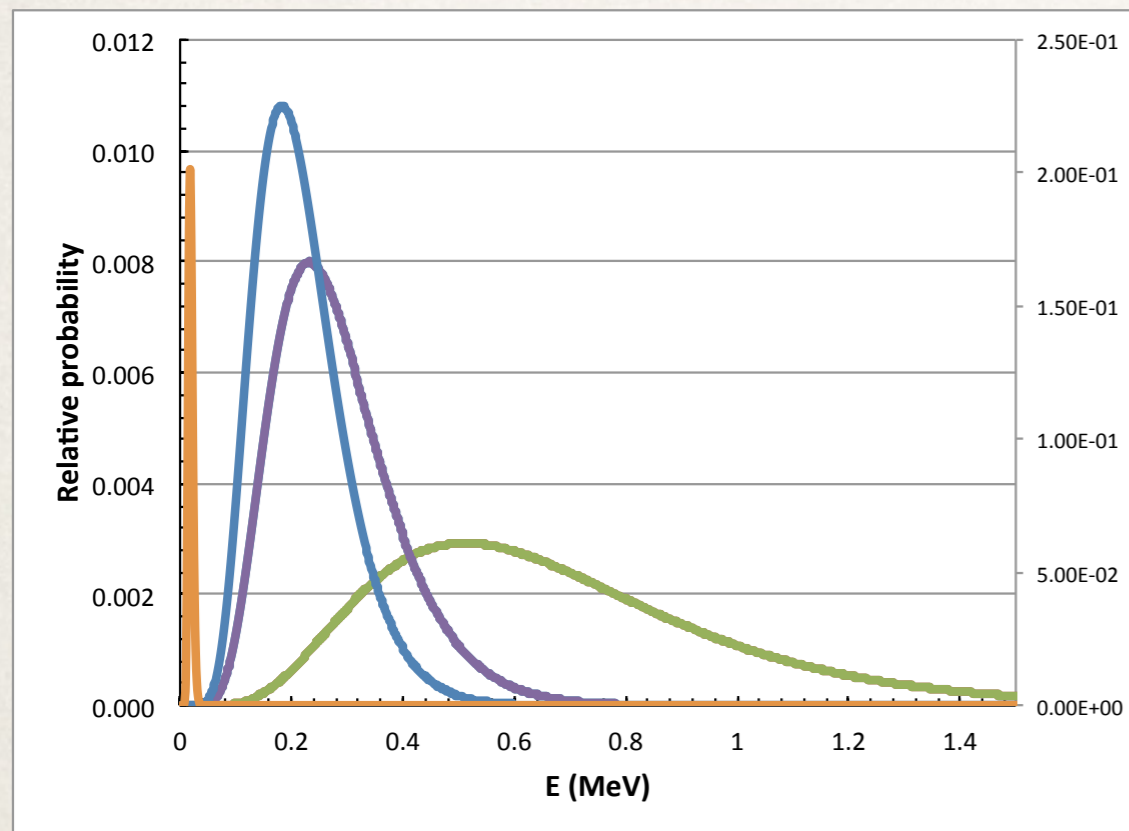
Separator

- \* Quiescent H and He burning:
  - \*  ${}^7\text{Be}(p,\gamma){}^8\text{B}$ 
    - \*  ${}^7\text{Be}$  RIB production
  - \*  ${}^{12}\text{C}(\alpha,\gamma){}^{16}\text{O}$
  - \*  ${}^{16}\text{O}(\alpha,\gamma){}^{20}\text{Ne}$ 
    - \* Jet gas target
- \* AGB  ${}^{19}\text{F}$  nucleosynthesis
  - \*  ${}^{14}\text{N}(\alpha,\gamma){}^{18}\text{F}$
  - \*  ${}^{15}\text{N}(\alpha,\gamma){}^{19}\text{F}$
- \* AMS of Super Heavy Elements

Particle spectroscopy

- \* Advanced burnings
  - \*  ${}^{12}\text{C}({}^{12}\text{C},p){}^{23}\text{Na}$  and  ${}^{12}\text{C}({}^{12}\text{C},\alpha){}^{20}\text{Ne}$
  - \*  ${}^{23}\text{Na}(p,\alpha){}^{20}\text{Ne}$
  - \*  ${}^{19}\text{F}(\alpha,p){}^{22}\text{Na}$

# ${}^7\text{Be}(p,\gamma){}^8\text{B}$



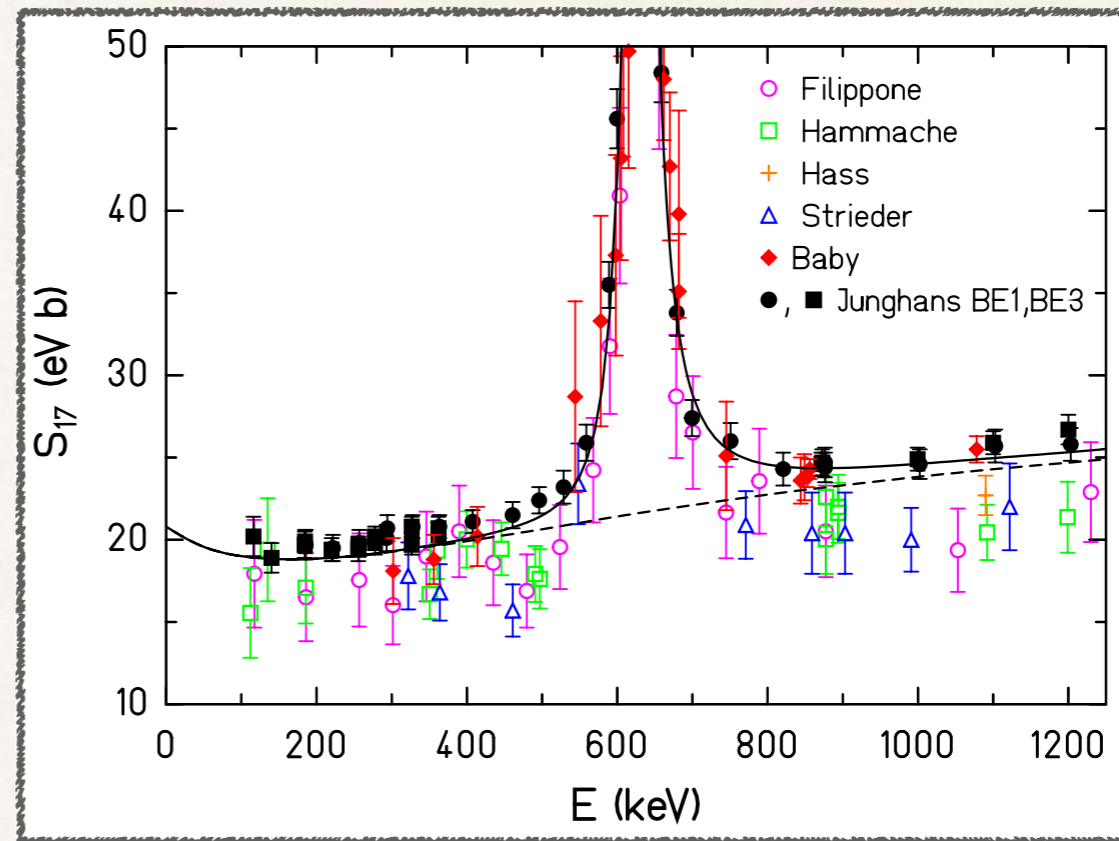
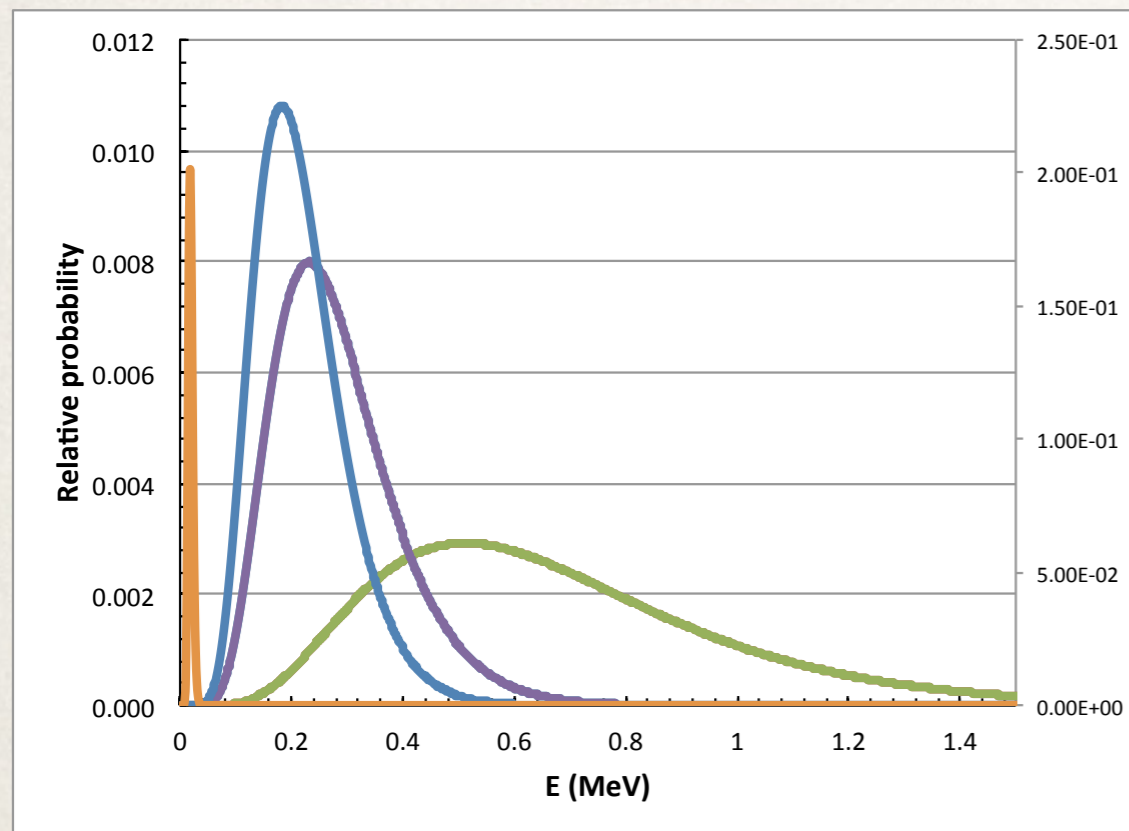
Adelberger et al. Rev.Mod.Phys.83(2011)

Direct measurements: p beam on  ${}^7\text{Be}$  target

Indirect measurements:  ${}^8\text{B}$  Coulomb break-up



# ${}^7\text{Be}(p,\gamma){}^8\text{B}$



Adelberger et al. Rev.Mod.Phys.83(2011)

Direct measurements: p beam on  ${}^7\text{Be}$  target

Indirect measurements:  ${}^8\text{B}$  Coulomb break-up

Direct Measurements		Indirect Measurements	
Strieder et al. NuPhA 696(2001) –	$S(0) = 18.4 \pm 1.6$ eVb	Azhari et al. PRL 82 (1999) - ANC	$S(0) = 17.8 \pm 2.8$ eVb
Hammache et al. PRL 86(2001) –	$S(0) = 18.8 \pm 1.7$ eVb	Tabacaru et al. PRC 73(2006) - ANC	$S(0) = 18.0 \pm 1.8$ eVb
Junghans et al. PRC 68(2003) – Seattle	$S(0) = 21.4 \pm 0.6 \pm 0.6$ eVb	Schumann et al. PRC 73(2006) - CD	$S(0) = 20.6 \pm 0.8 \pm 1.2$ eVb
Baby et al. PRC 67 (2003) – Weizmann	$S(0) = 21.2 \pm 0.6$ eVb		

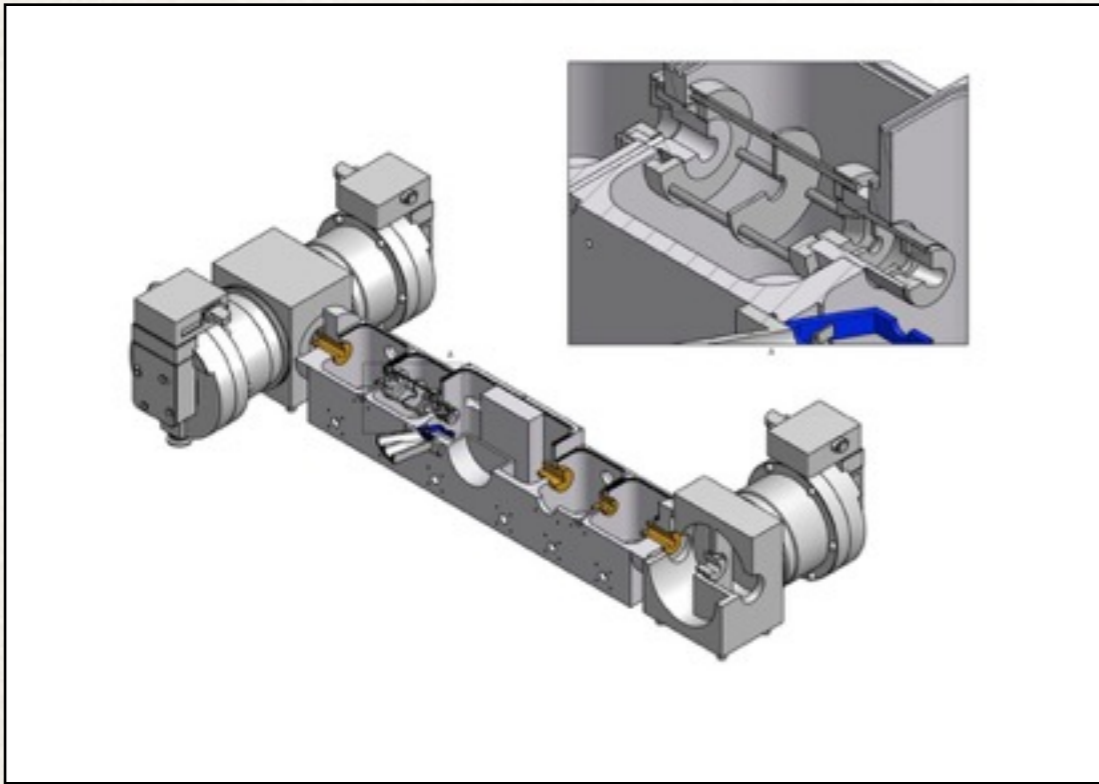
# H<sub>2</sub> extended gas target

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# H<sub>2</sub> extended gas target

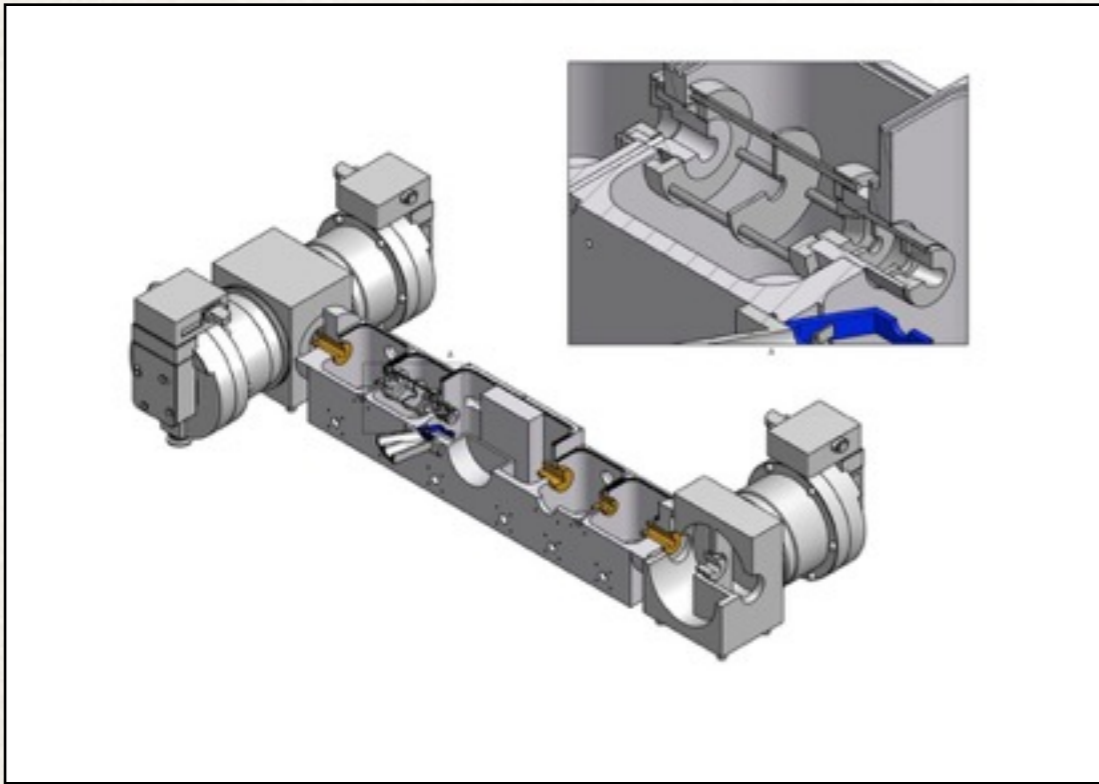
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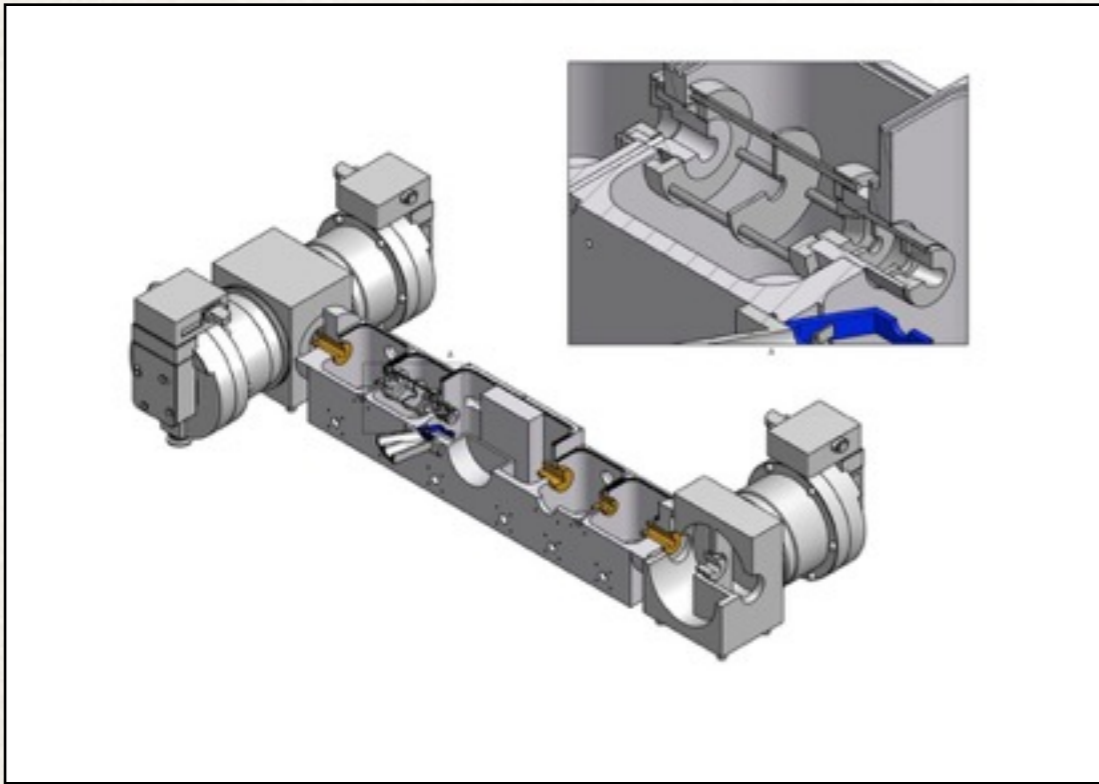
# H<sub>2</sub> extended gas target

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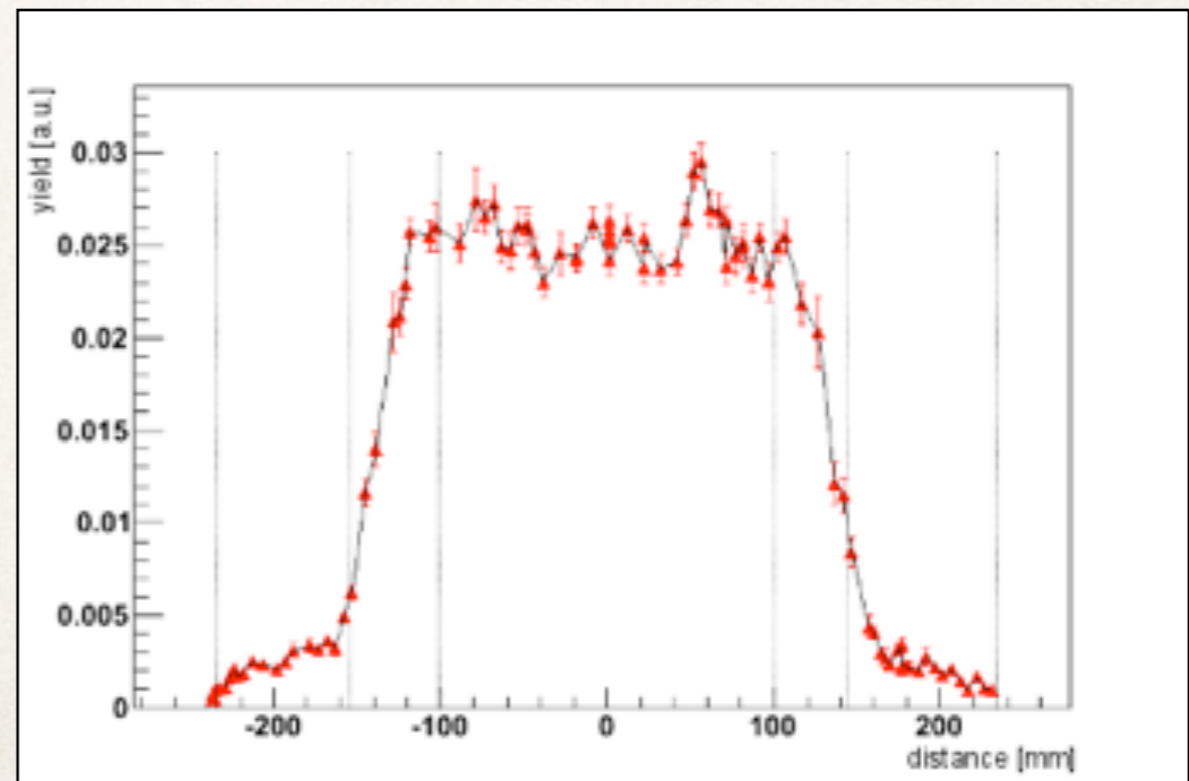




# H<sub>2</sub> extended gas target



thickness up to  $1\text{E}19$  atoms/cm<sup>2</sup>,  
effective length 29.8 cm





# ${}^7\text{Be}$ beam

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hot chemistry

$${}^7\text{Be}/{}^7\text{Li} \approx 1/1$$



cathodes production



beam from SNICS source



# $^7\text{Be}$ beam

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$^7\text{Li}(p,n)^7\text{Be}$  @  $\sim 11.4\text{MeV} \rightarrow ^7\text{Be}/^7\text{Li} \approx 10^{-7}-10^{-9}$



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hot chemistry

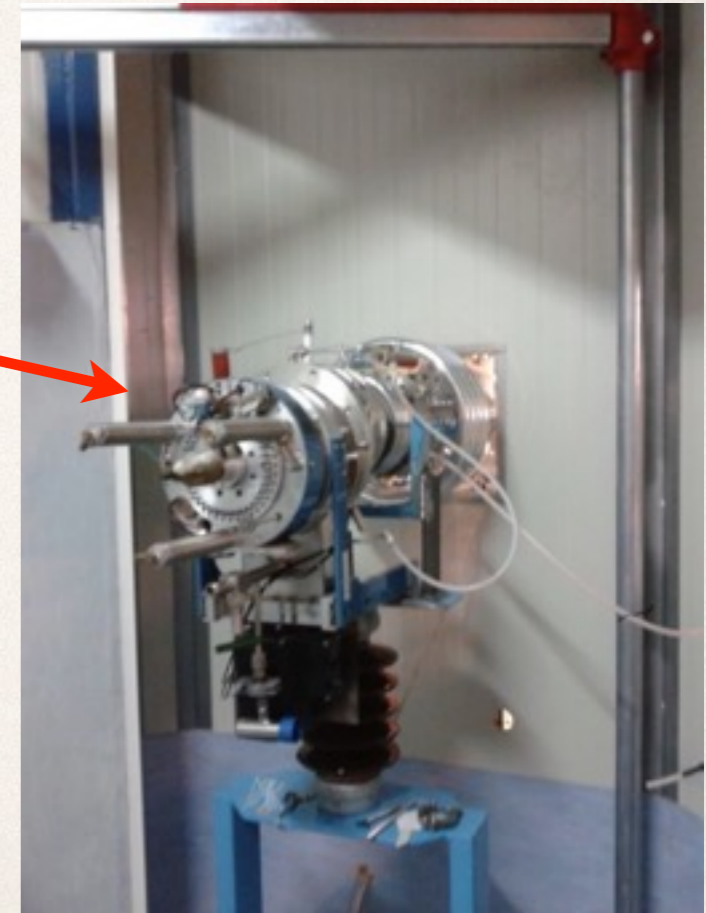
${}^7\text{Be}/{}^7\text{Li} \approx 1/1$



cathodes production

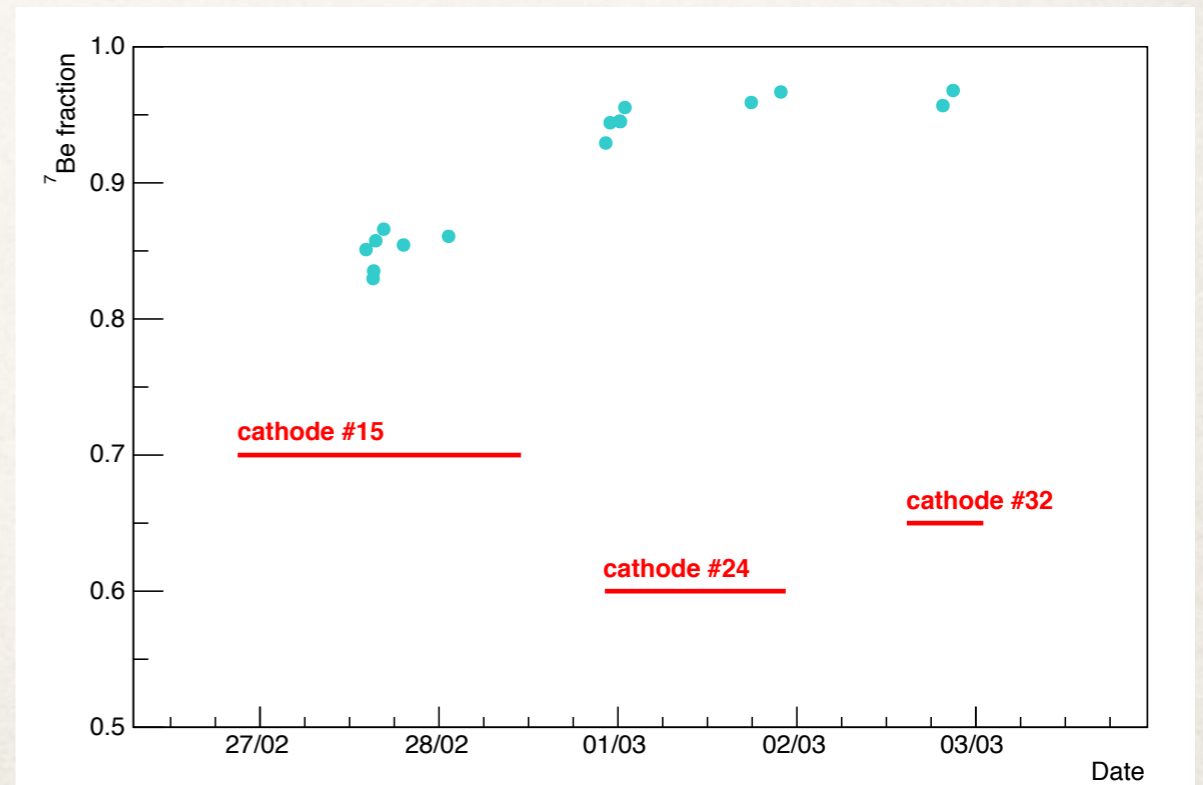
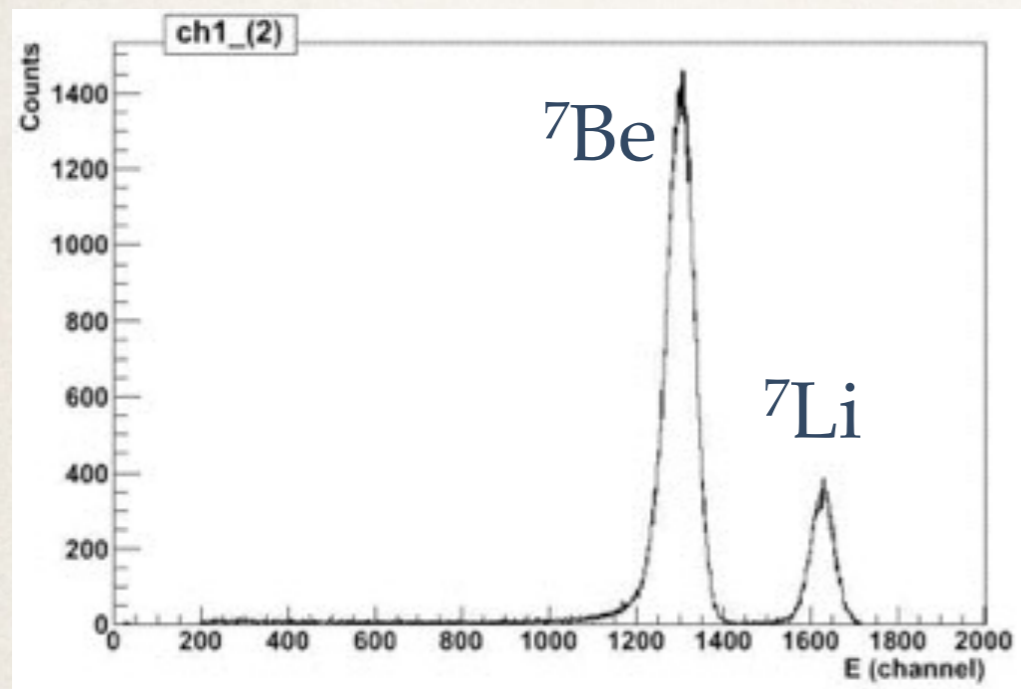
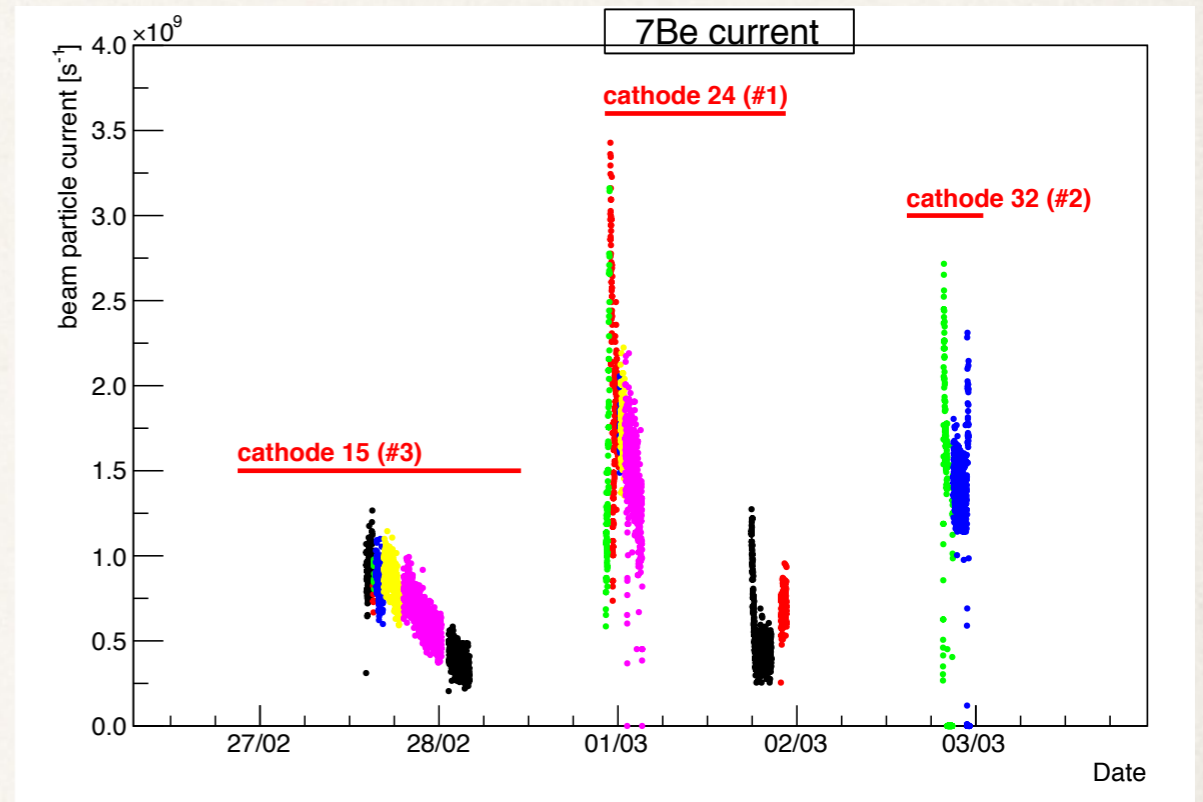
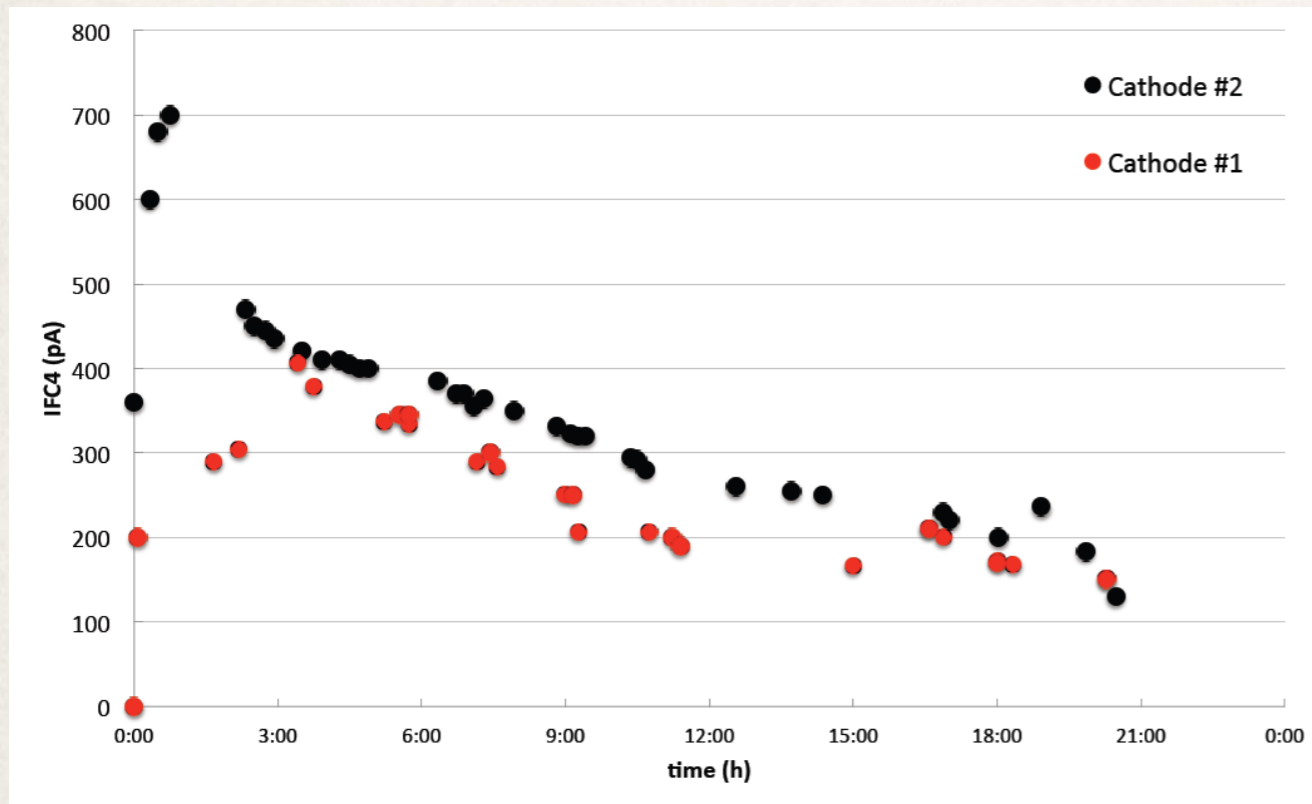


beam from SNICS source

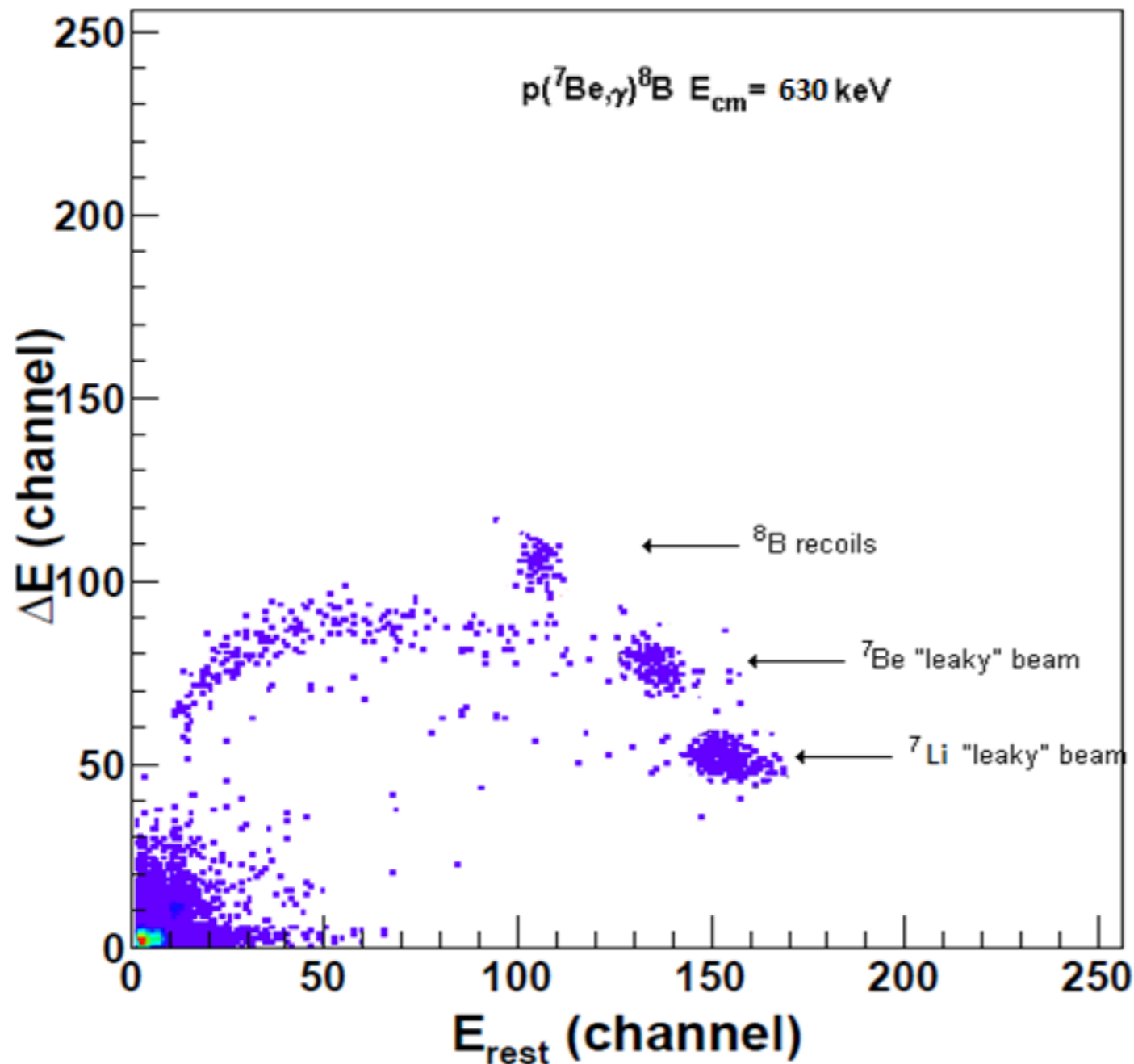




# $^7\text{Be}$ beam



# ${}^7\text{Be}(p,\gamma){}^8\text{B}$ measurements



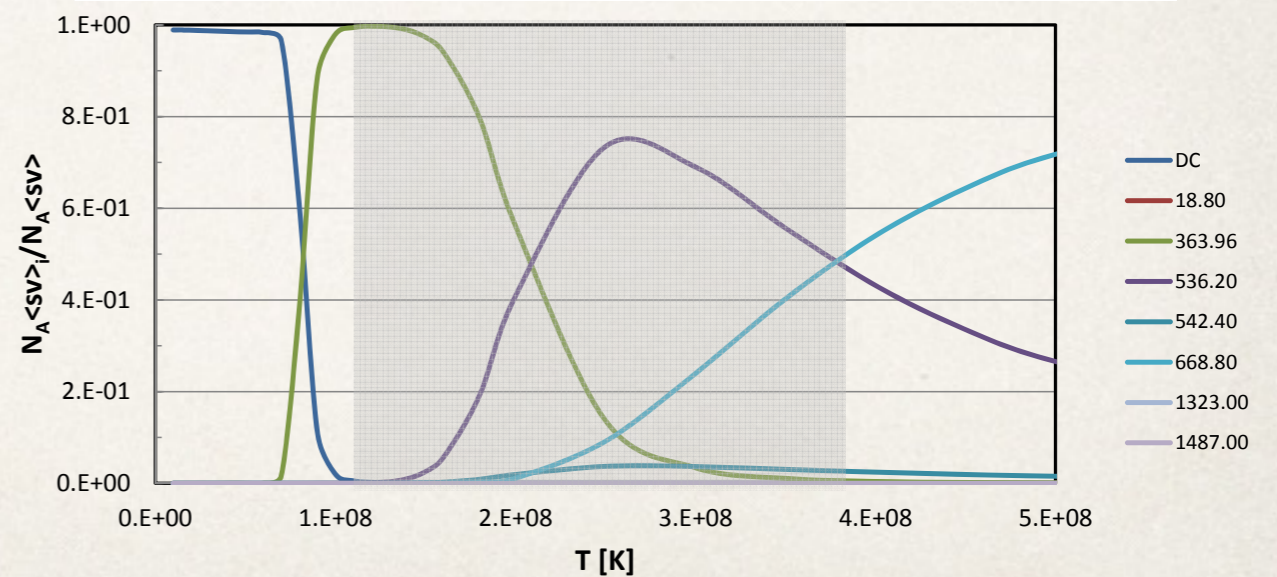
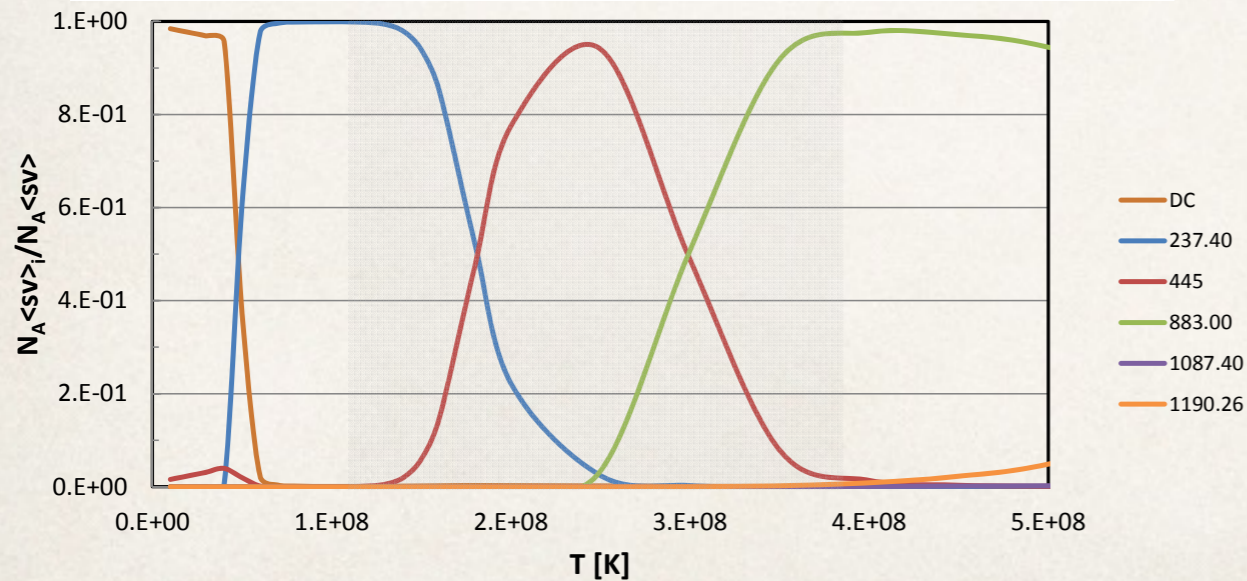
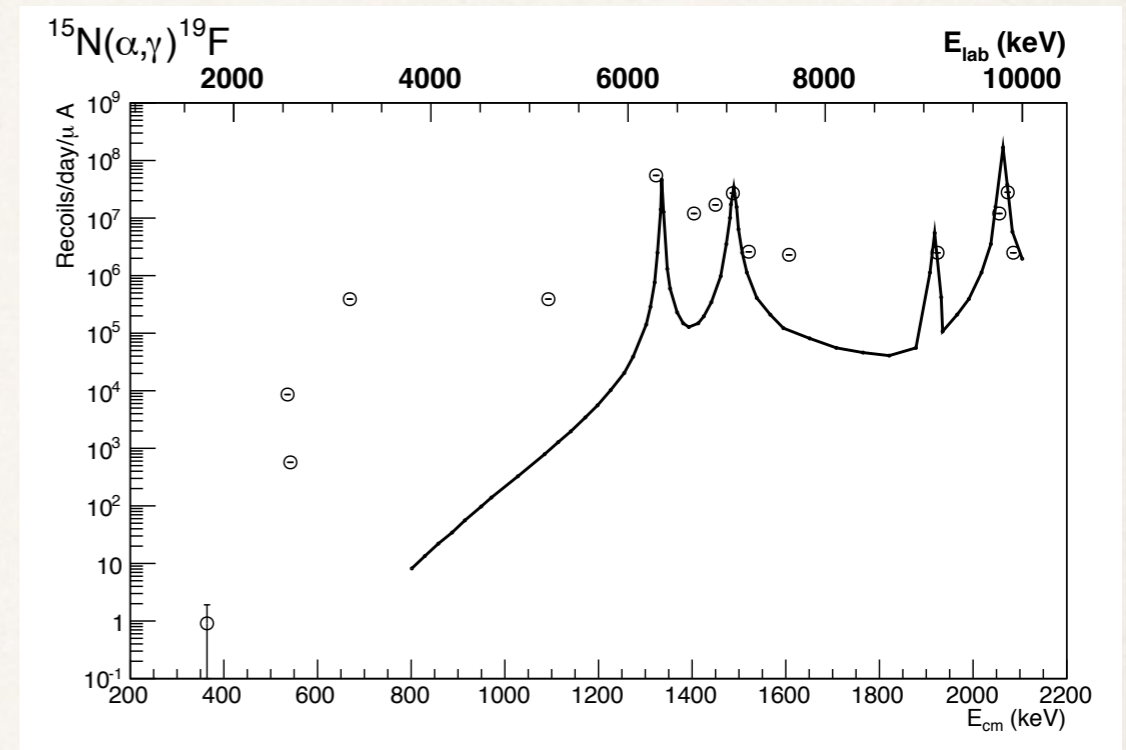
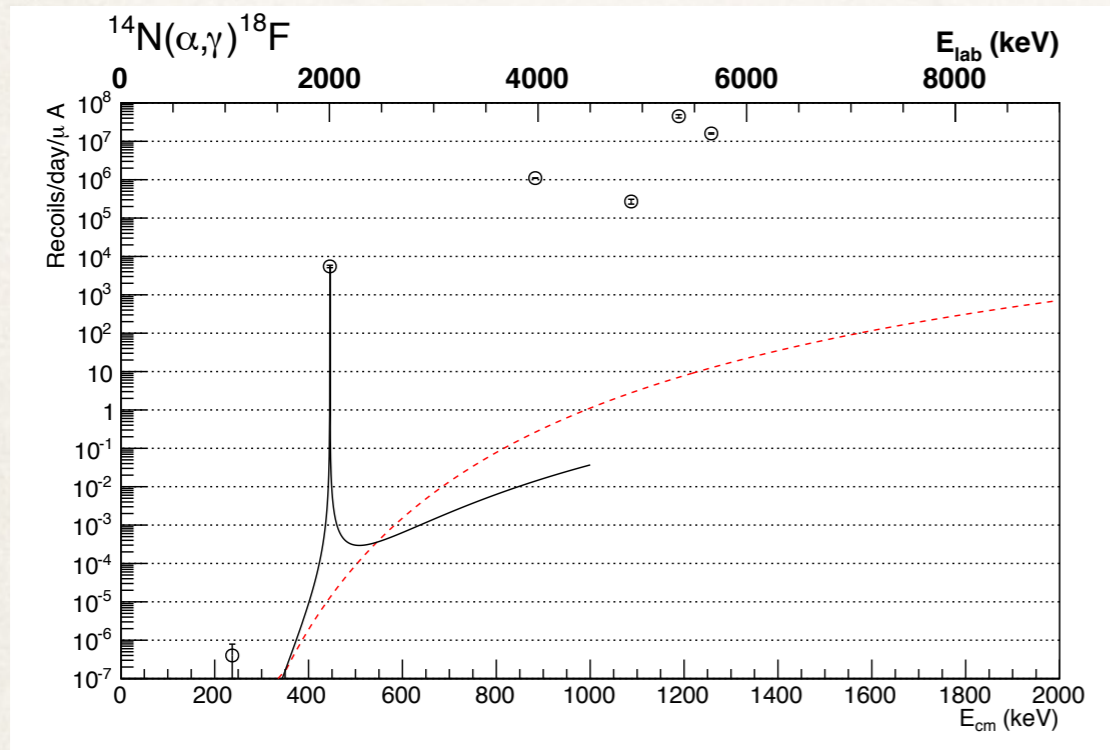
First run:  
ca. 36 h  
630, 660, 690 keV  
>150 counts



# $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ and $^{15}\text{N}(\alpha,\gamma)^{19}\text{F}$

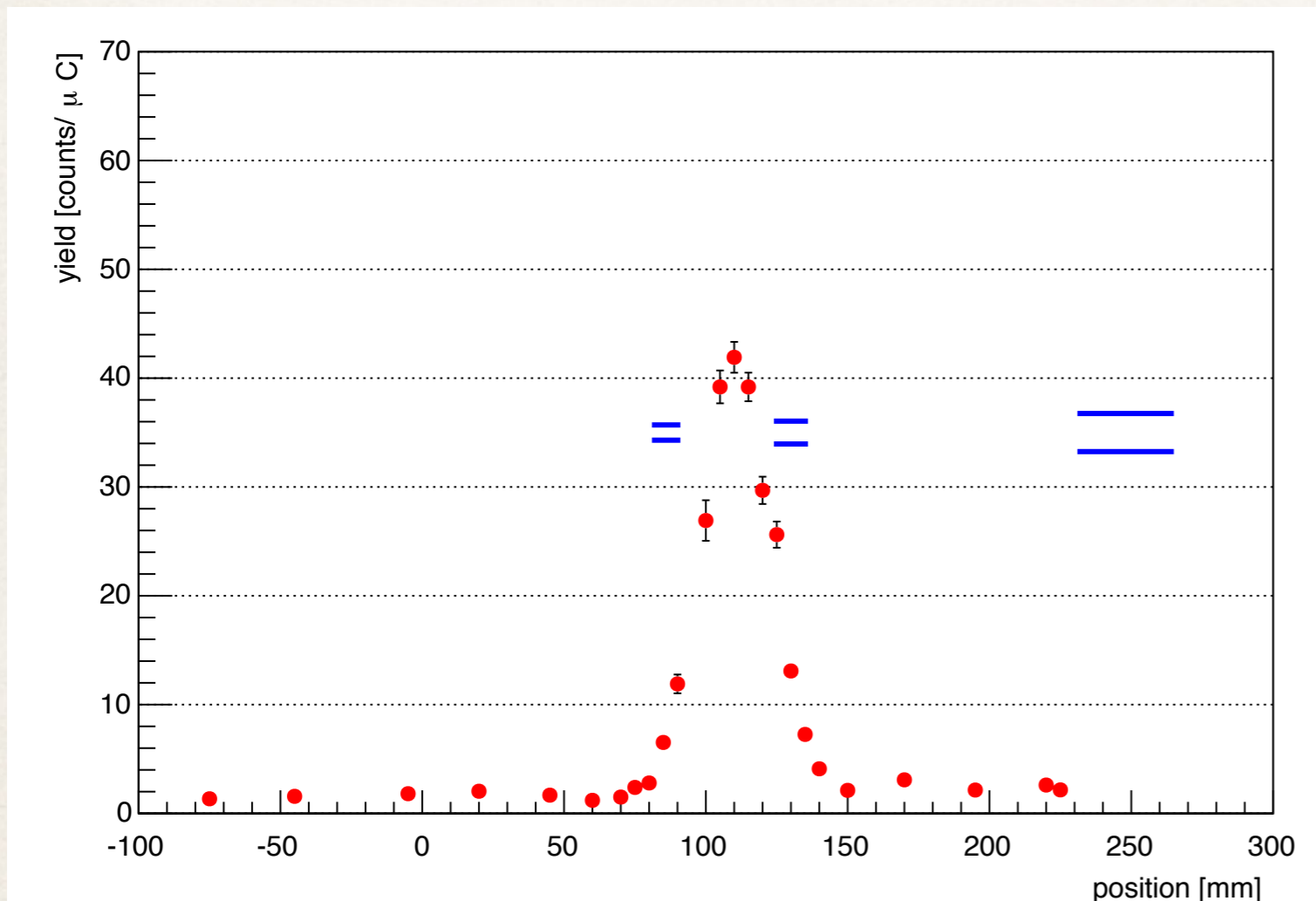
$^{13}\text{C}(\alpha,n)^{16}\text{O}$

$^{14}\text{N}(n,p)^{14}\text{C}(\alpha,\gamma)^{18}\text{O}(p,\alpha)^{15}\text{N}(\alpha,\gamma)^{19}\text{F}$



# $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ and $^{15}\text{N}(\alpha,\gamma)^{19}\text{F}$

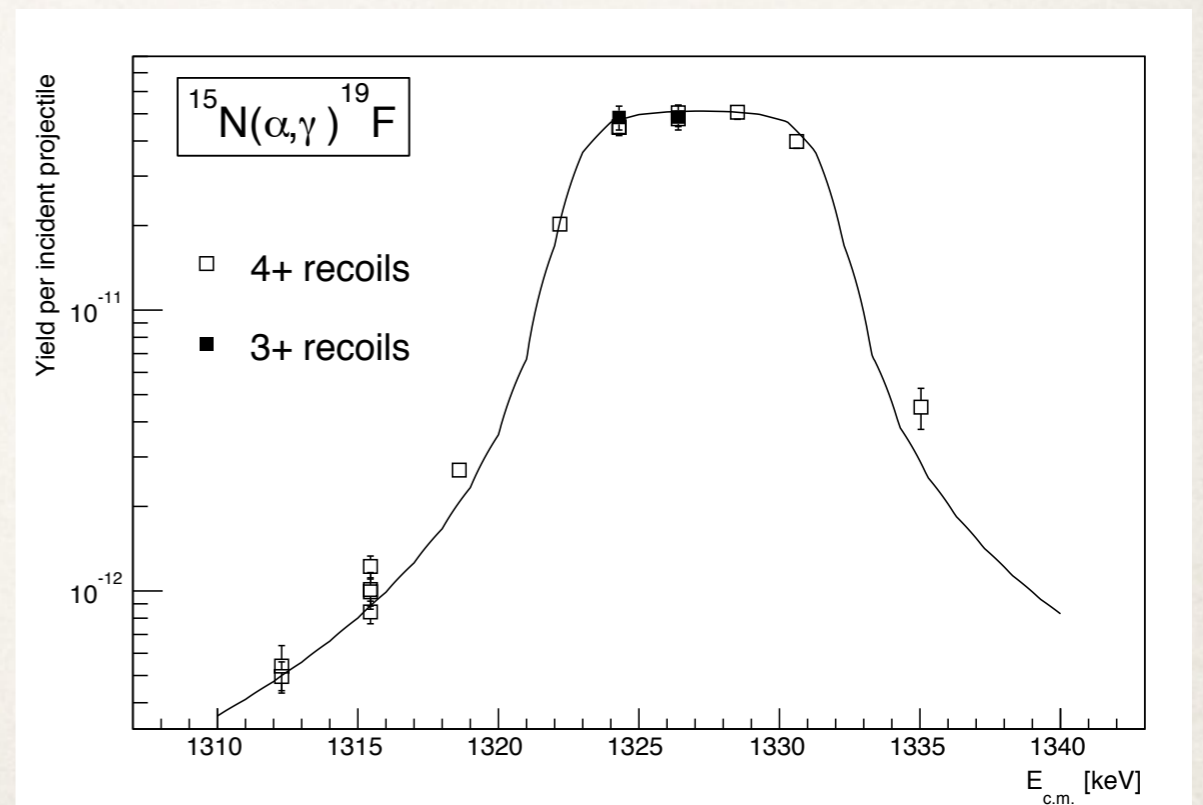
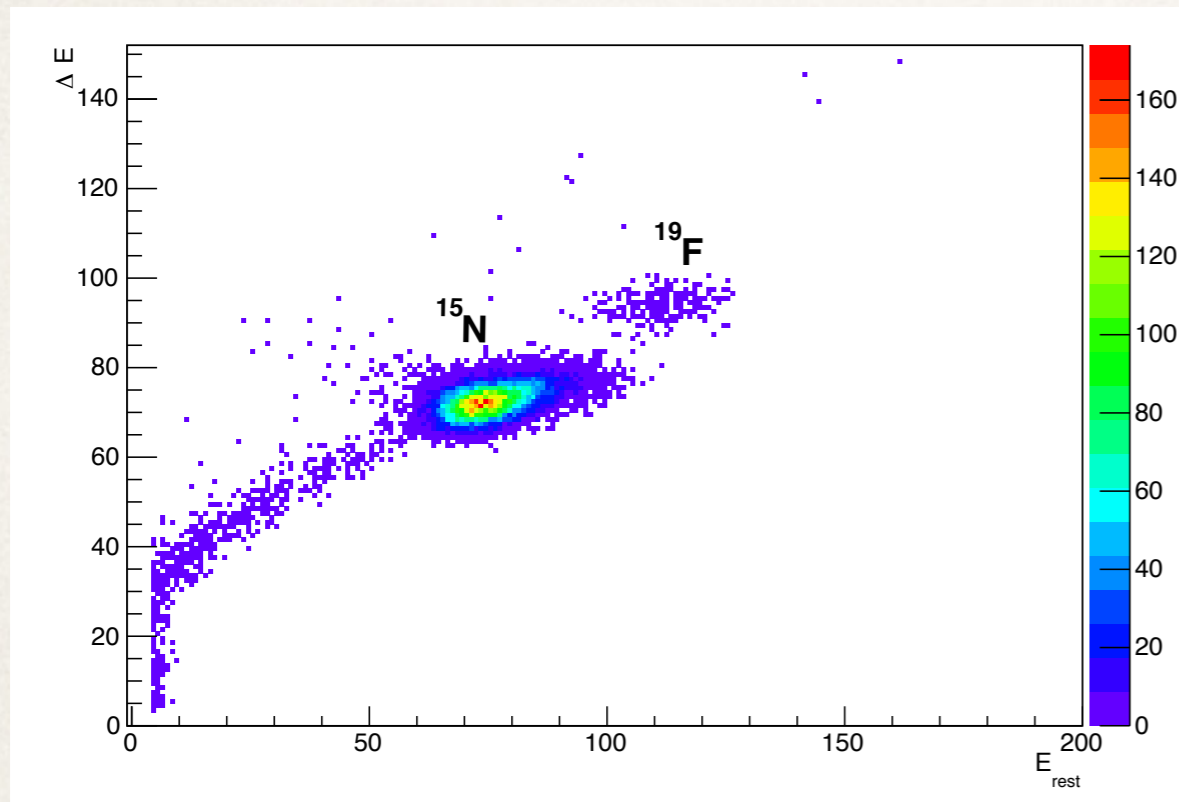
- \* intense N beam production (not trivial with SNICS)
- \* extended  $^4\text{He}$  target characterisation



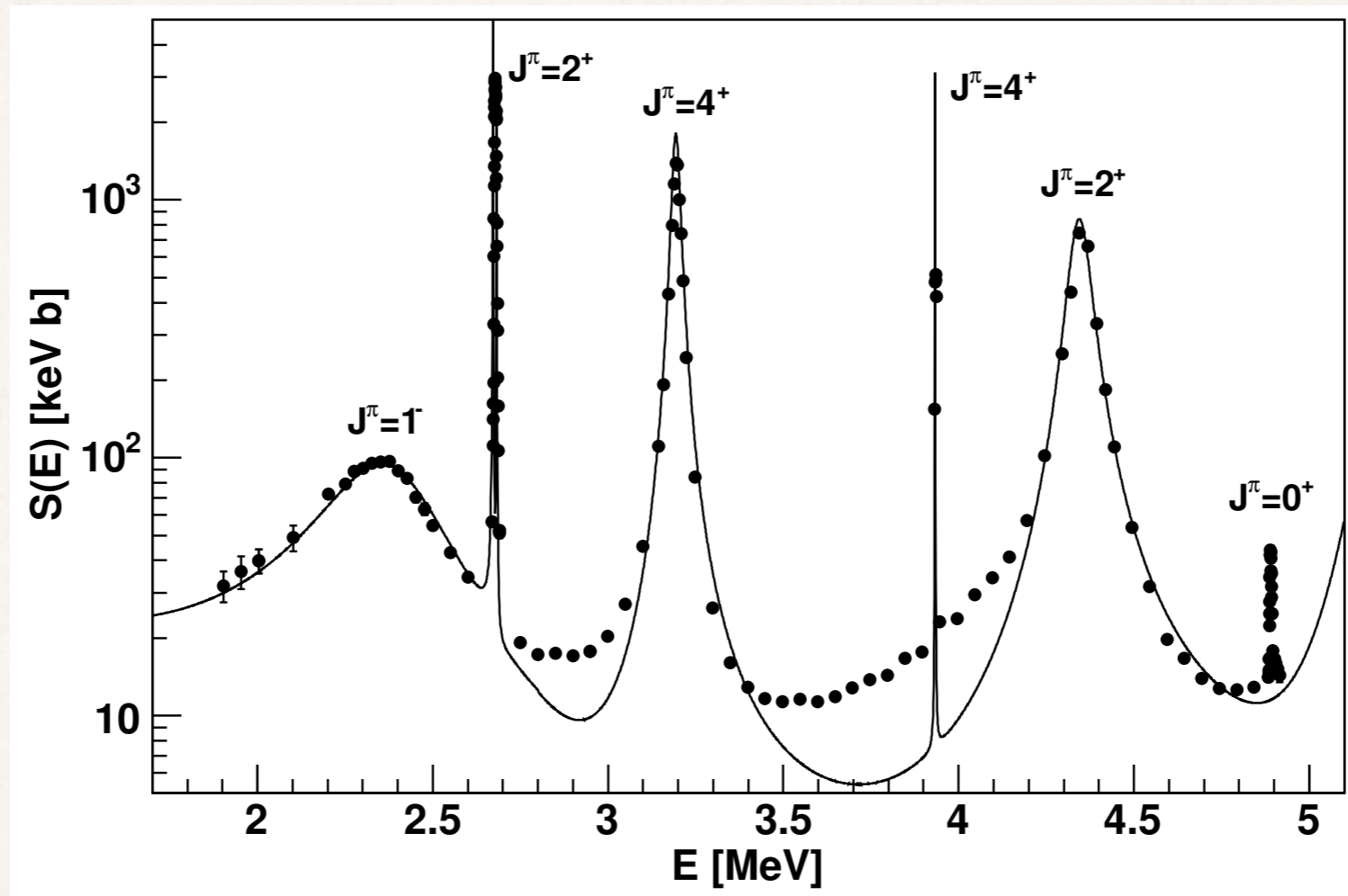
Thickness:  $5.5\text{E}17\text{atoms/cm}^2$



# $^{14}\text{N}(\alpha,\gamma)^{18}\text{F}$ and $^{15}\text{N}(\alpha,\gamma)^{19}\text{F}$



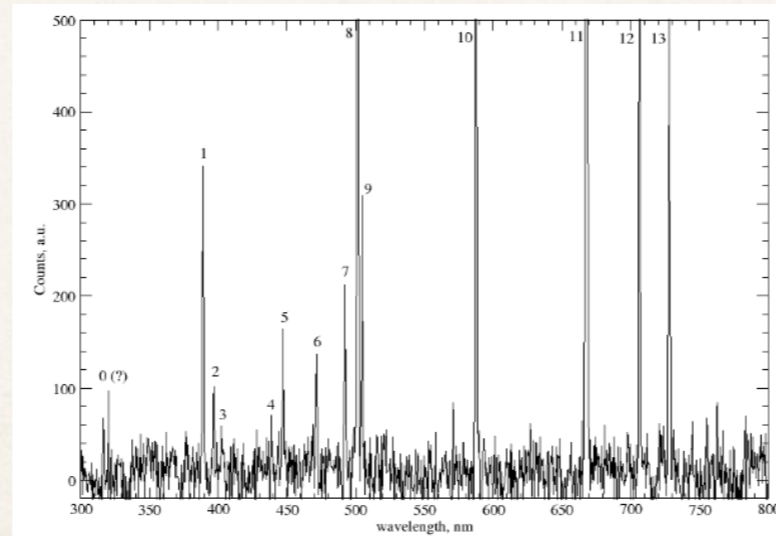
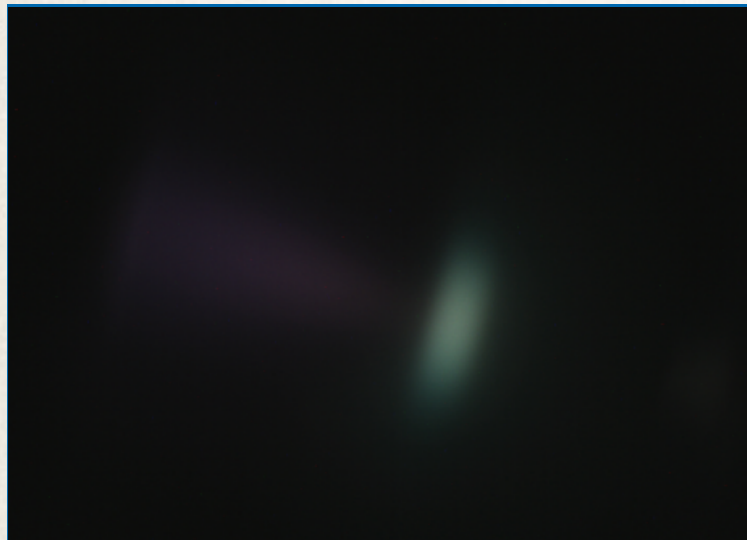
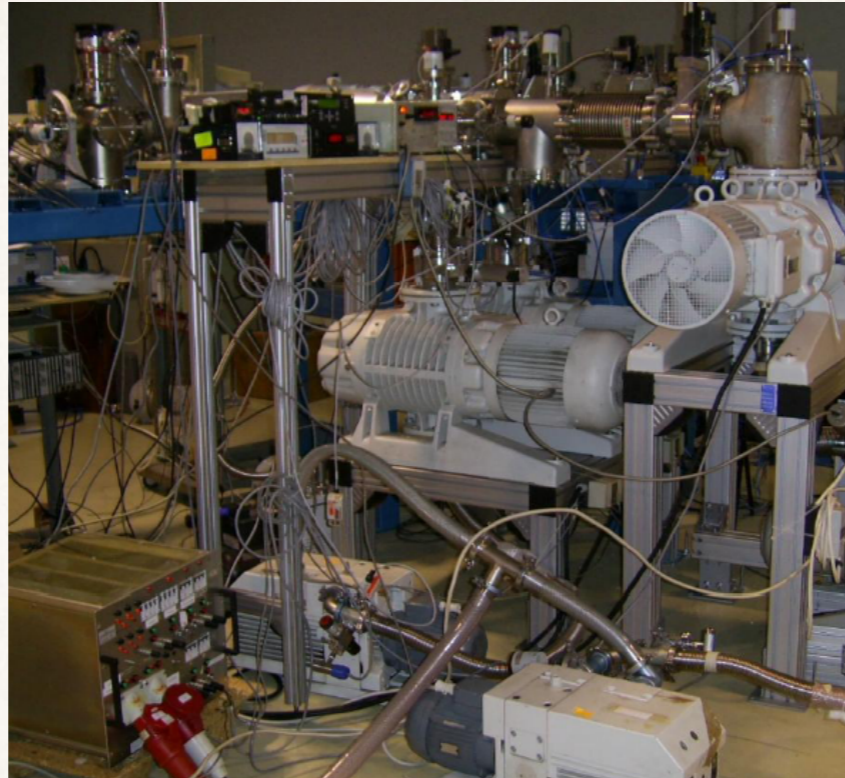
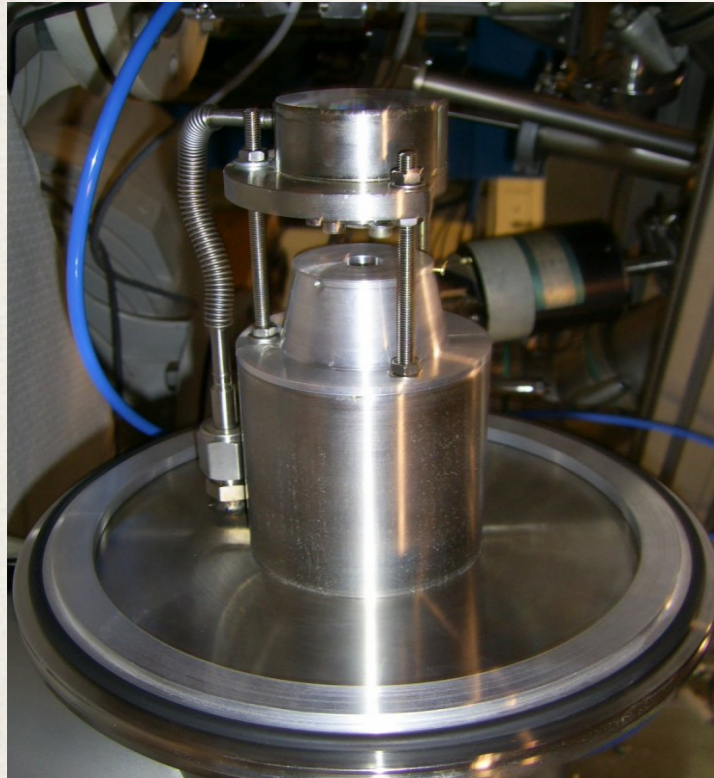
# $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$



Schuermann et al. EPJA 26(2005)



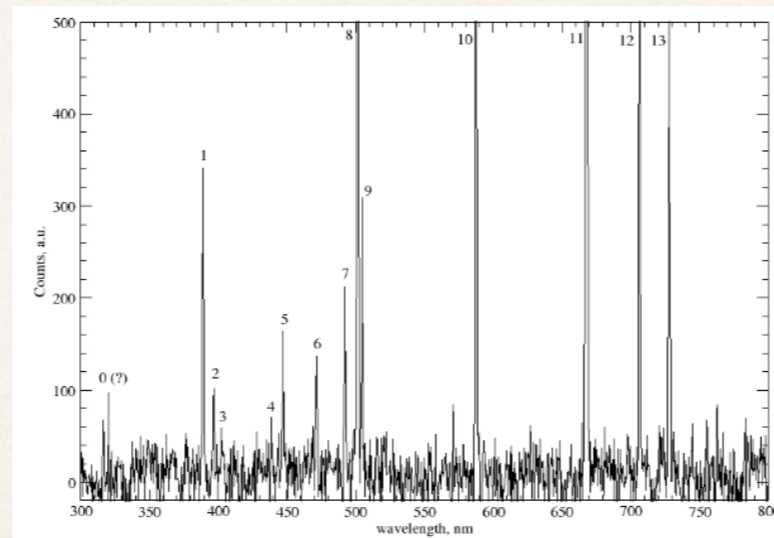
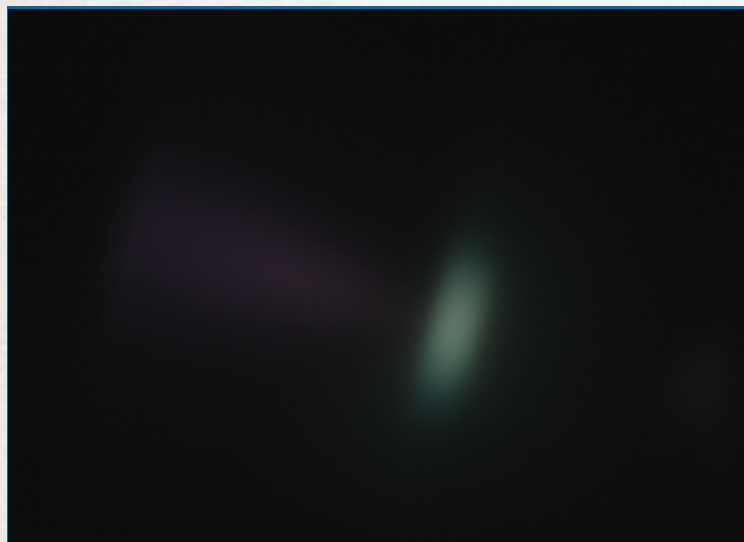
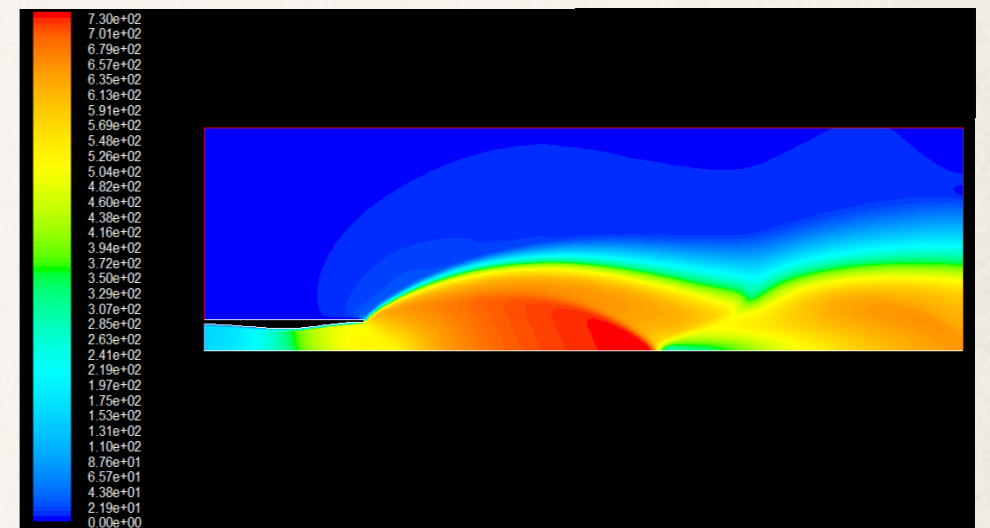
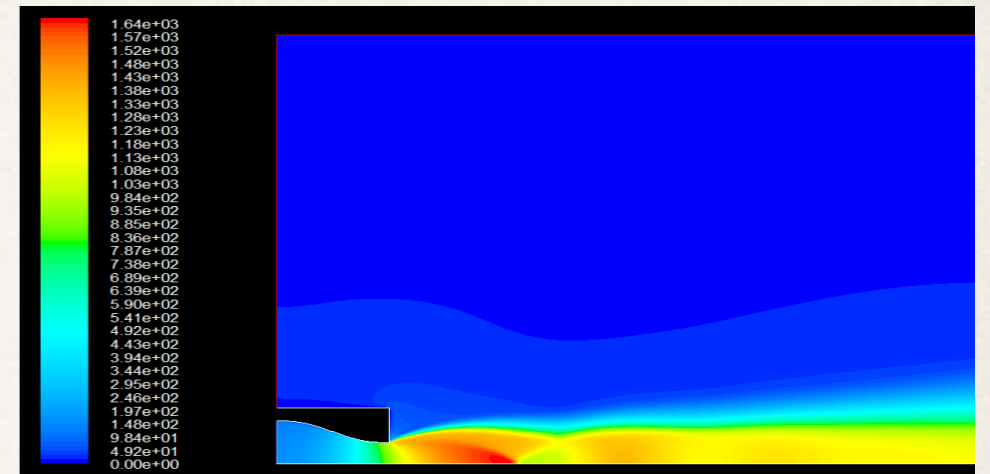
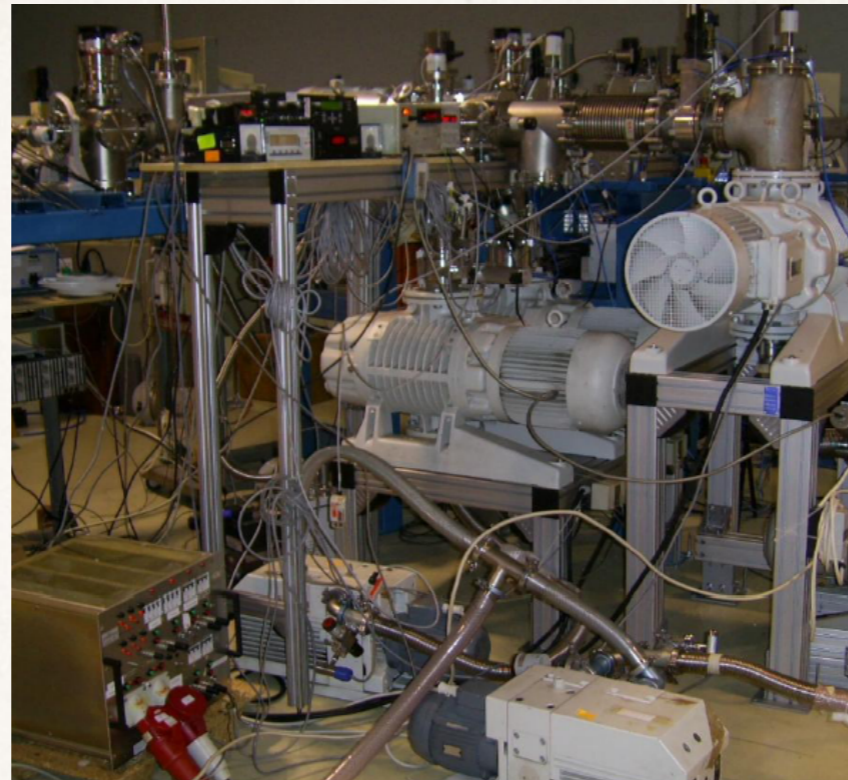
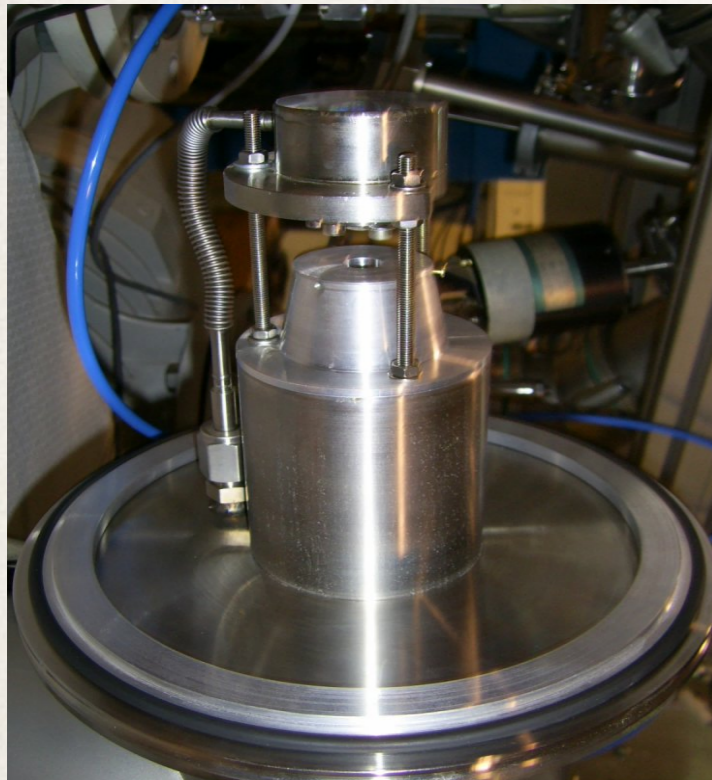
# Jet gas target



Optical spectroscopy on He excited by 6 MeV  $^{12}\text{C}$  beam  
G-resist INFN - INO CNR Pisa



# Jet gas target

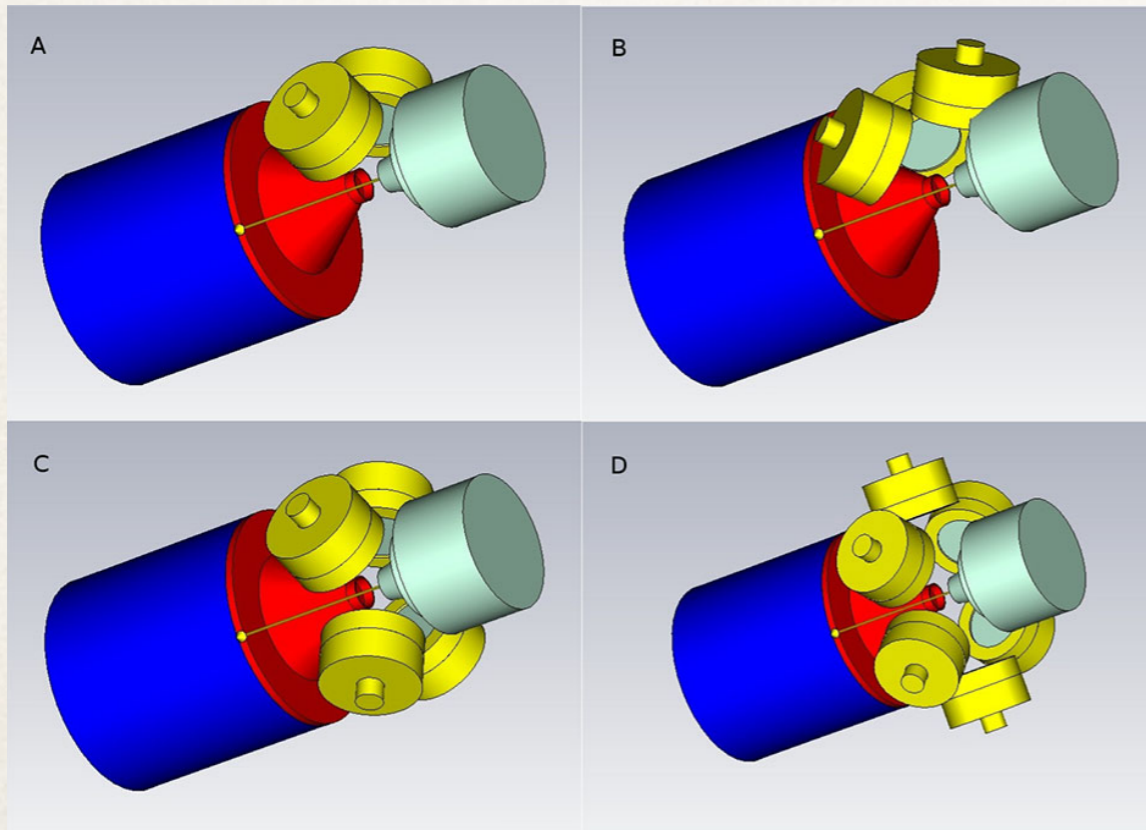
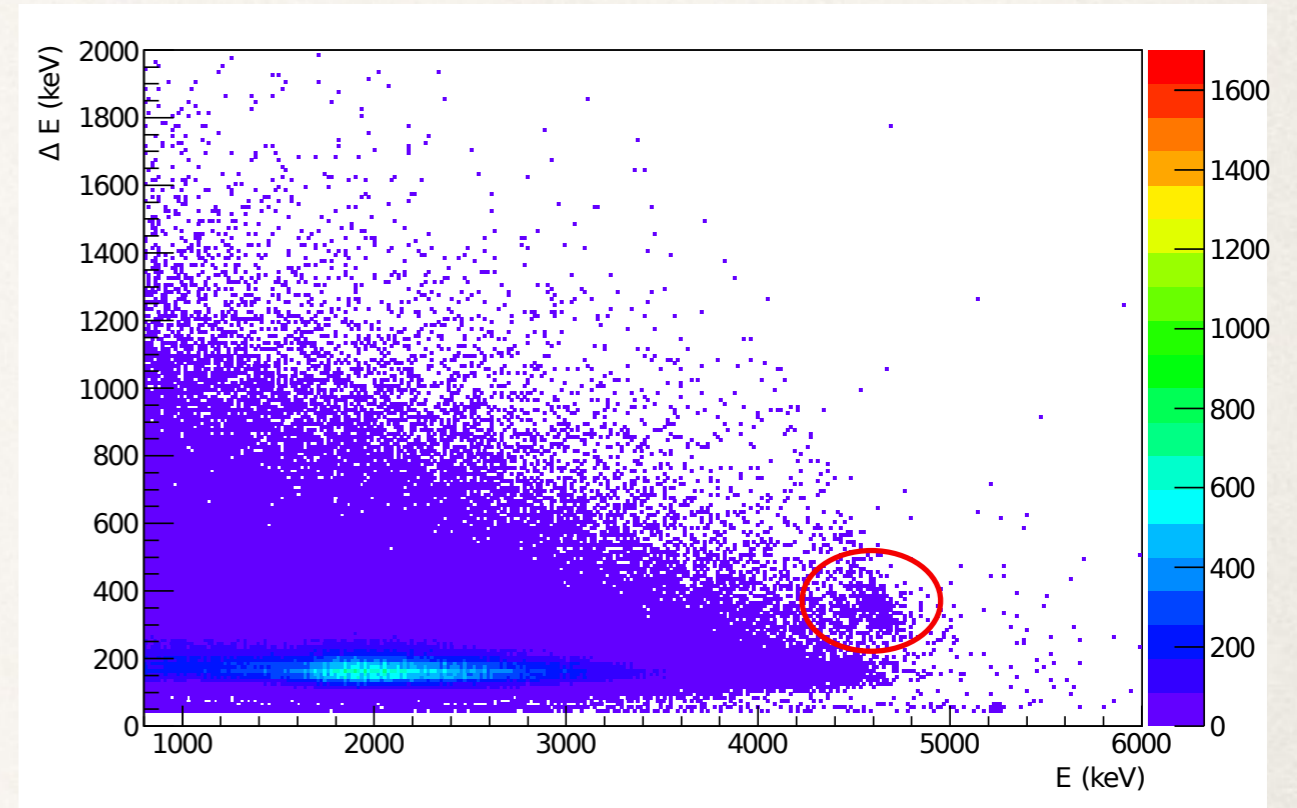
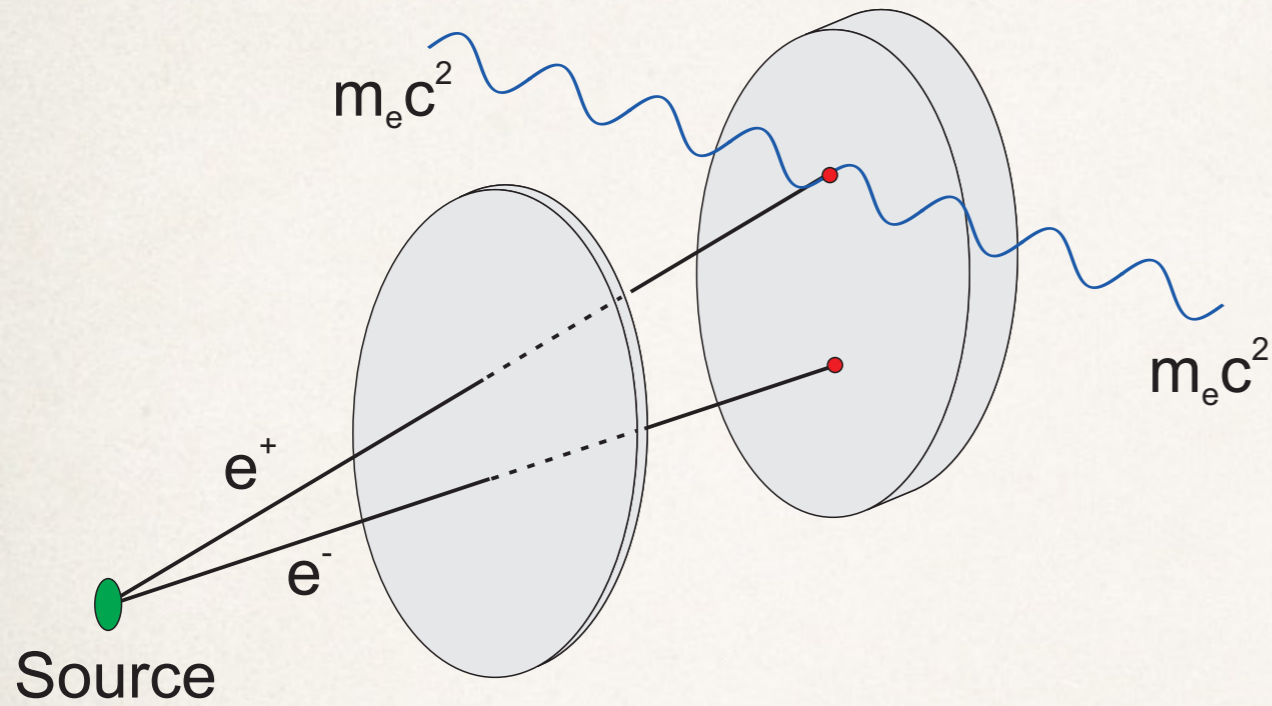


- Dipartimento per l'Ingegneria Industriale  
e per l'Informazione-SUN  
- Università di Perugia

Optical spectroscopy on He excited by 6 MeV  $^{12}\text{C}$  beam  
G-resist INFN - INO CNR Pisa

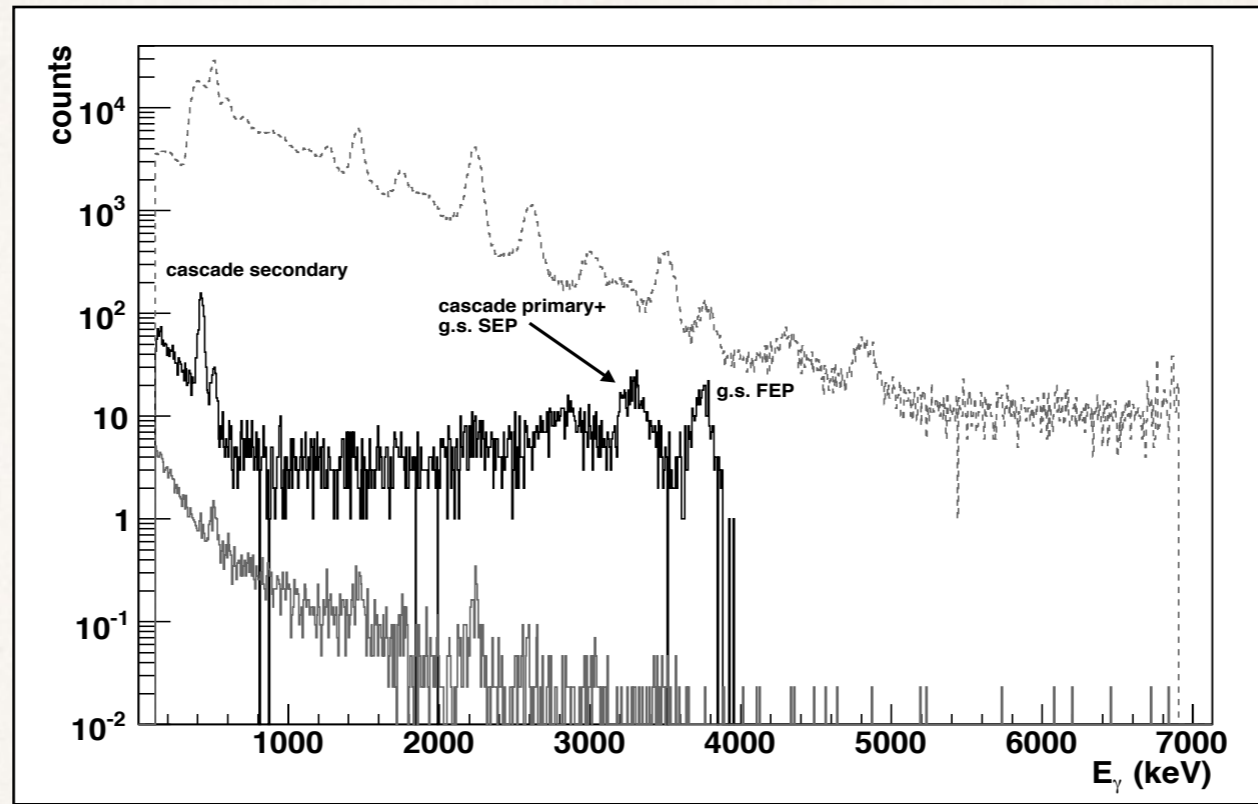


# $e^+e^-$ pair spectrometer



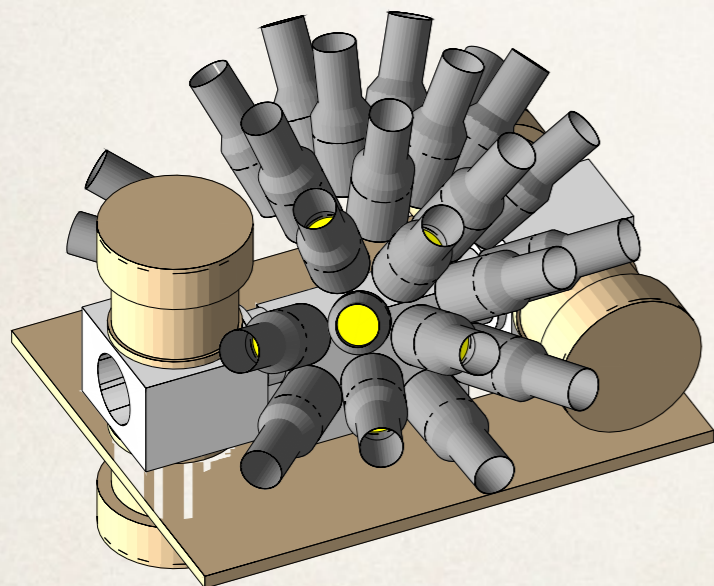
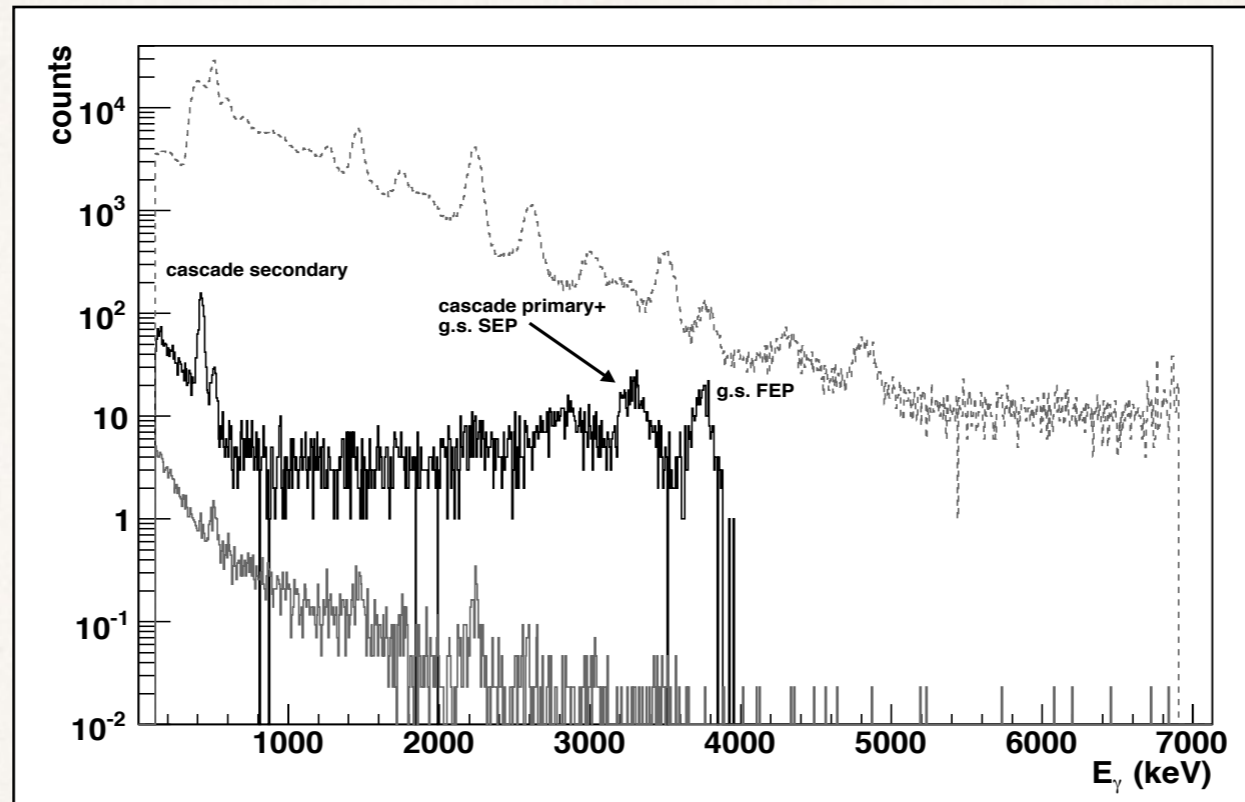
Guerro et al. EPJA 50(2014)

# $\gamma$ -ray detection array

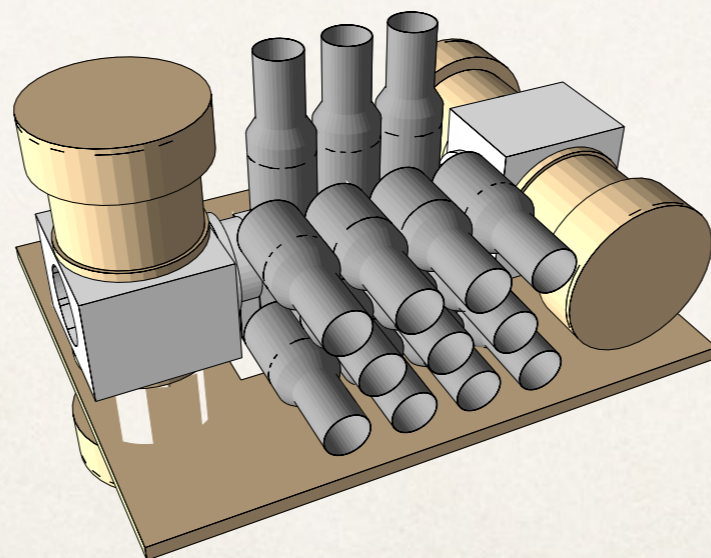
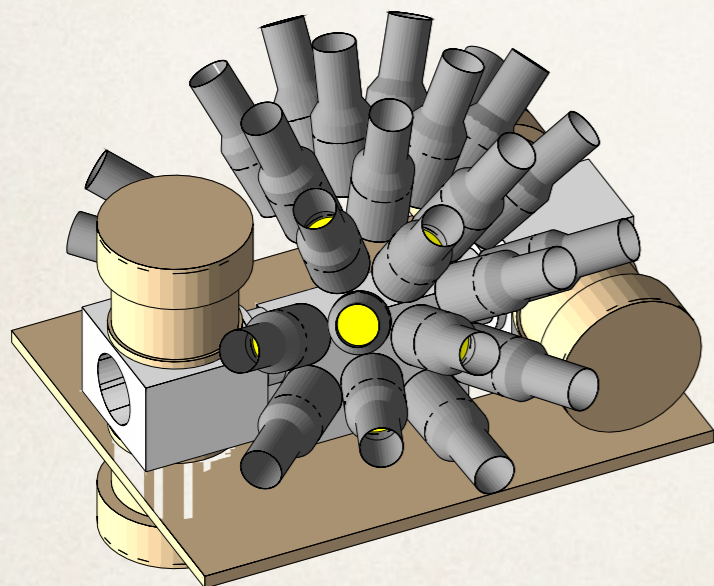
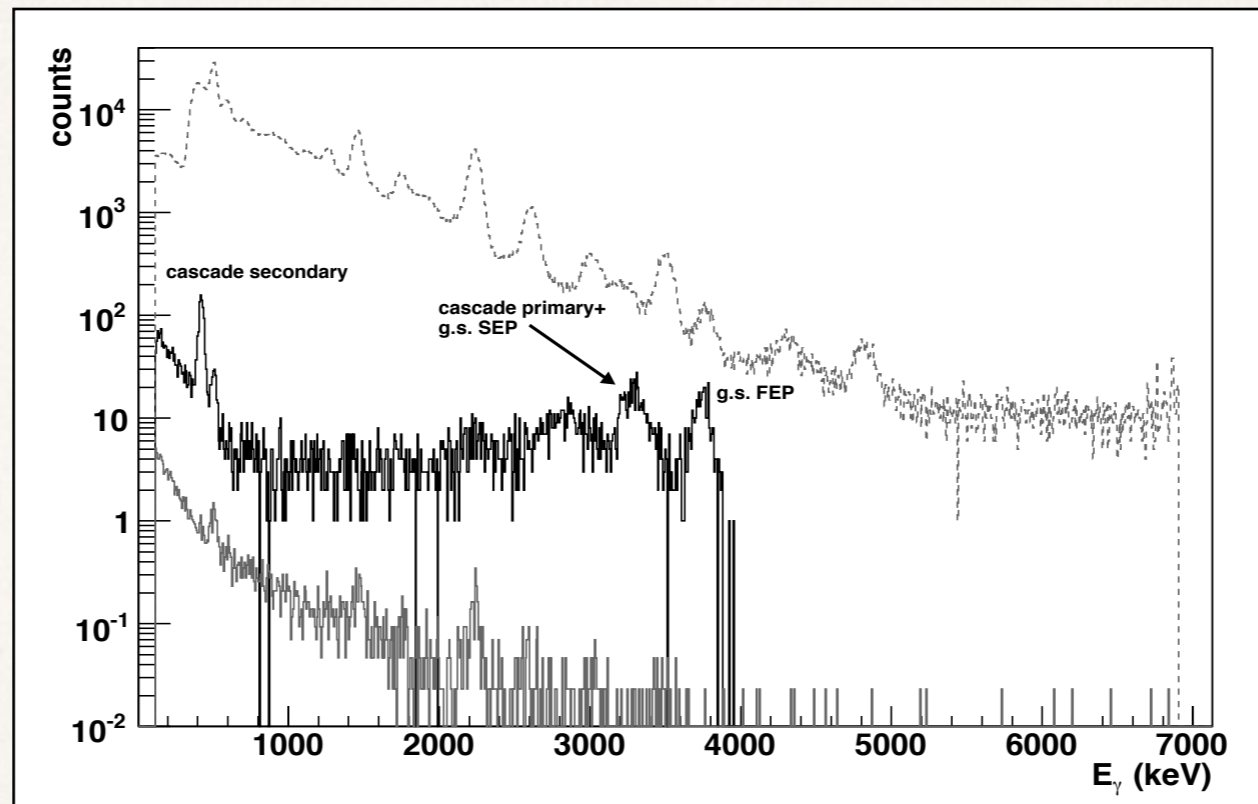




# $\gamma$ -ray detection array

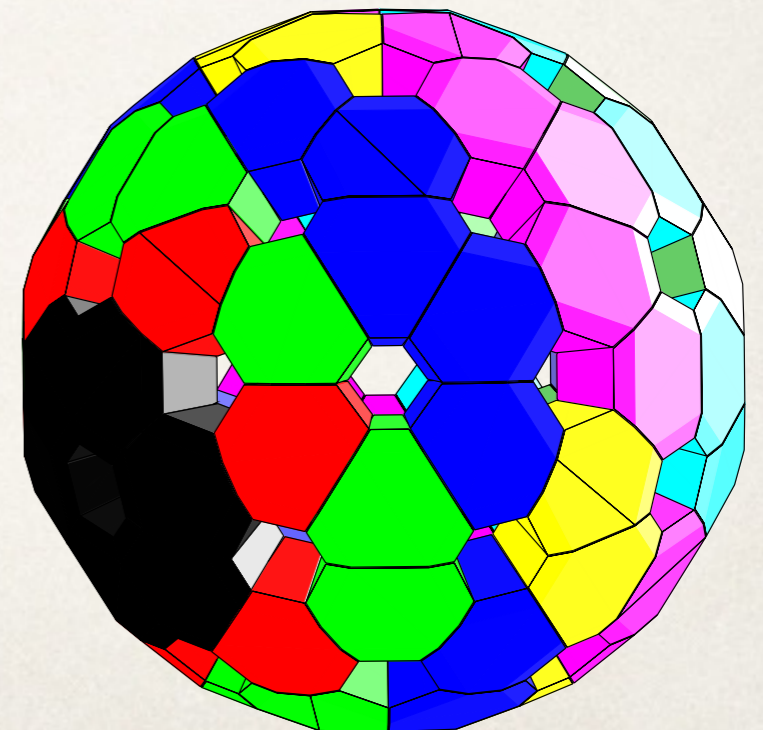
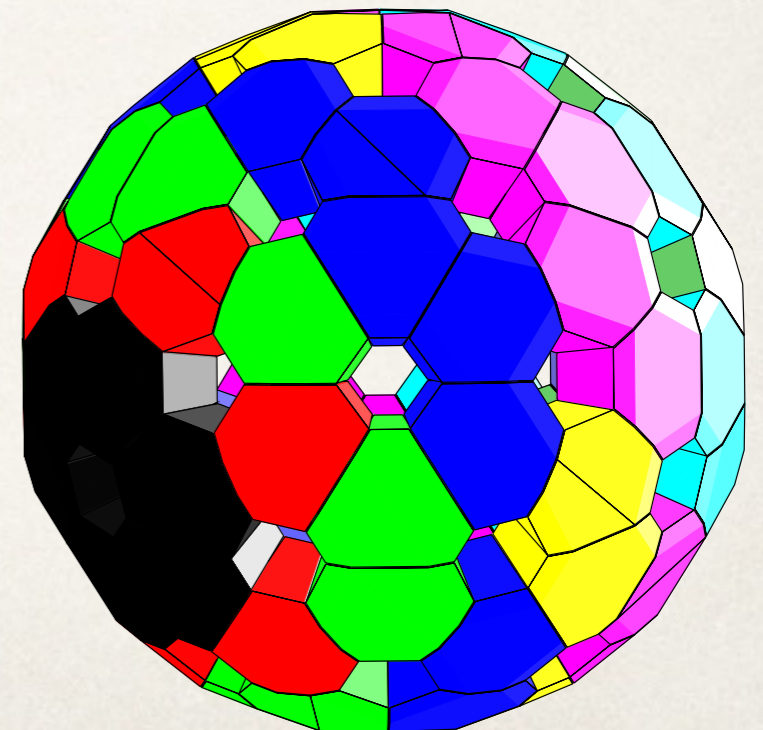
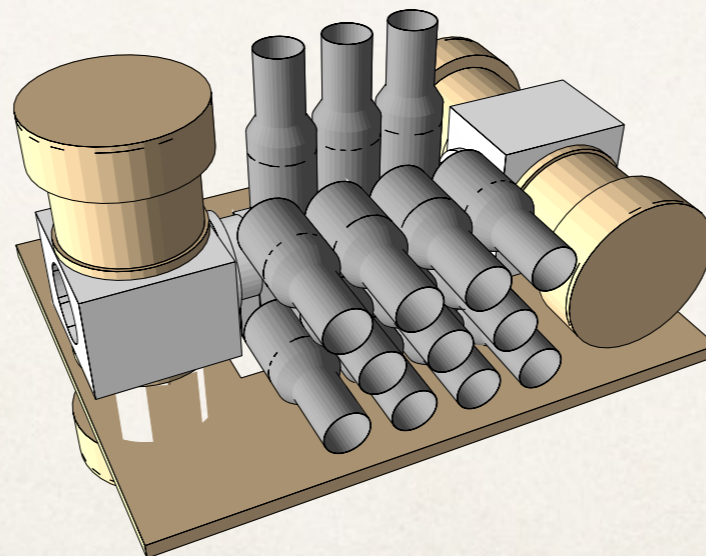
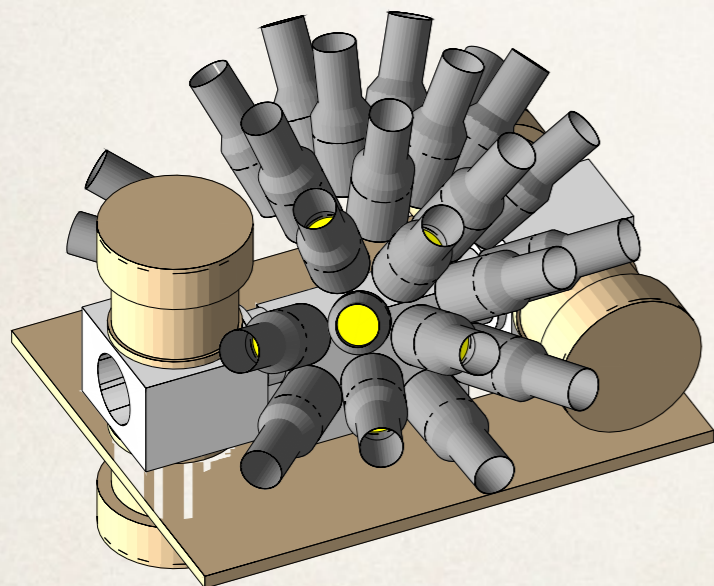
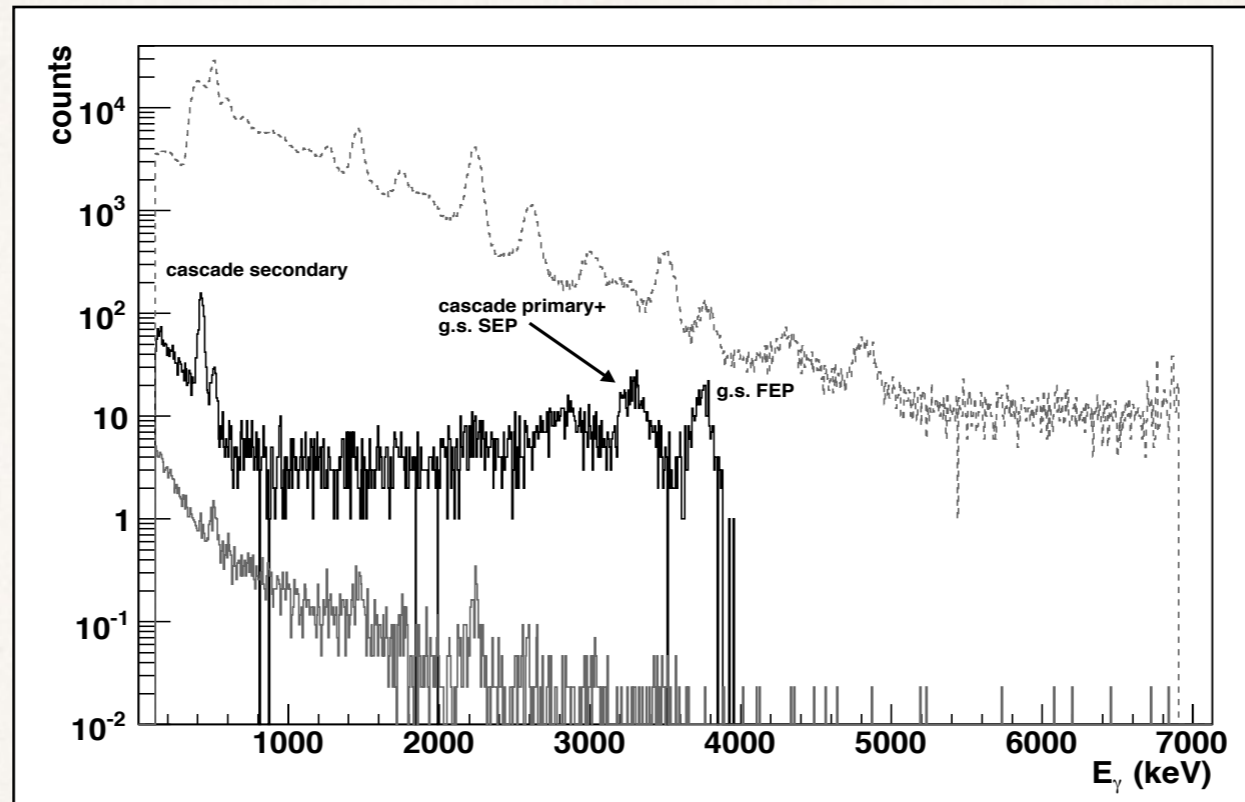


# $\gamma$ -ray detection array

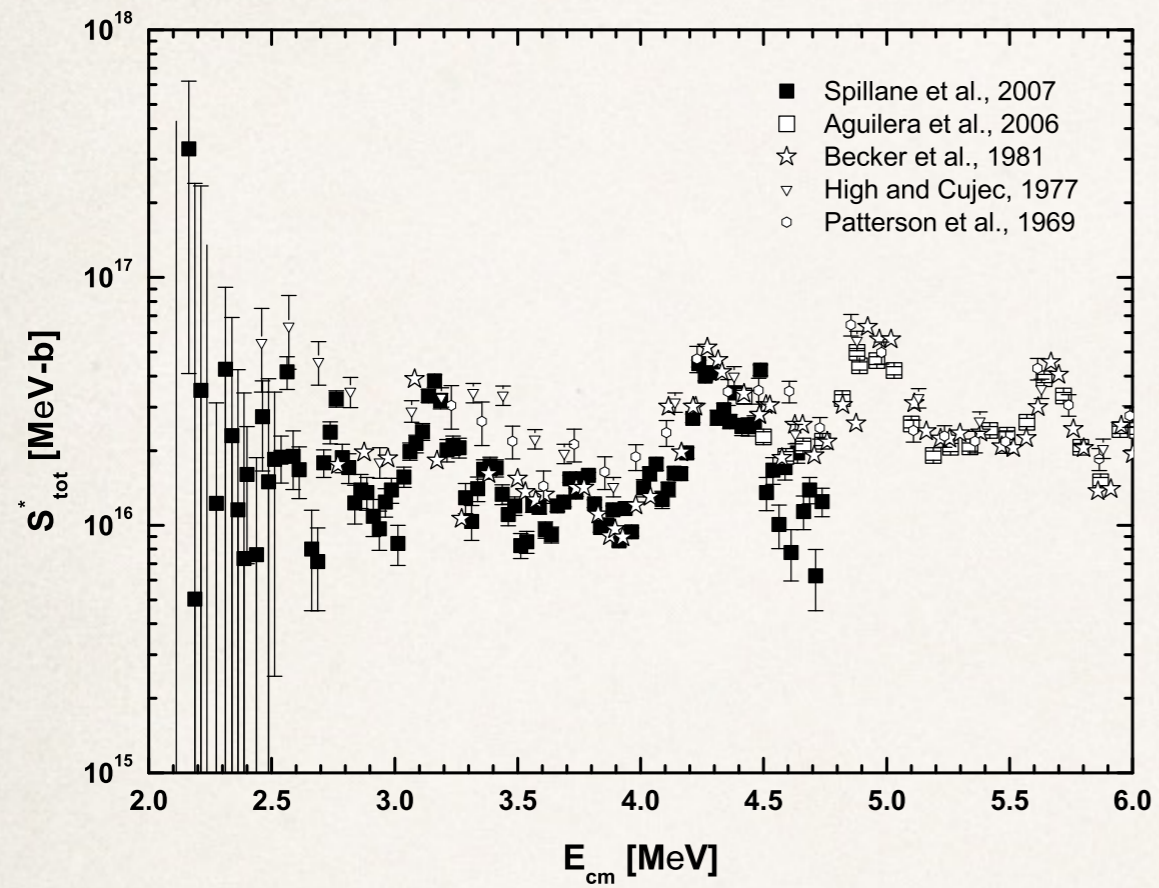




# $\gamma$ -ray detection array

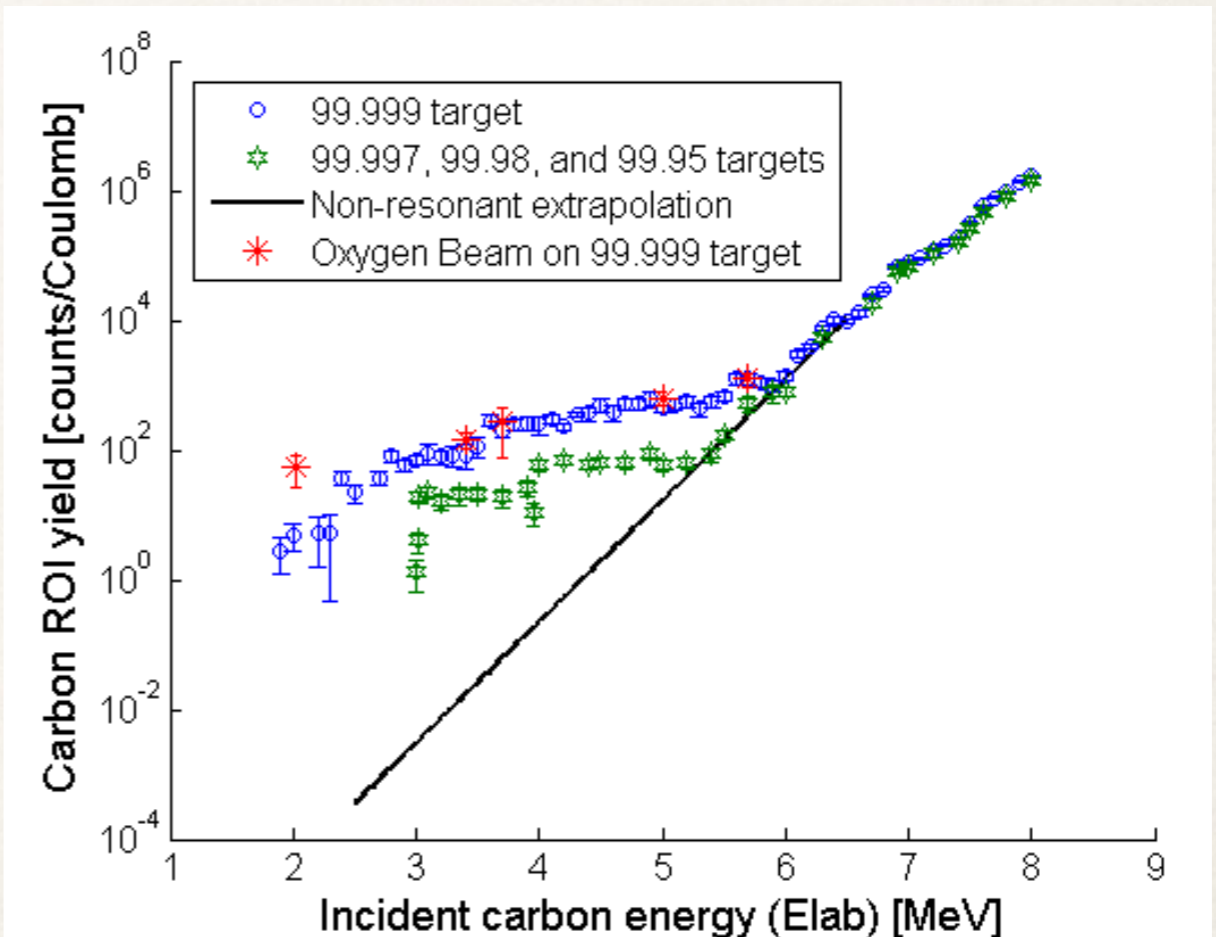
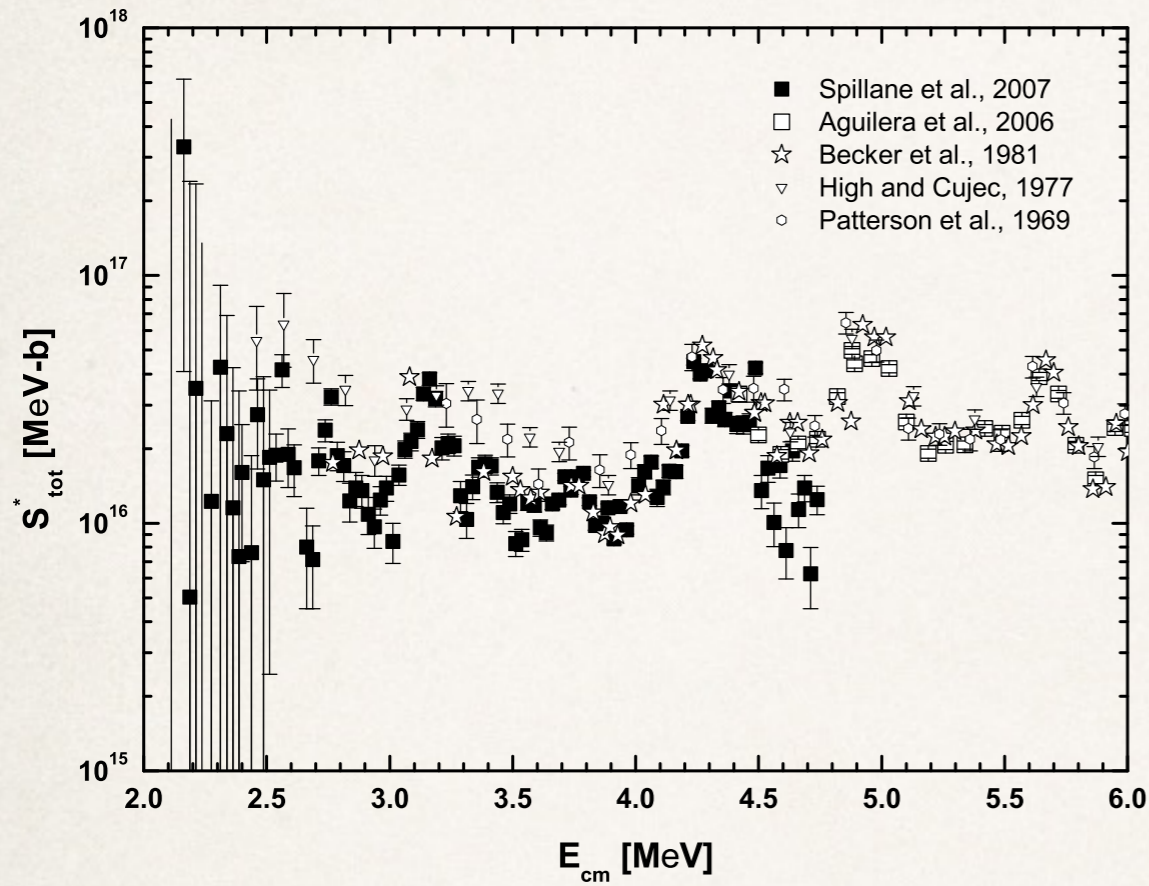


# $^{12}\text{C}(^{12}\text{C},\text{p})^{23}\text{Na}$ and $^{12}\text{C}(^{12}\text{C},\alpha)^{20}\text{Ne}$





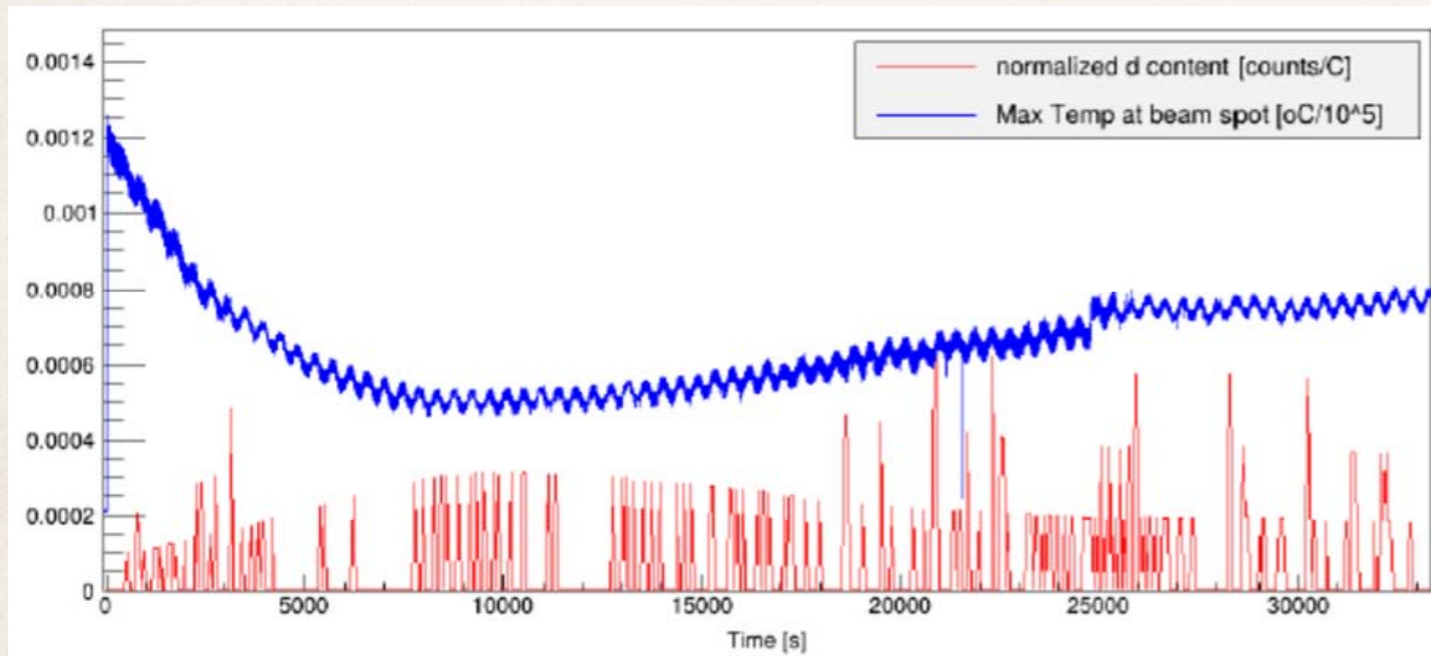
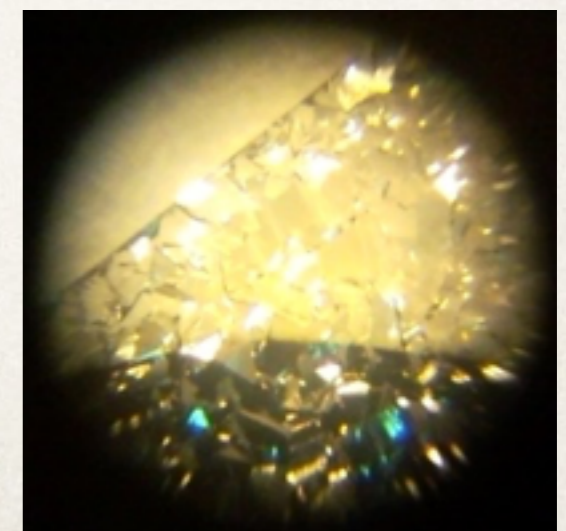
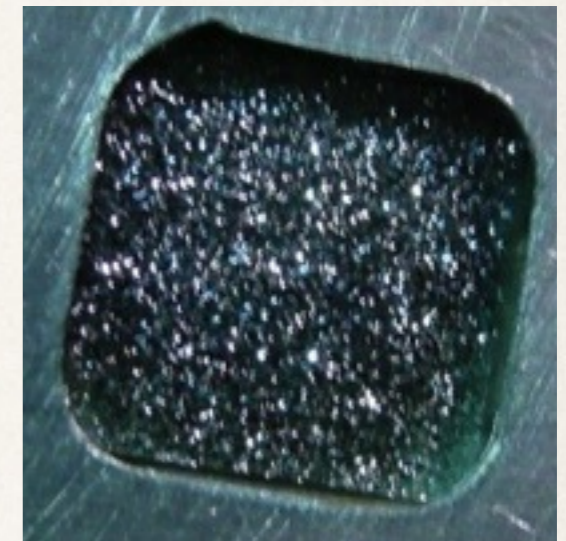
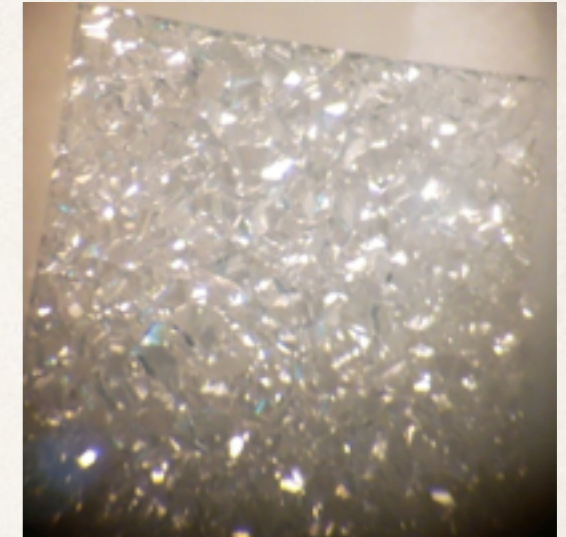
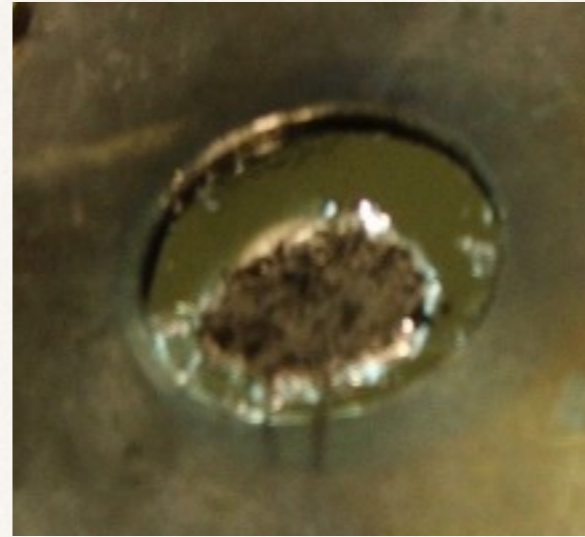
# $^{12}\text{C}(^{12}\text{C},\text{p})^{23}\text{Na}$ and $^{12}\text{C}(^{12}\text{C},\alpha)^{20}\text{Ne}$



J. Zickefoose PoS (NIC XI)

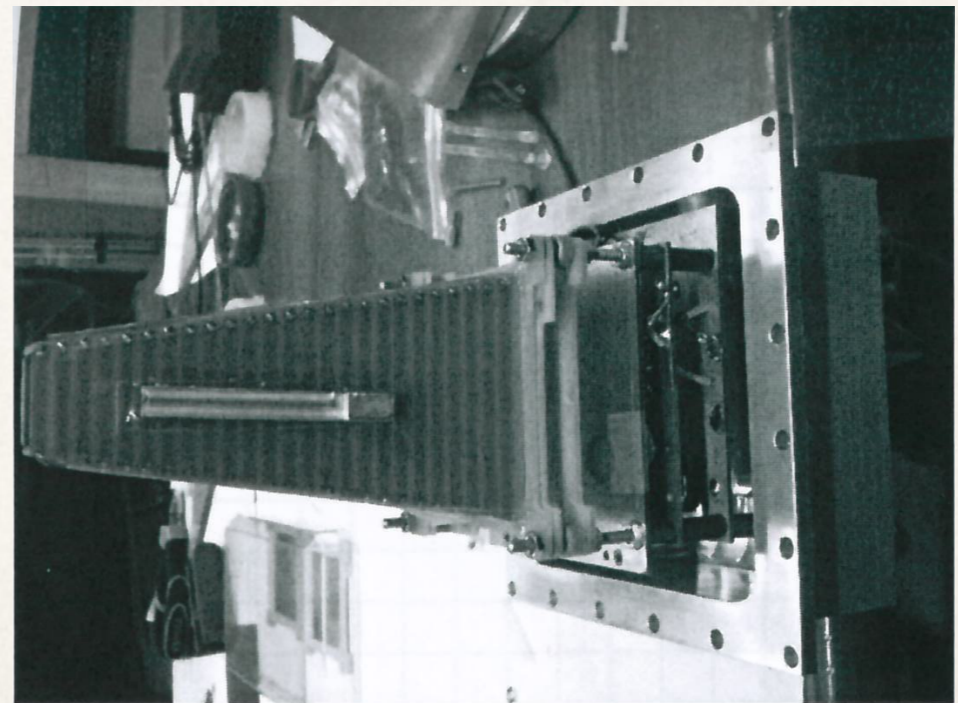
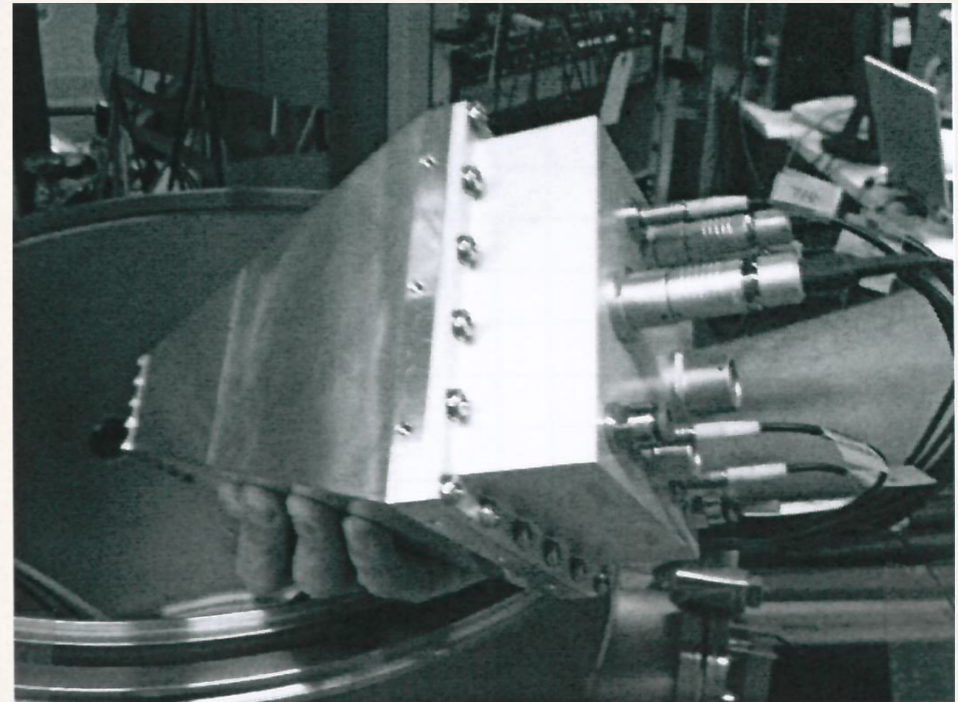
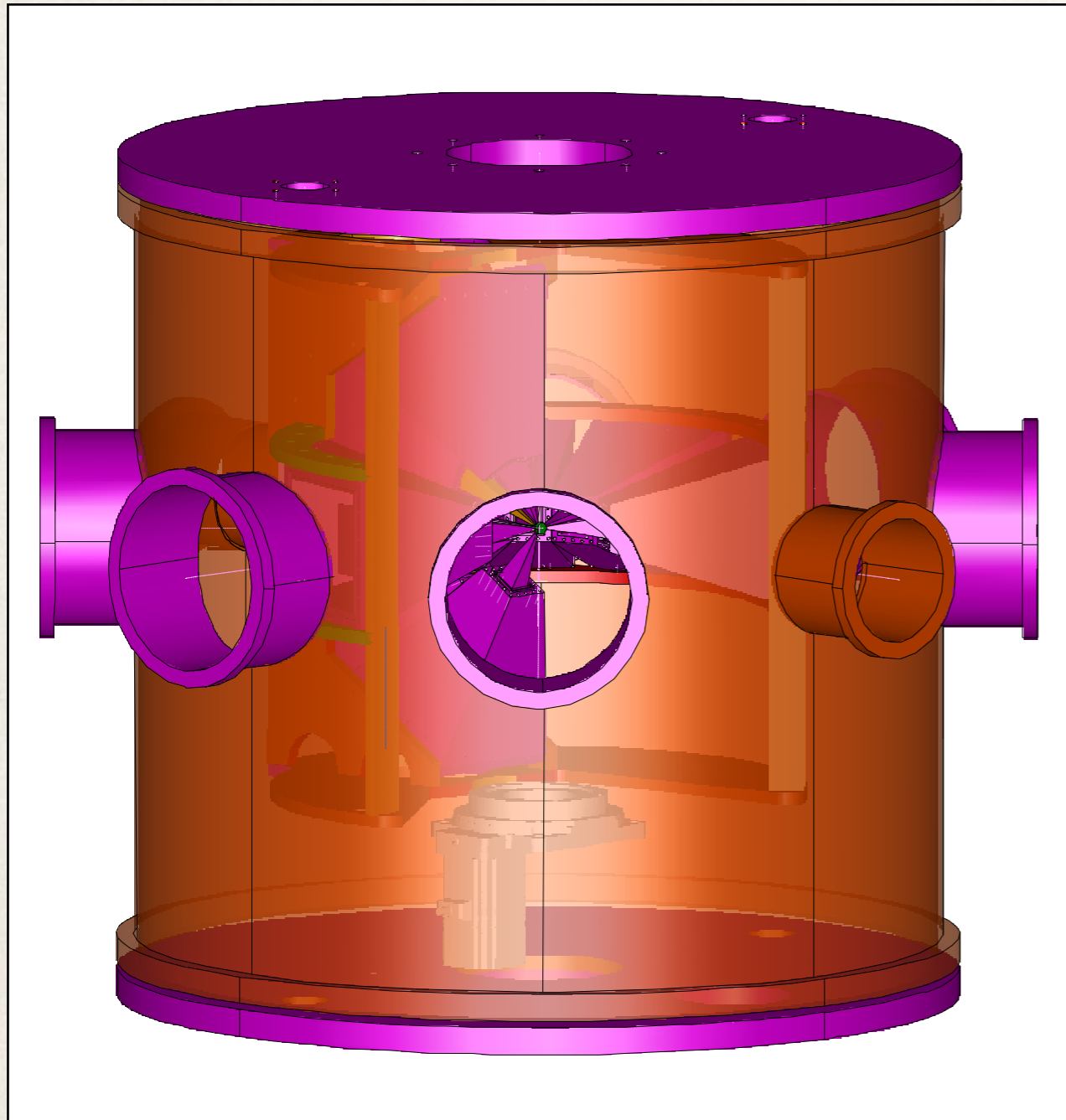


# $^{12}\text{C}$ targets characterisation



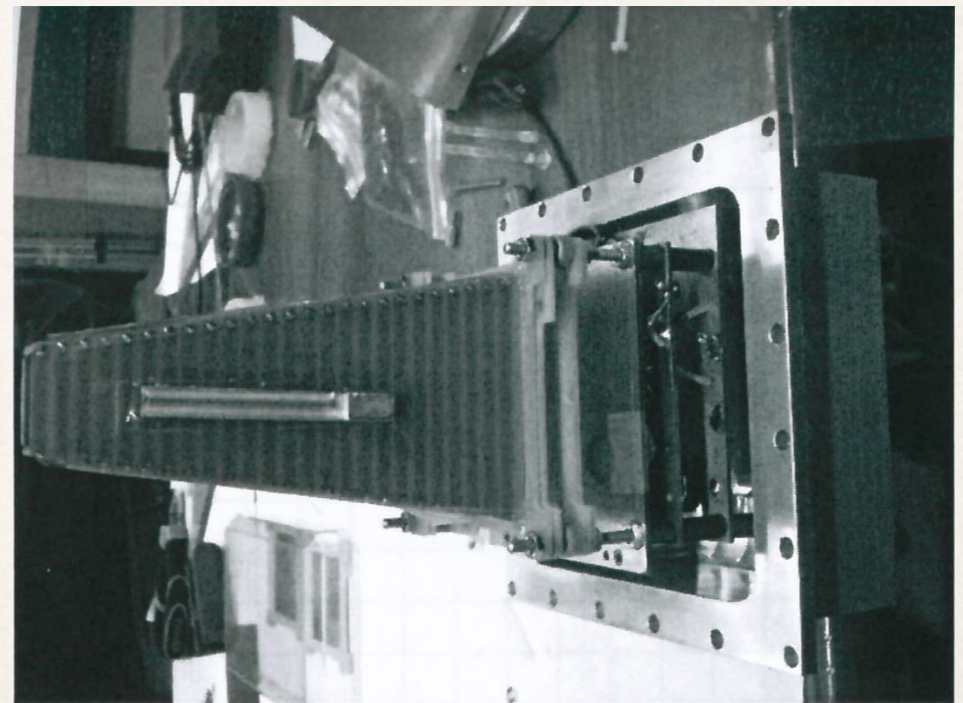
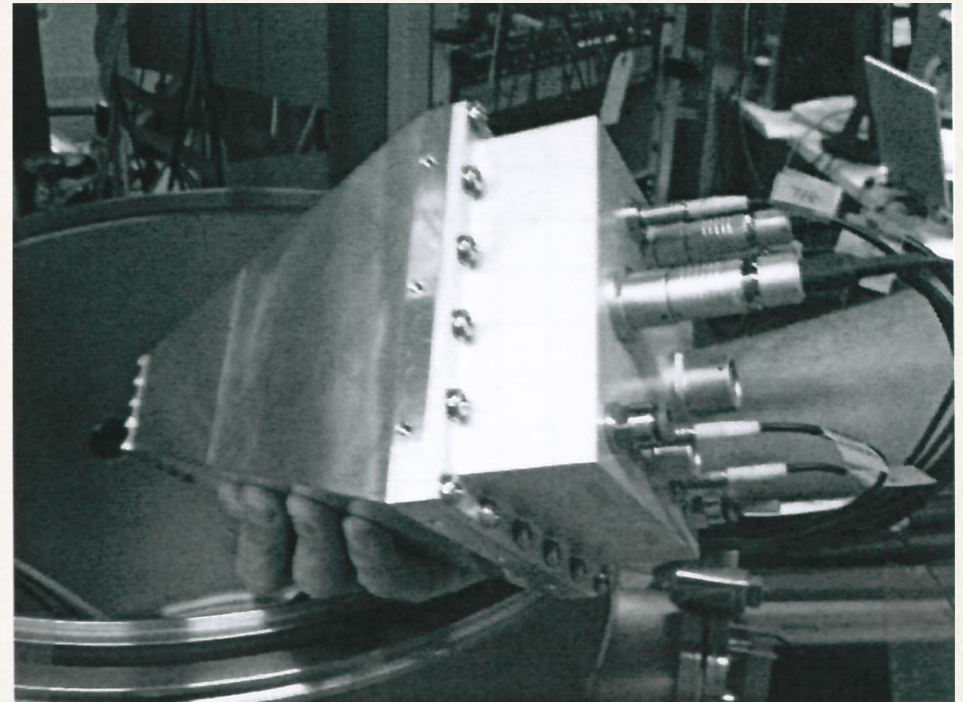
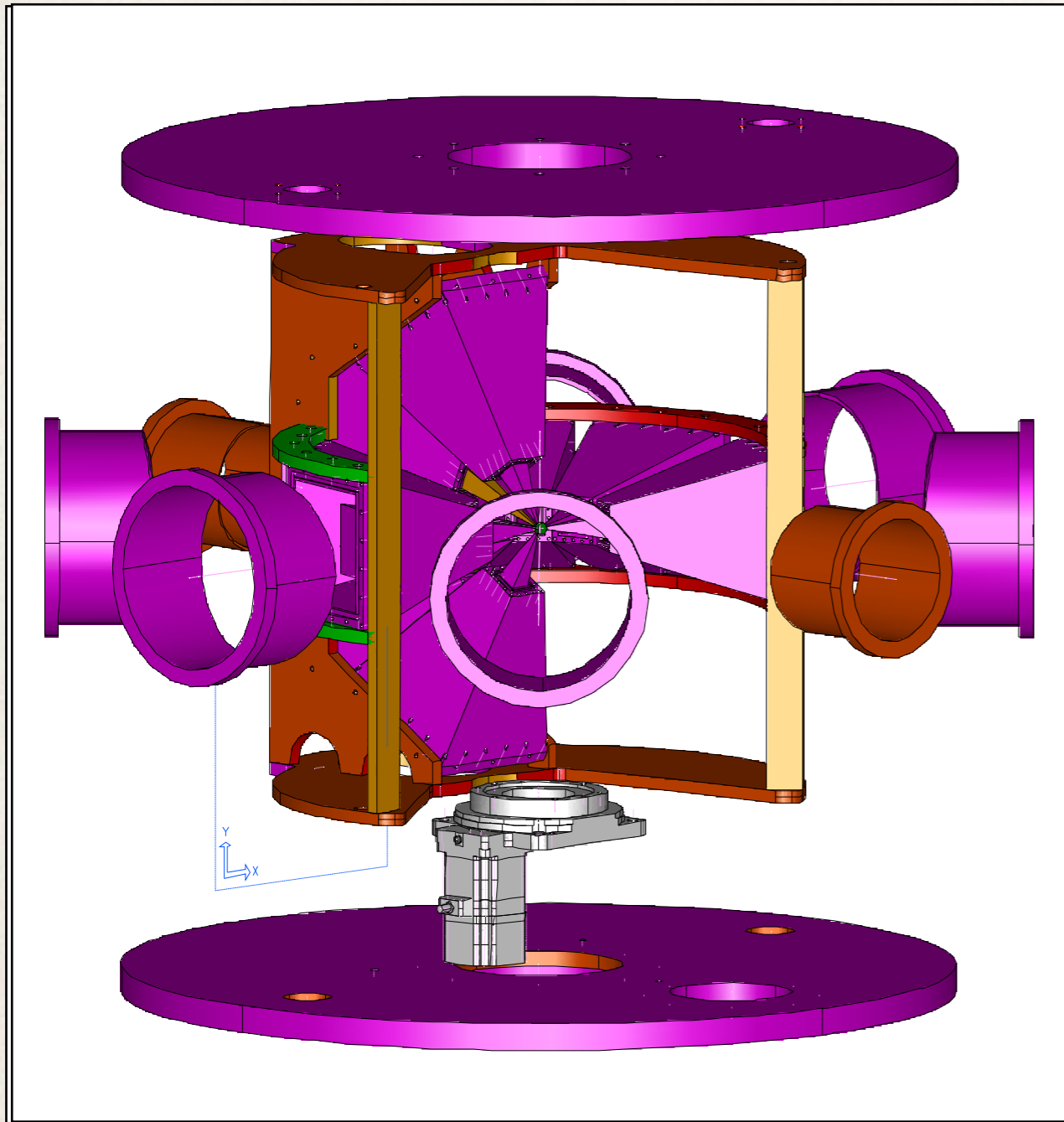


# $^{12}\text{C}(^{12}\text{C},\text{p})^{23}\text{Na}$ and $^{12}\text{C}(^{12}\text{C},\alpha)^{20}\text{Ne}$





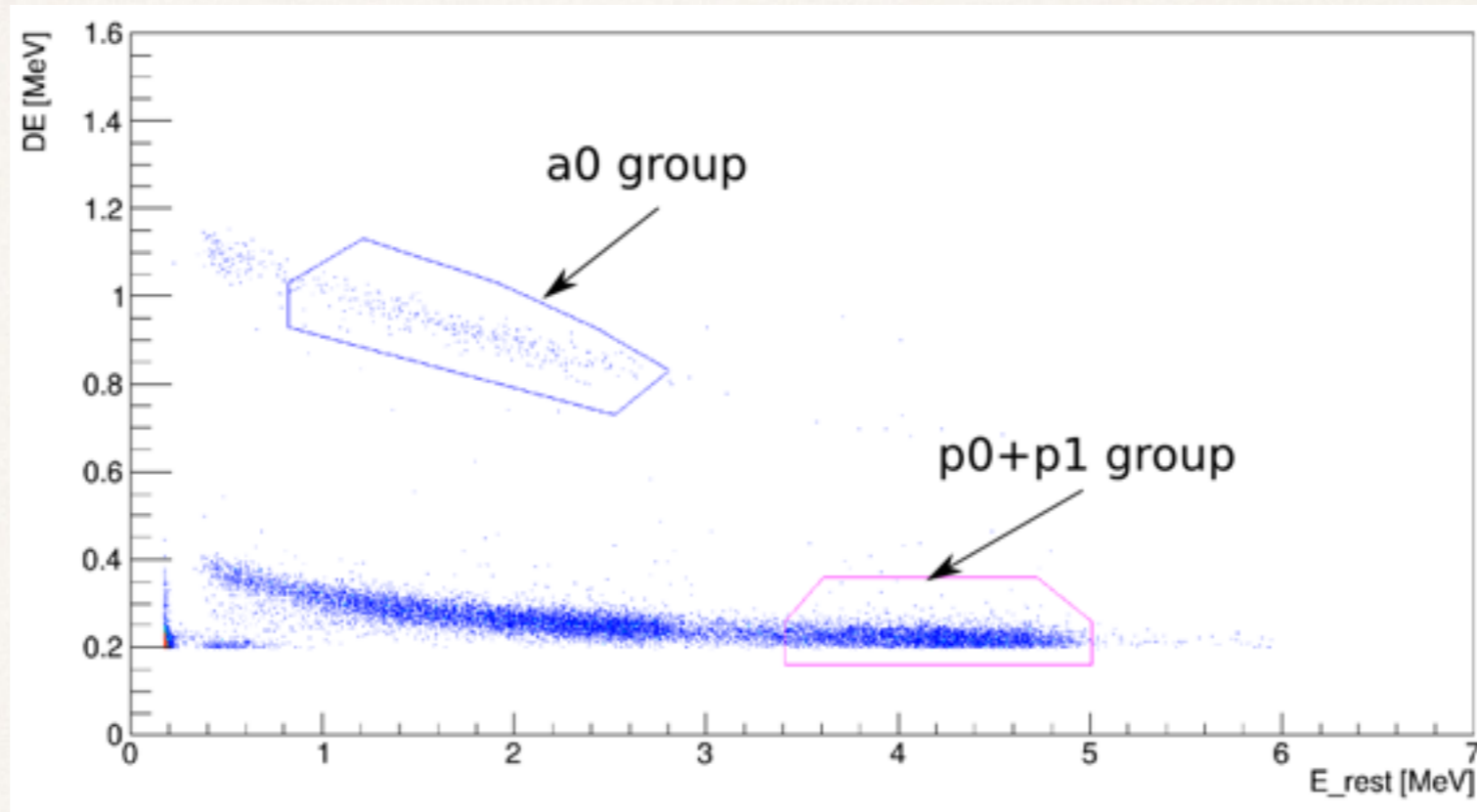
# $^{12}\text{C}(^{12}\text{C},\text{p})^{23}\text{Na}$ and $^{12}\text{C}(^{12}\text{C},\alpha)^{20}\text{Ne}$



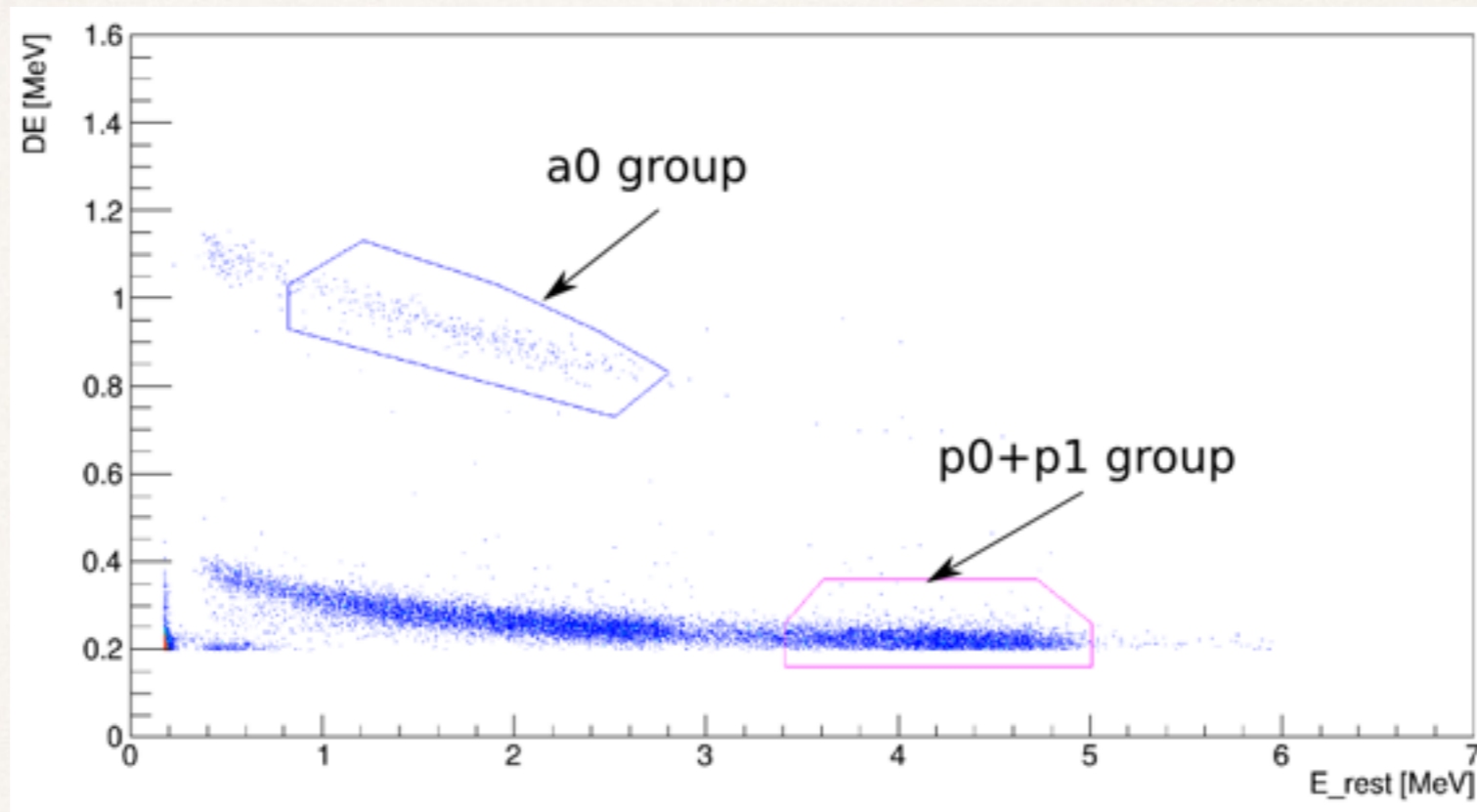


# Measurements

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# Measurements



$^{23}\text{Na}(p,\alpha)^{20}\text{Ne}$  will use the same setup with solid  $^{23}\text{Na}$  targets  
possibly  $^{19}\text{F}(a,p)^{22}\text{Na}$  will use same detectors and jet gas target



# AMS of Super Heavy Elements

