SEVENTH WORKSHOP ON THE CHEMISTRY OF THE HEAVIEST ELEMENTS 13.10.2009

Stopping force estimations for element 114 in Mylar and argon gas

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0. Content

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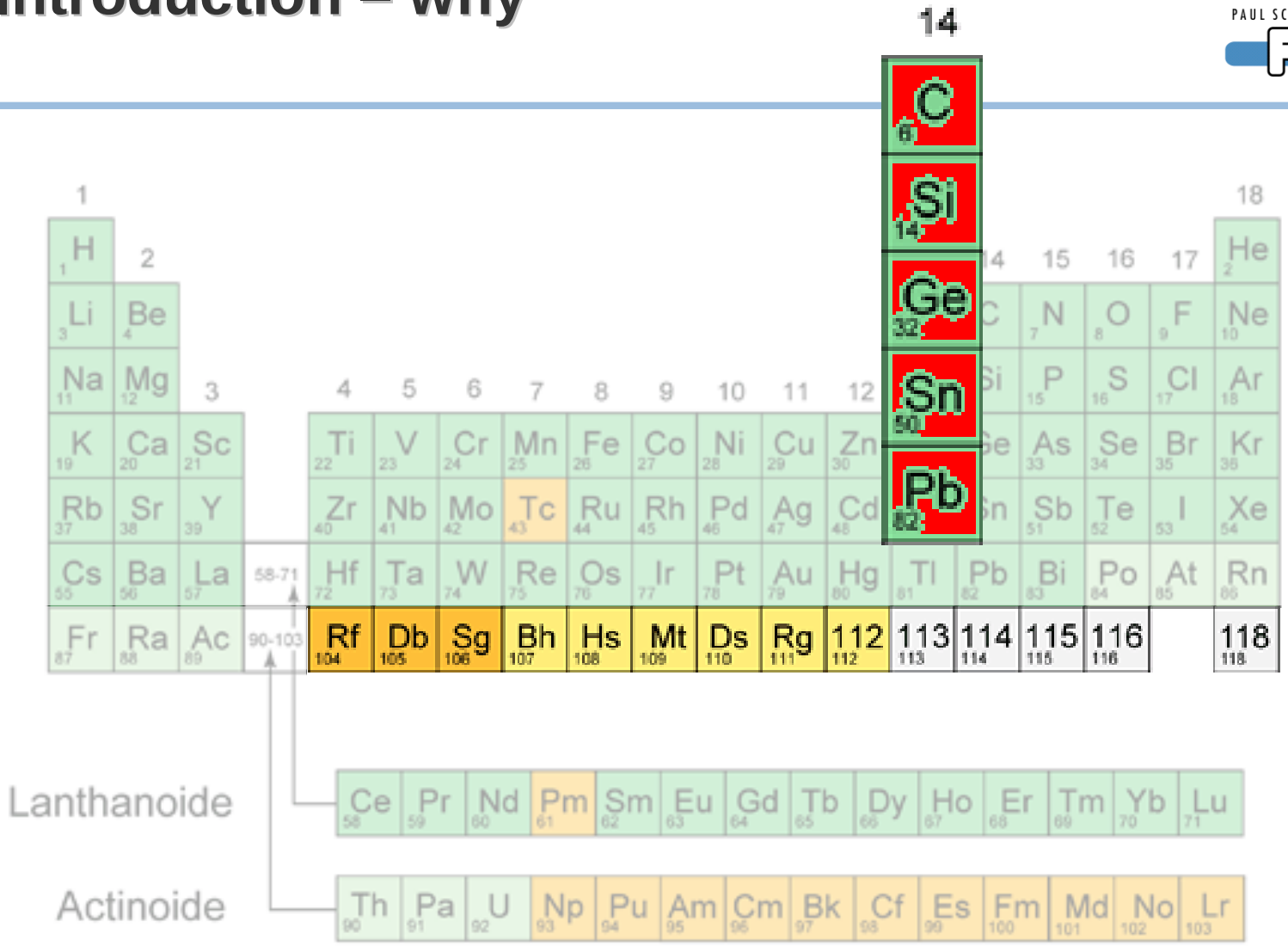
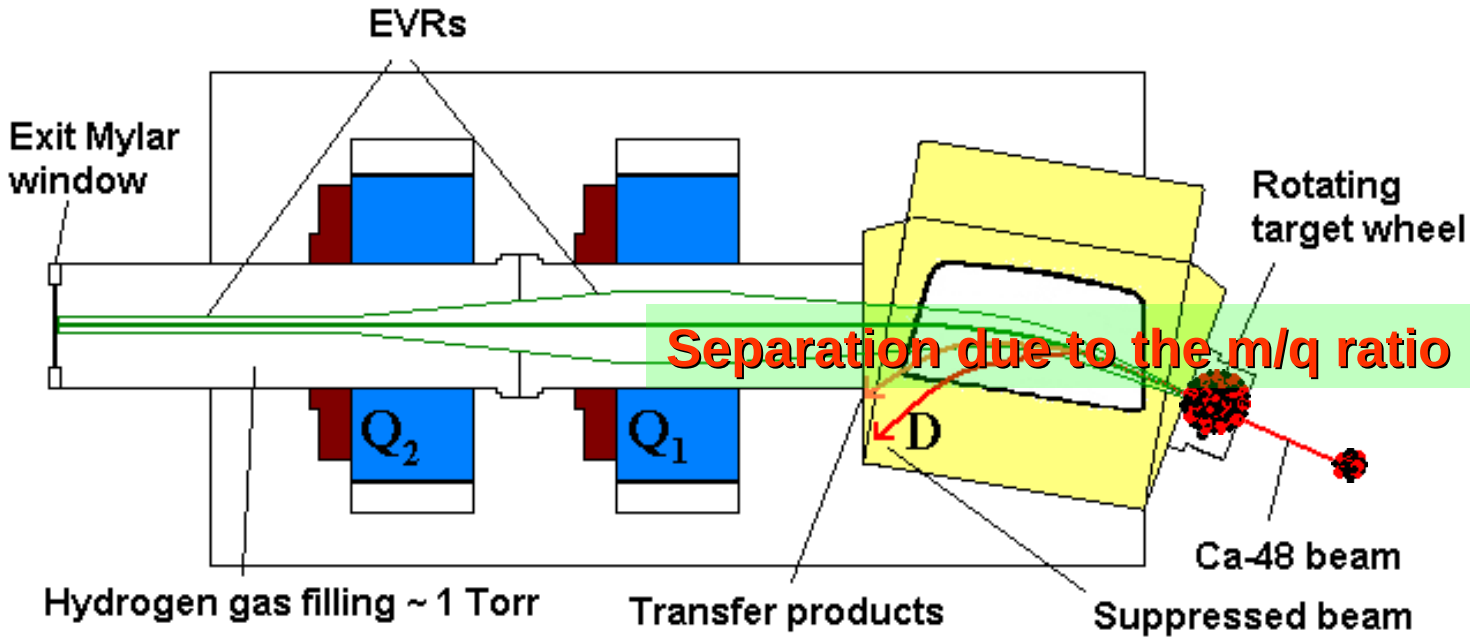
1. Introduction – why



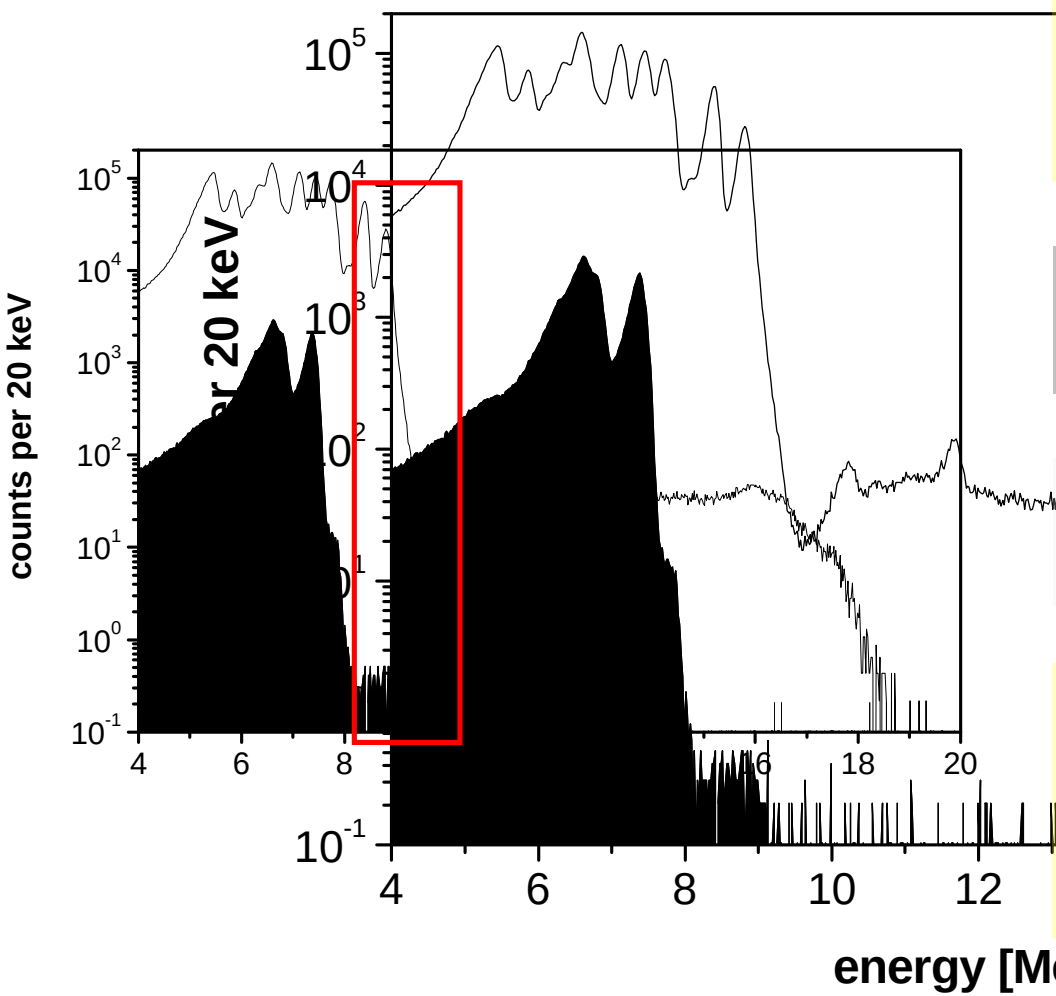
1. Introduction – why

Physical preseparation:

Example: DGFRS – Dubna gas-filled recoil separator



1. Introduction – why



α-sum spectra comparison:

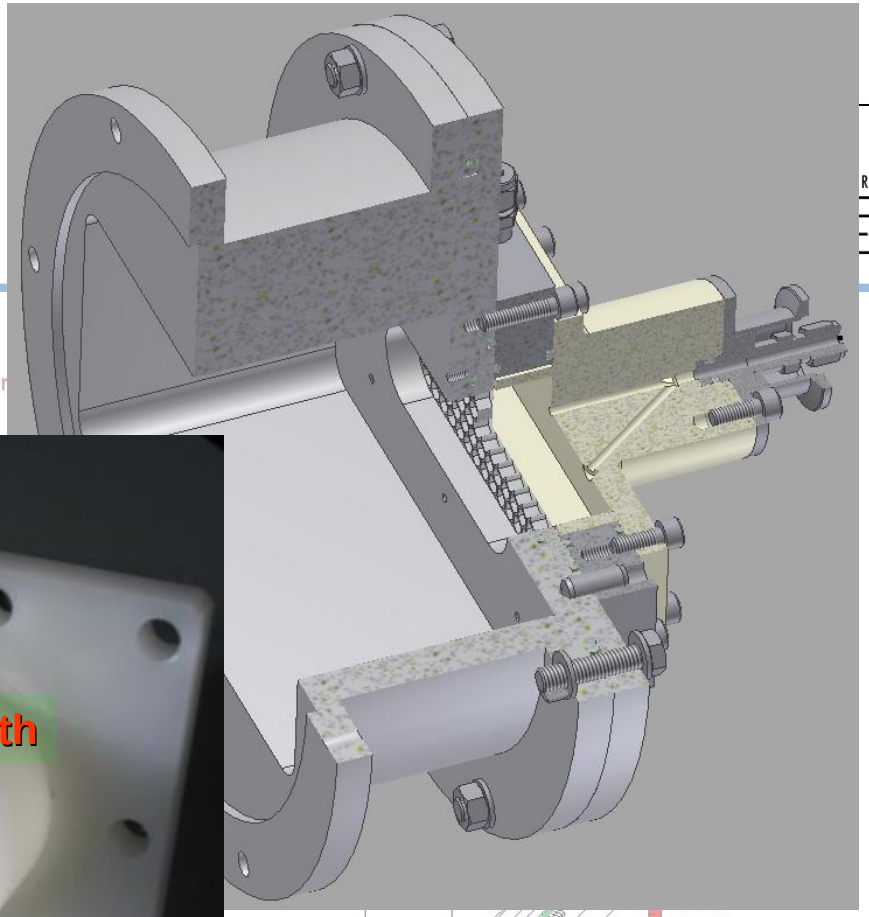
$^{242/244}$Pu(^{48}Ca, 3-4n)$^{287-289}$114

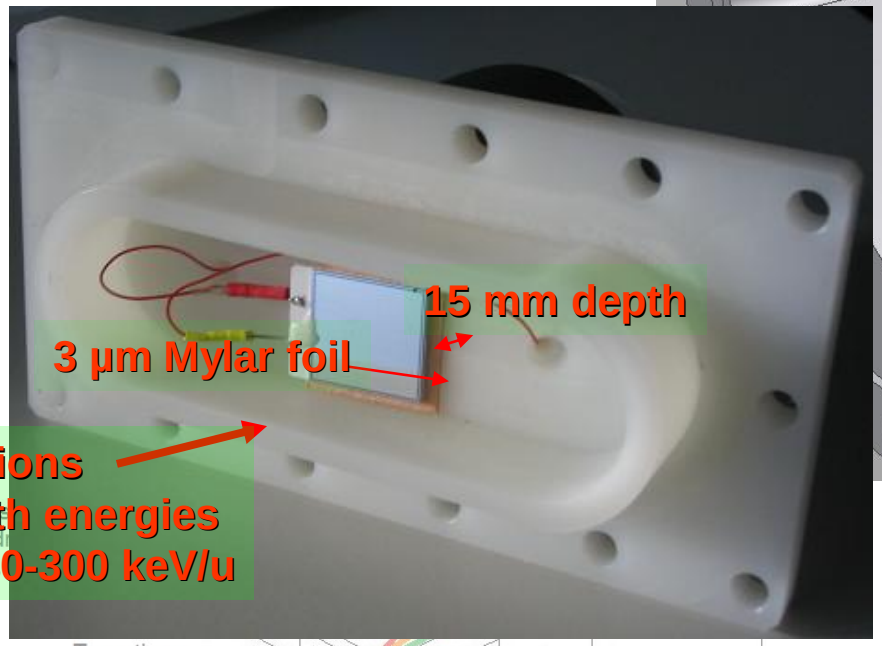
white spectrum: experiment in 2007 without preseparation

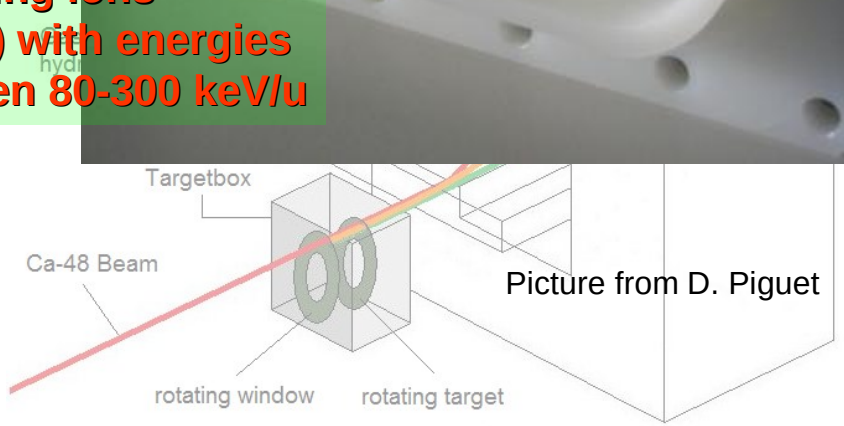
black spectrum: experiment in 2008 with preseparation

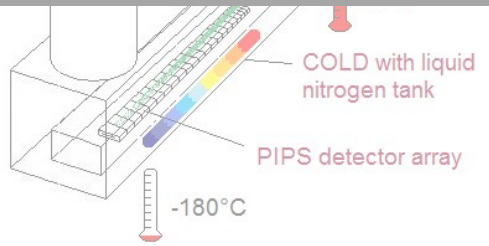
Same gas flow conditions
All data normalized to:
- 0.44 mg/cm2 $^{242/244}$Pu
- 10^{18} ^{48}Ca particles

1. Introduction – where



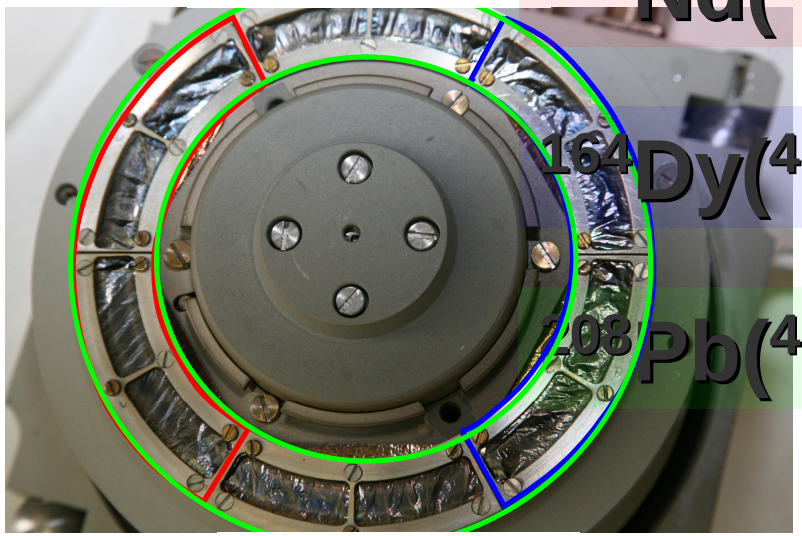






Picture from D. Piguet

1. Introduction – how



$^{142}Nd(^{48}Ca,5n)^{185}Hg$

$^{164}Dy(^{48}Ca,6n)^{206}Rn$

$^{208}Pb(^{48}Ca,2n)^{254}No$

Partition	Material	Surface density [µg/cm^2]	Material	Surface density [µg/cm^2]
1	Nd_2O_3	289.92	^{208}Pb	446
			Cu	1091
2	Nd_2O_3	318.31	^{208}Pb	433
			Cu	1068
3	empty		^{208}Pb	461
			Cu	1039
4	Dy_2O_3	317.40	^{208}Pb	327
			Cu	1023
5	Dy_2O_3	346.25	^{208}Pb	443
			Cu	1144
6	empty		^{208}Pb	423
			Cu	1164

2. Stopping force - what

$$-\frac{dE}{dx}$$

2. Stopping force - what

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Four different interactions of ions with matter:

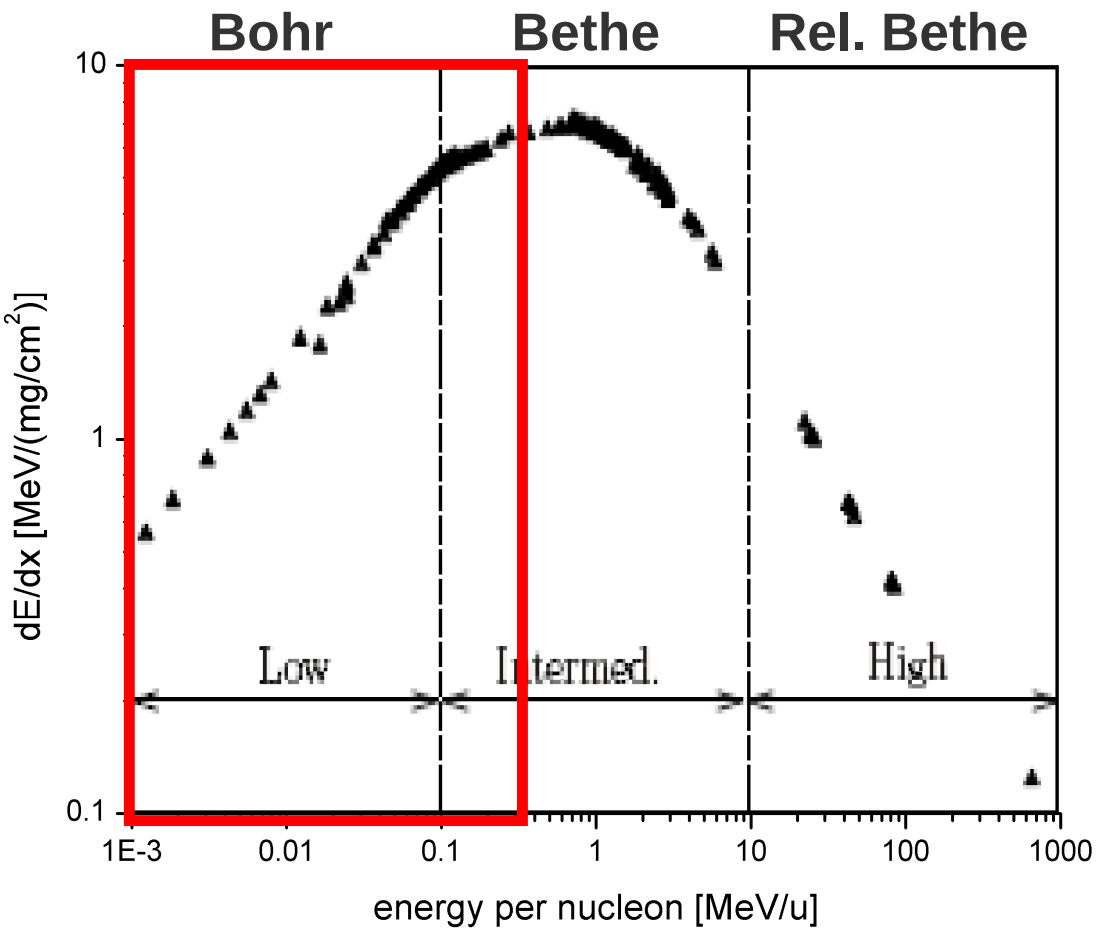
-elastic collisions with the target nucleus

-inelastic collisions with the target nucleus

-elastic collisions with the target electrons

-inelastic collisions with the target electrons

2. Stopping force - what



oxygen in aluminium

Picture from P. Sigmund: „Stopping of heavy ions“

2. Stopping force - what

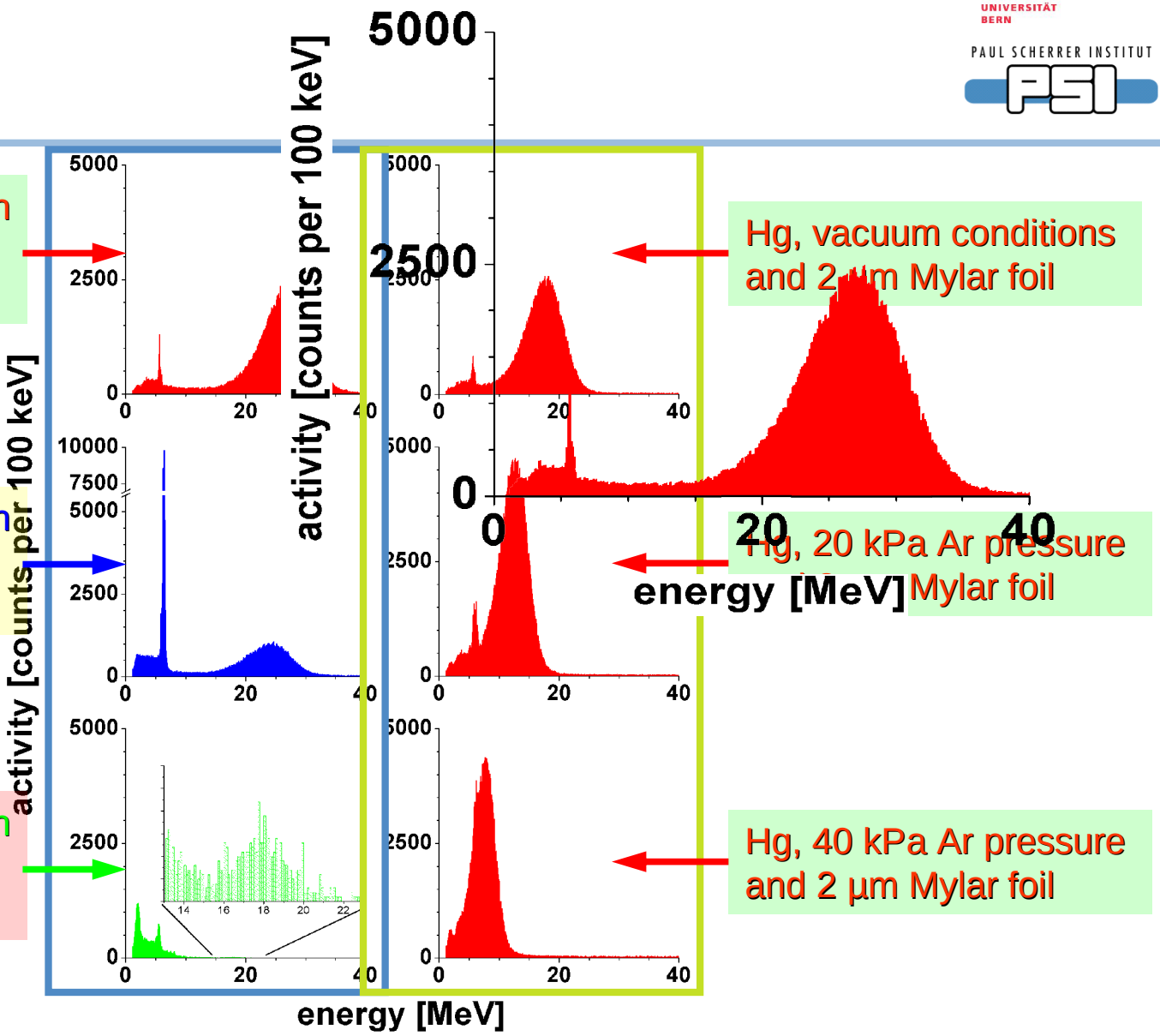
$$\frac{dE}{dx} = R\frac{4\pi Z_1^2}{m_e v_1^2}\int_{E_I}^{0} z_2 \left[\mu m\right] \text{or} \left[cm\right] \ln\left(\frac{C m_e v_1^3}{Z_1 v_0 I}\right) dx$$

3. Results

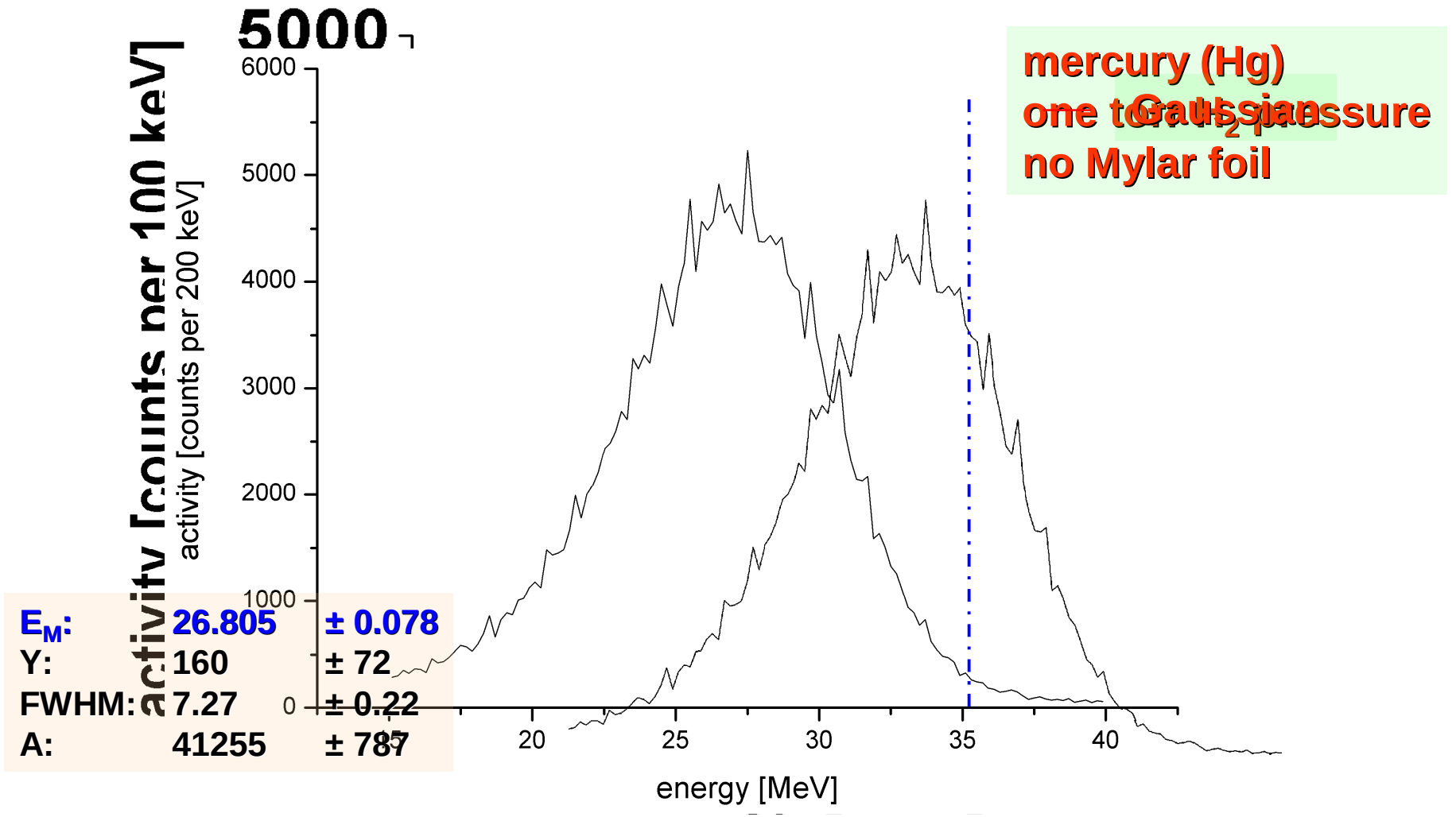
Hg at 1 torr H_2 pressure in the RTC and no Mylar foil in between

Rn at 1 torr H_2 pressure in the RTC and no Mylar foil in between

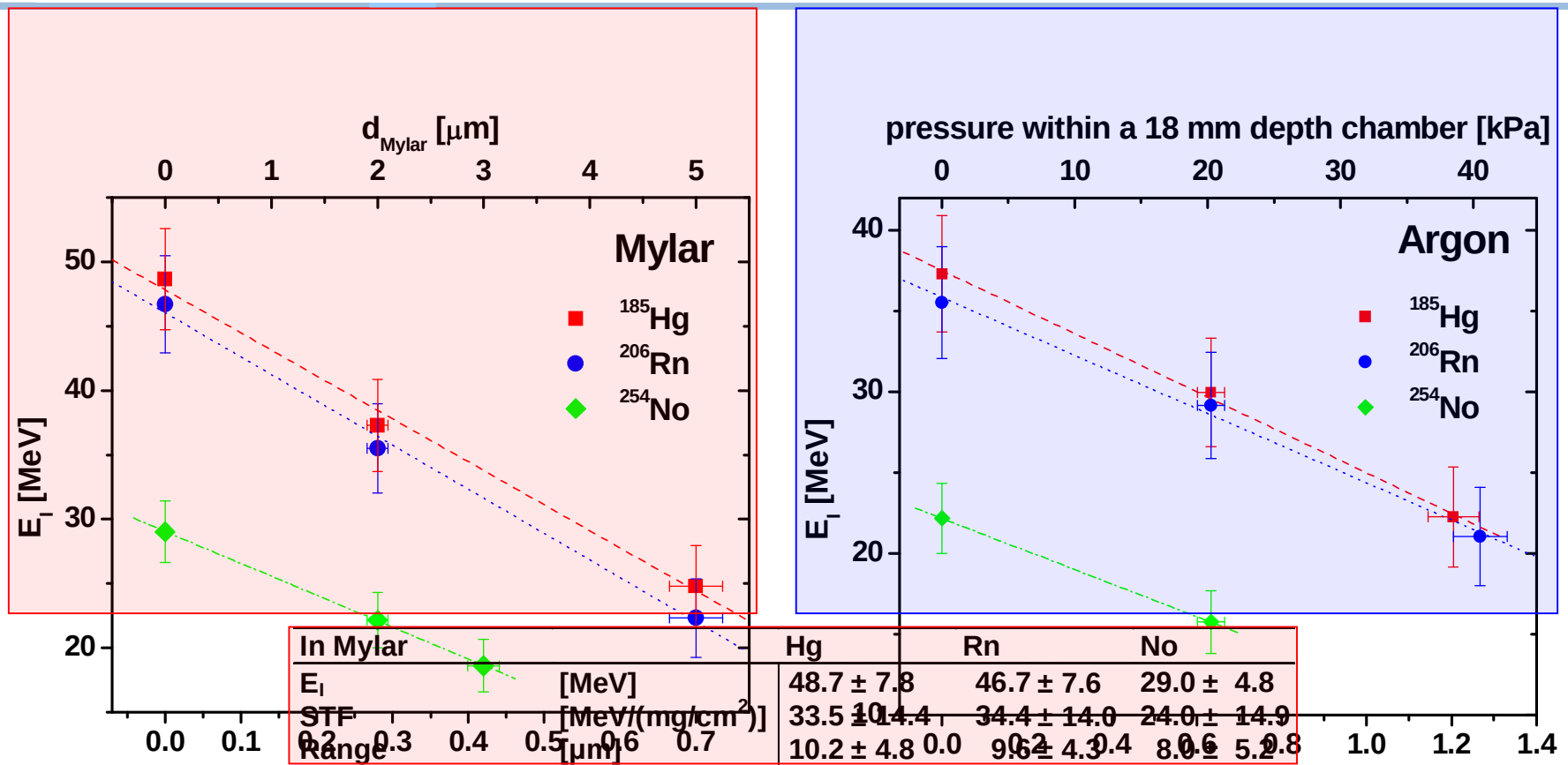
No at 1 torr H_2 pressure in the RTC and no Mylar foil in between



3. Results


5000
6000
5000
4000
3000
2000
1000
0
activity [counts per 200 keV]
activity [counts per 100 keV]
20
25
30
35
40
energy [MeV]
mercury (Hg)
one torr H_2 pressure
no Mylar foil
Gaussian
E_M: 26.805 ± 0.078
Y: 160 ± 72
FWHM: 7.27 ± 0.22
A: 41255 ± 787

3. Results



In Mylar		Hg	Rn	No
E_I	[MeV]	48.7 ± 7.8	46.7 ± 7.6	29.0 ± 4.8
STF	[MeV/(mg/cm^2)]	33.5 ± 14.4	34.4 ± 14.0	24.0 ± 14.9
Range	[μm]	10.2 ± 4.8	9.6 ± 4.3	8.0 ± 5.2

In Ar		Hg	Rn	No
E_I	[MeV]	37.3 ± 7.2	35.5 ± 7.0	8.4 ± 4.4
STF	[MeV/(mg/cm^2)]	12.5 ± 6.7	11.5 ± 6.3	10.1 ± 6.7*
Range at 101 kPa	[cm]	1.7 ± 1.0	1.7 ± 1.0	1.2 ± 1.0*

* STF and Range uncertainties for No in Ar are estimated maximal values

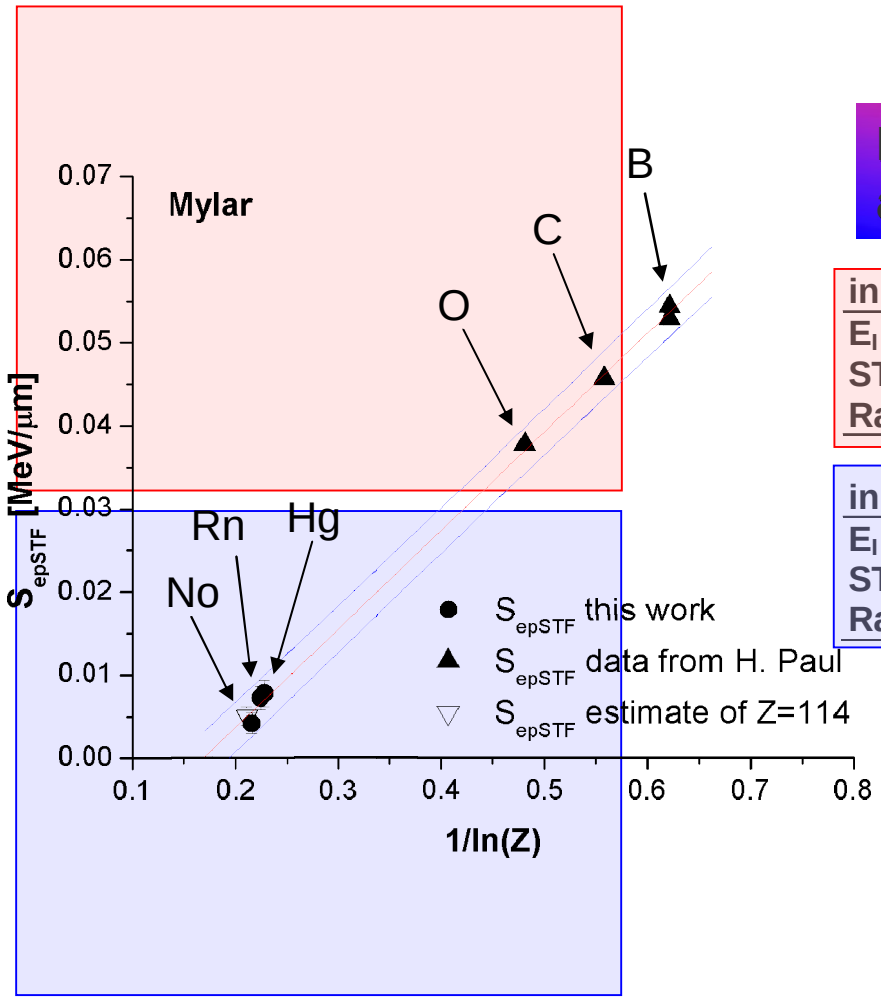
3.1 Extrapolation

Extrapolation to the STF of $^{289}114$ was done using:

$$-\left.\frac{dE}{dx}\right|_Z = q_{eff}^2(E_{real}, Z, A) \cdot \left[-\frac{dE}{dx}\right]_{Z=1}$$

All ions must have the same specific energy !

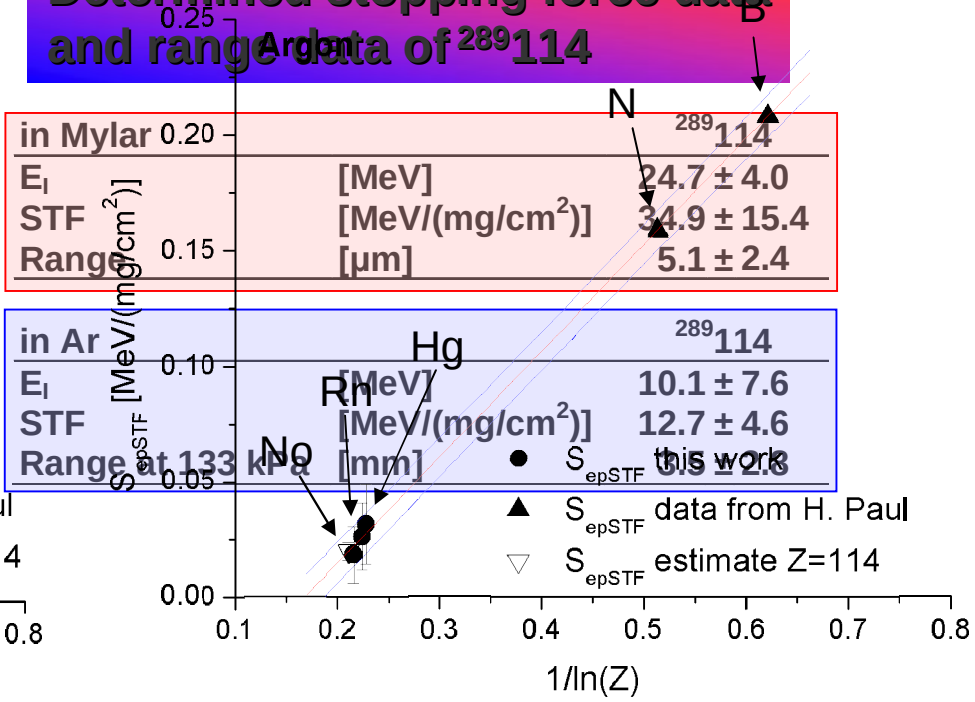
3.1 Extrapolation



Determined stopping force data and range data of ^{289}114

in Mylar		^{289}114
E_I	[MeV]	24.7 ± 4.0
STF	[MeV/(mg/cm^2)]	34.9 ± 15.4
Range	[µm]	5.1 ± 2.4

in Ar		^{289}114
E_I	[MeV]	10.1 ± 7.6
STF	[MeV/(mg/cm^2)]	12.7 ± 4.6
Range at 133 kPa	[mm]	6.3 ± 2.8

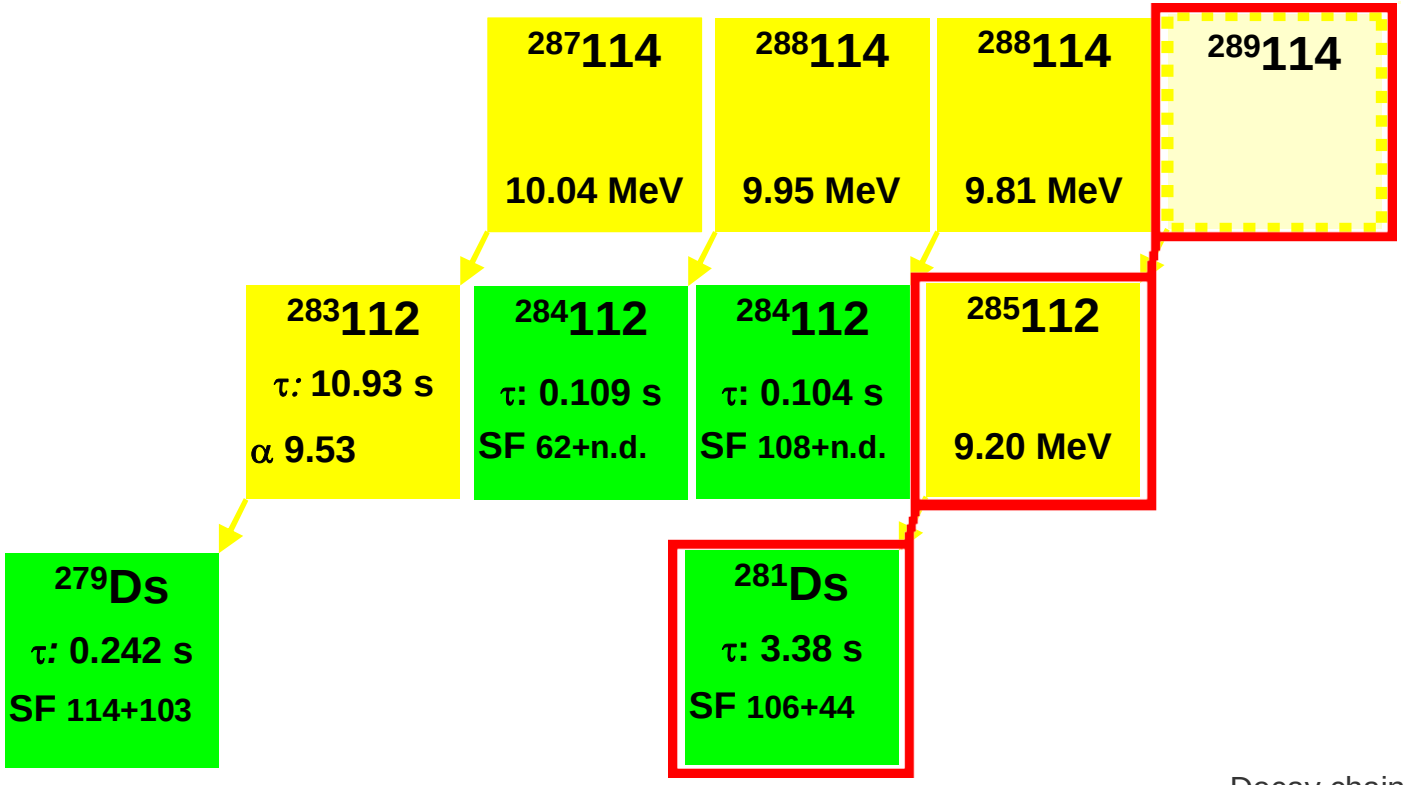


Light ion data from from H. Paul.
www.exphys.uni-linz.ac.at/stopping

3.2 Verification

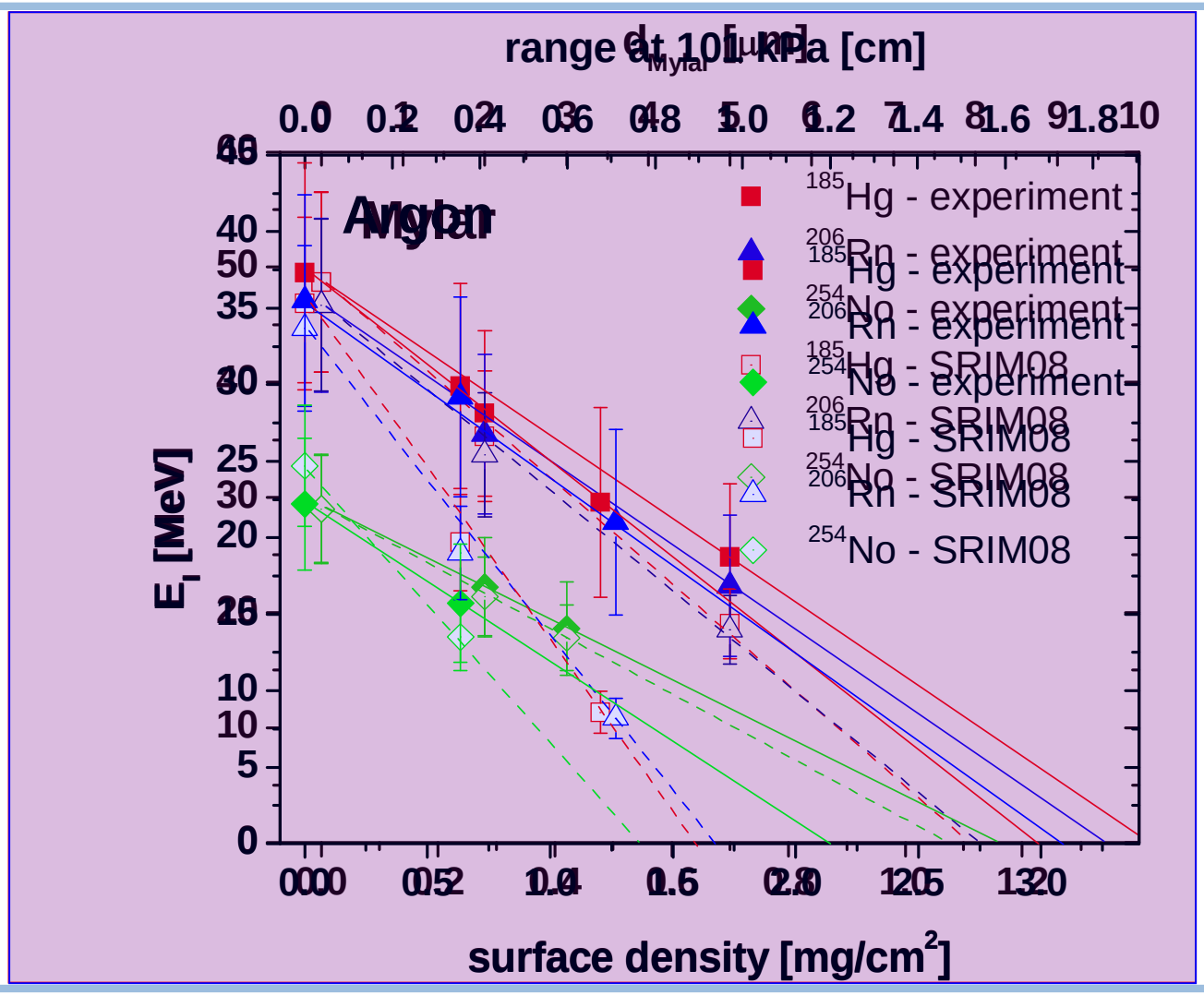
^{244}Pu (^{48}Ca, 3-4n) $^{288\text{-}289}114$

1.43•10^{19} ^{48}Ca particles during 51 days

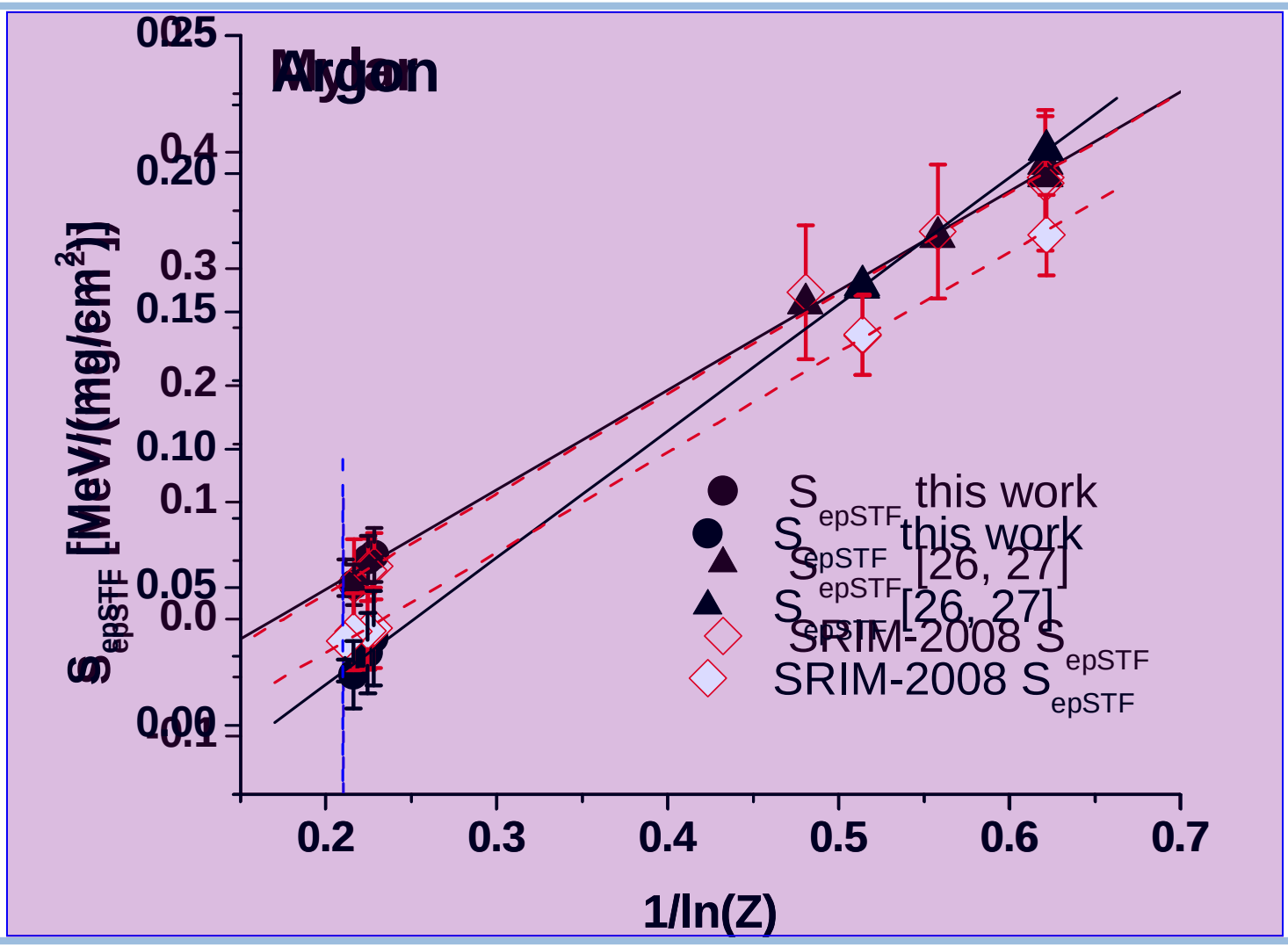


Decay chains from R. Eichler

3.3 Comparison with SRIM-2008



3.3 Comparison with SRIM-2008



4. Summary

-The recoil energy of ^{289}114 in Mylar is high enough so that it passes the 3 µm Mylar foil

-The recoil energy of ^{289}114 in argon after the Mylar foil is low enough so that it stops completely in the RTC

-SRIM-2008 values and experimental values are almost identical for Mylar but have larger differences for gaseous argon

Acknowledgements

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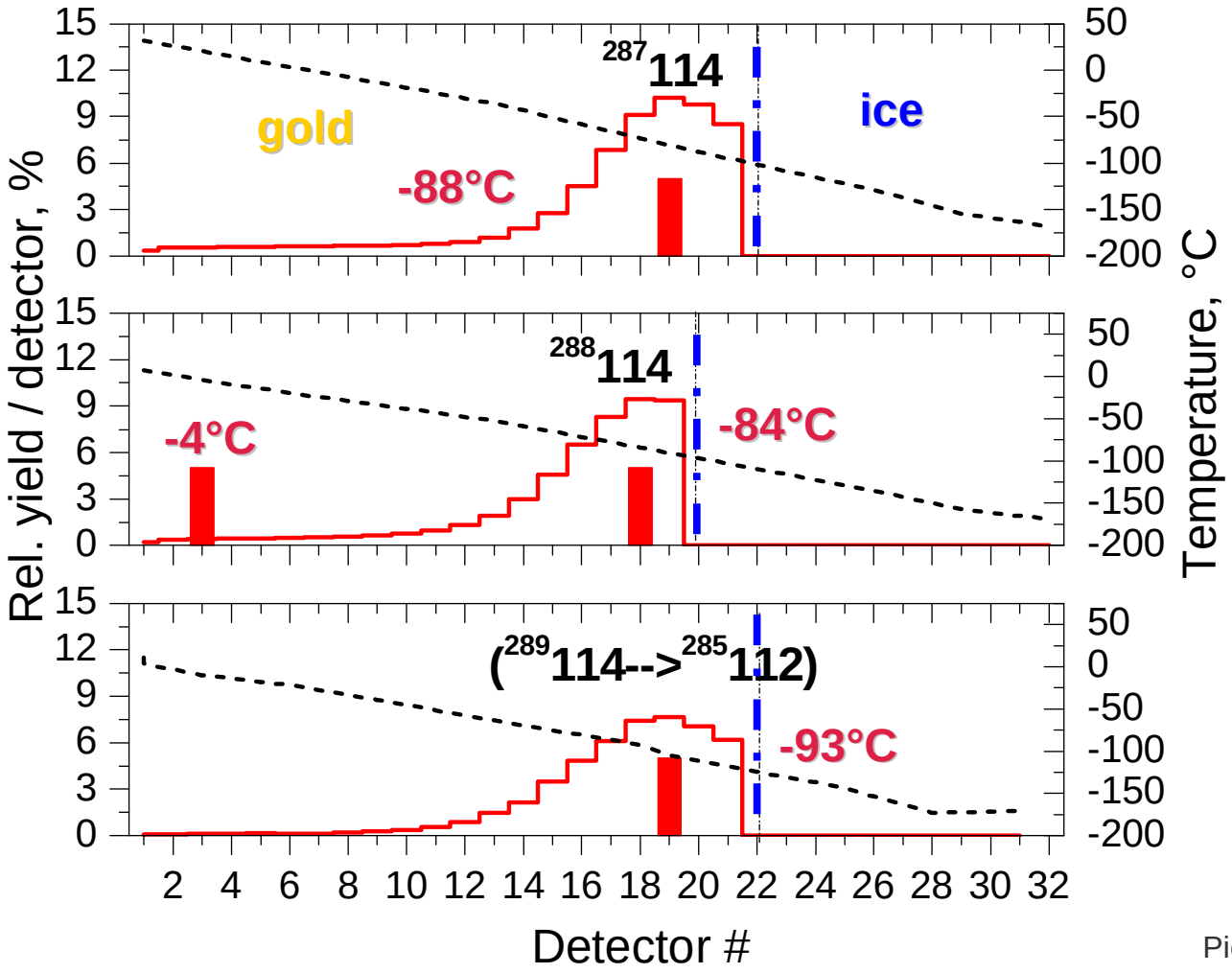
People:

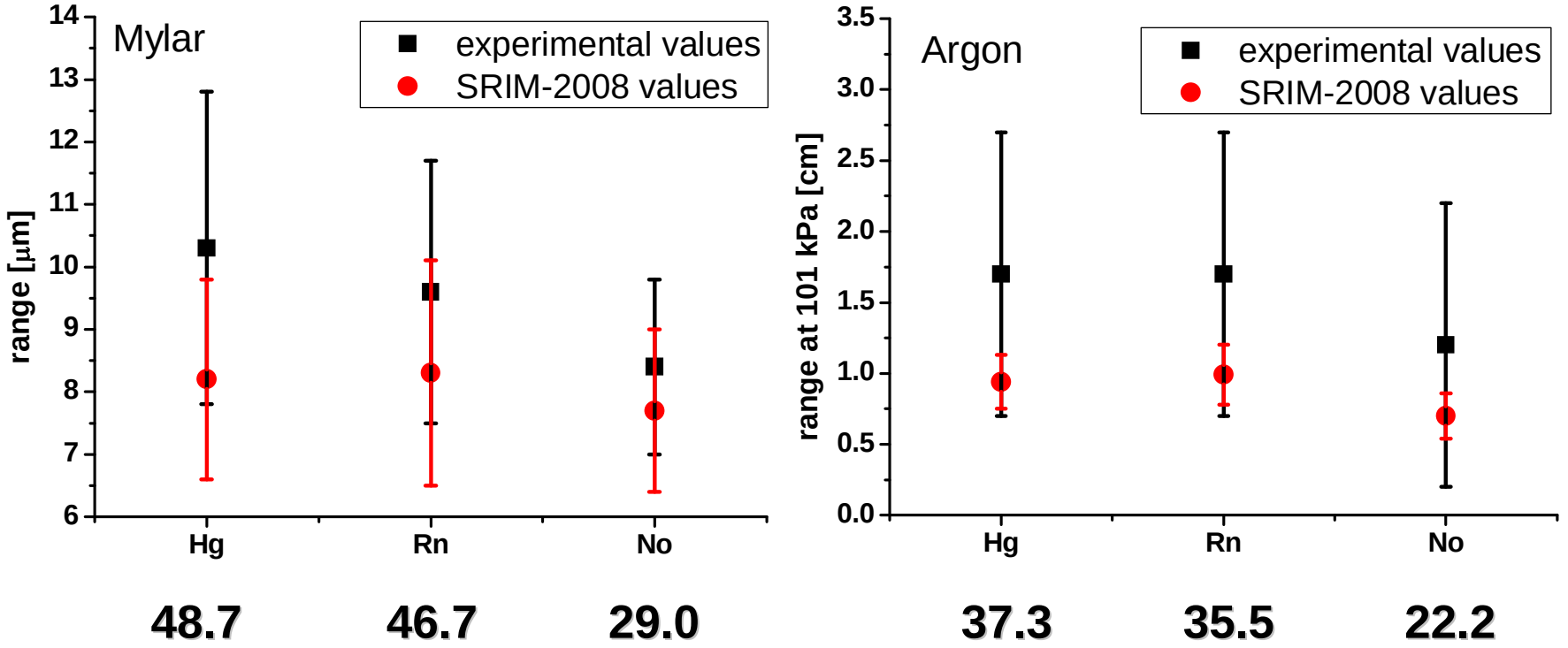
- Accelerator and ECR crews:
  FLNR: U400; PSI: Philips cyclotron
- Tech-shops @ University Bern, PSI, FLNR
- US Department of Energy (^{244}Pu)

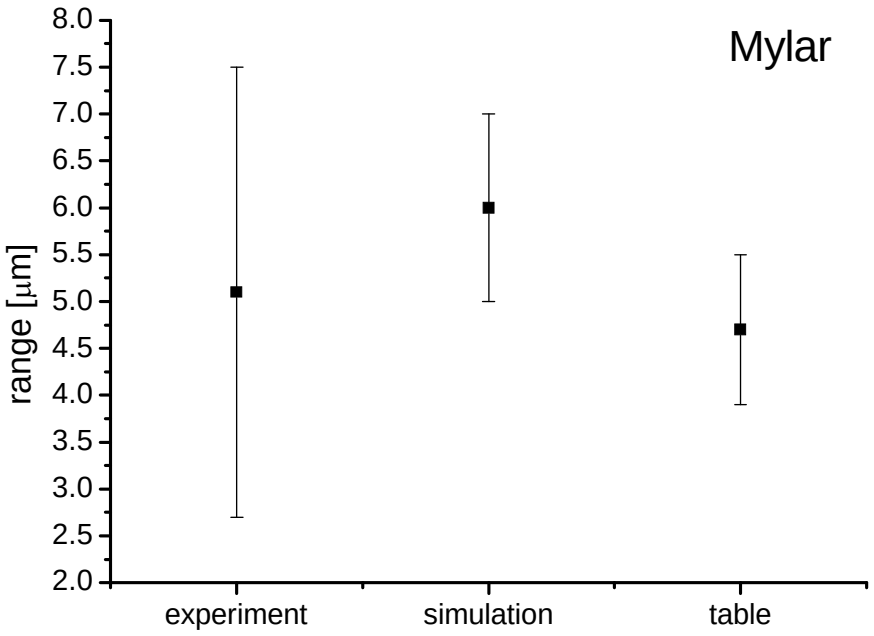
Funding:

-US Department of Energy
-Russian Foundation for Basic Research
-Swiss National Science Foundation

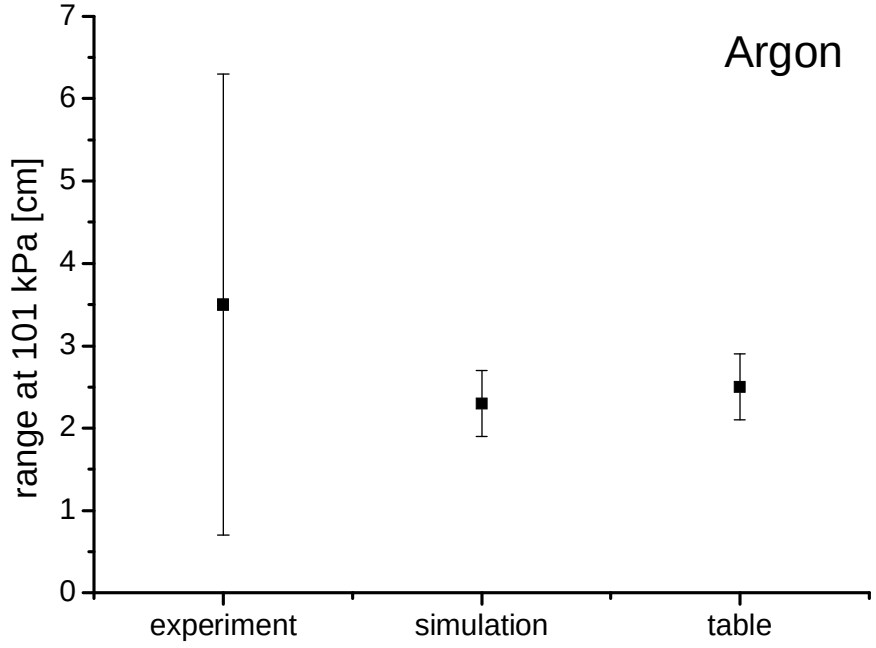


Picture from R. Eichler


Mylar
experimental values
SRIM-2008 values
range [µm]
14
13
12
11
10
9
8
7
6
Hg
Rn
No
48.7
46.7
29.0
Argon
experimental values
SRIM-2008 values
range at 101 kPa [cm]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Hg
Rn
No
37.3
35.5
22.2
TKE (MeV)



24.7 MeV TKE



10.1 MeV TKE

	Efficiency $\varepsilon_{transp}*\varepsilon_{deposition}*\varepsilon_{det}*\varepsilon_{Window}*\varepsilon_{Separator}$	1 event σ[pb]	2 event σ[pb]	3 event σ[pb]
alpha-SF				
$^{285}112$	0.192	0.54	1.09	1.63
$^{288}114$	0.036	2.90	5.80	8.71
$^{284}112$	0.043	2.43	4.86	7.29
alpha-alpha-SF				
$^{289}114$	0.096	1.09	2.18	3.27