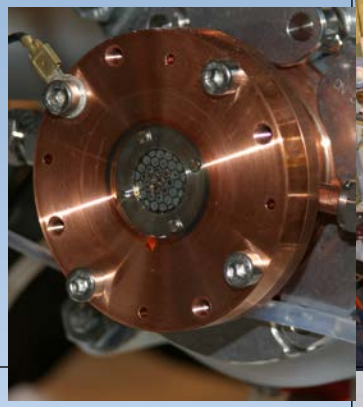
PAUL SCHERRER INSTITUT

PSI

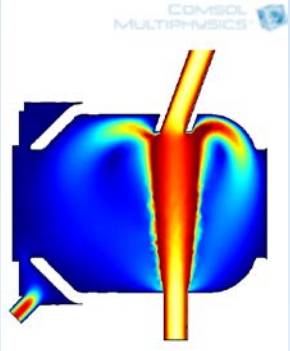
COMSOL CONFERENCE EUROPE 2012



COMSOL Conference Europe 2012 Milan

Paul Scherrer Institut

Rugard Dressler

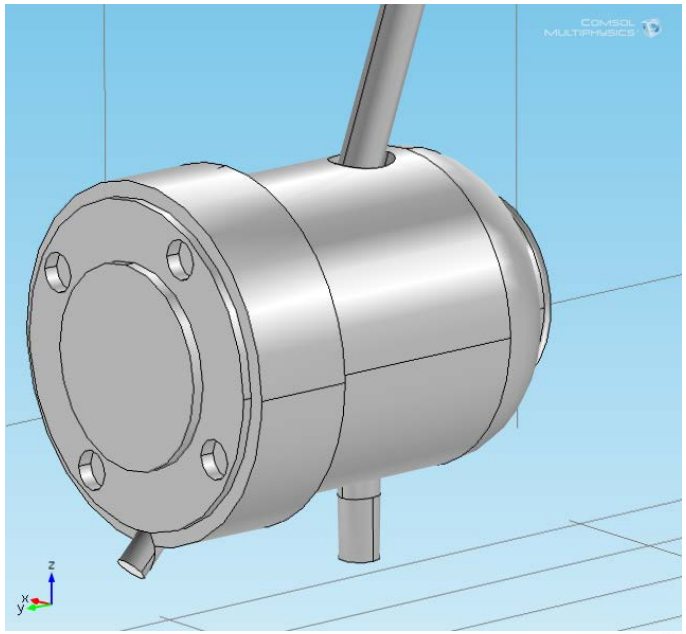


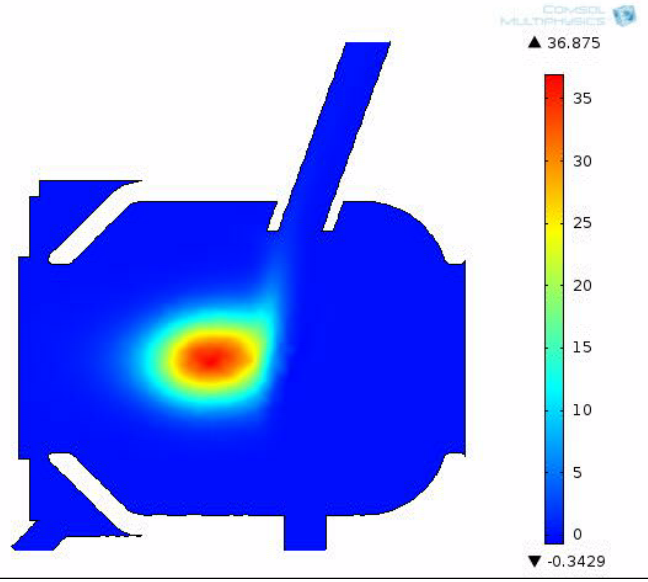
Predicting the retention time of nuclear reaction products in the PSI recoil chamber using COMSOL® Multiphysics

Acknowledgments

- Dr. Andreas Jakob
  (Laboratory for Waste Management)
  for the possibility to use COMSOL® Multiphysics

- Sven Friedel, Thierry Luthy and Zoran Vidakovic
  (COMSOL® Multiphysics Switzerland)
  for technical support and help





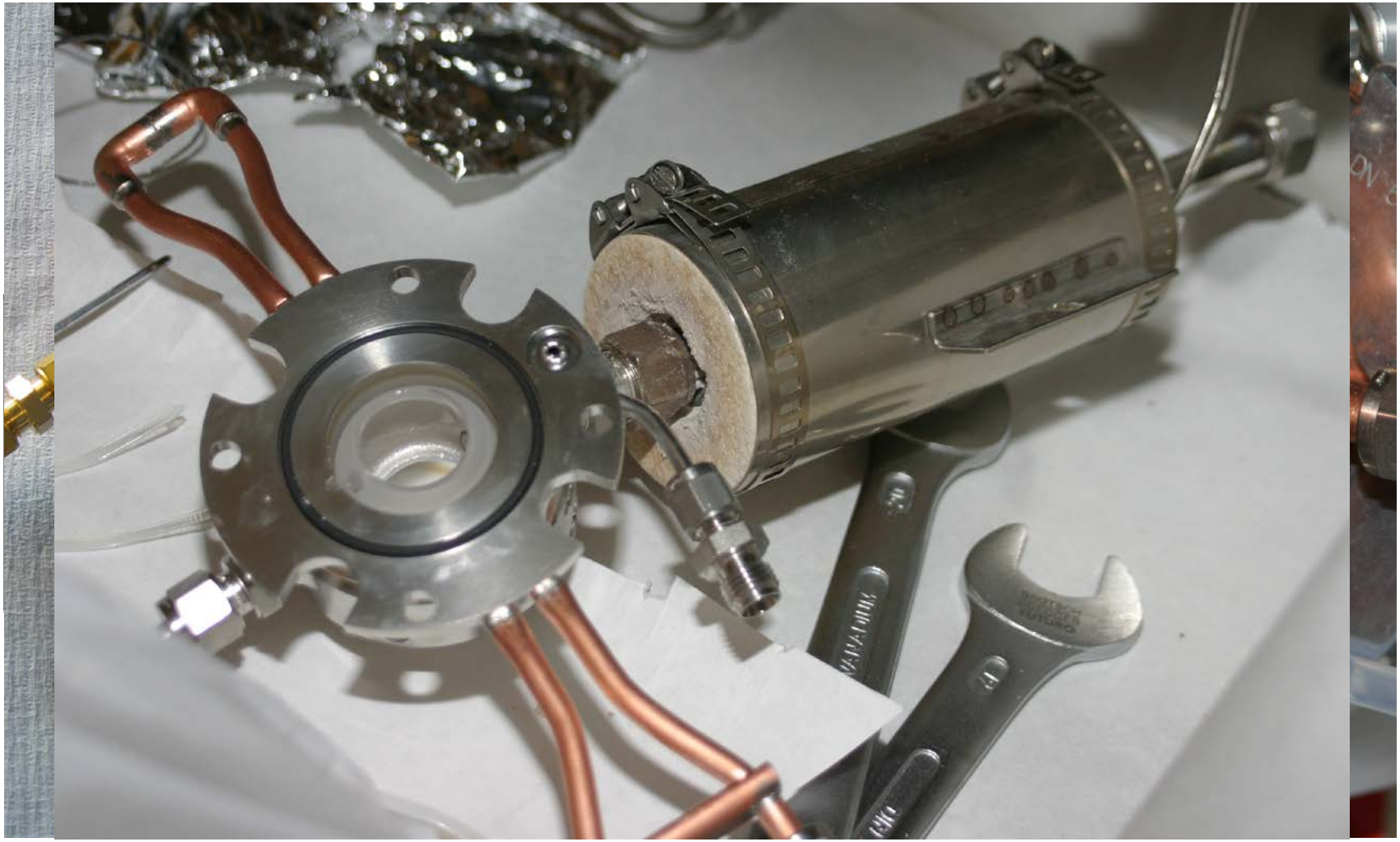
Periodic Table of Elements

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

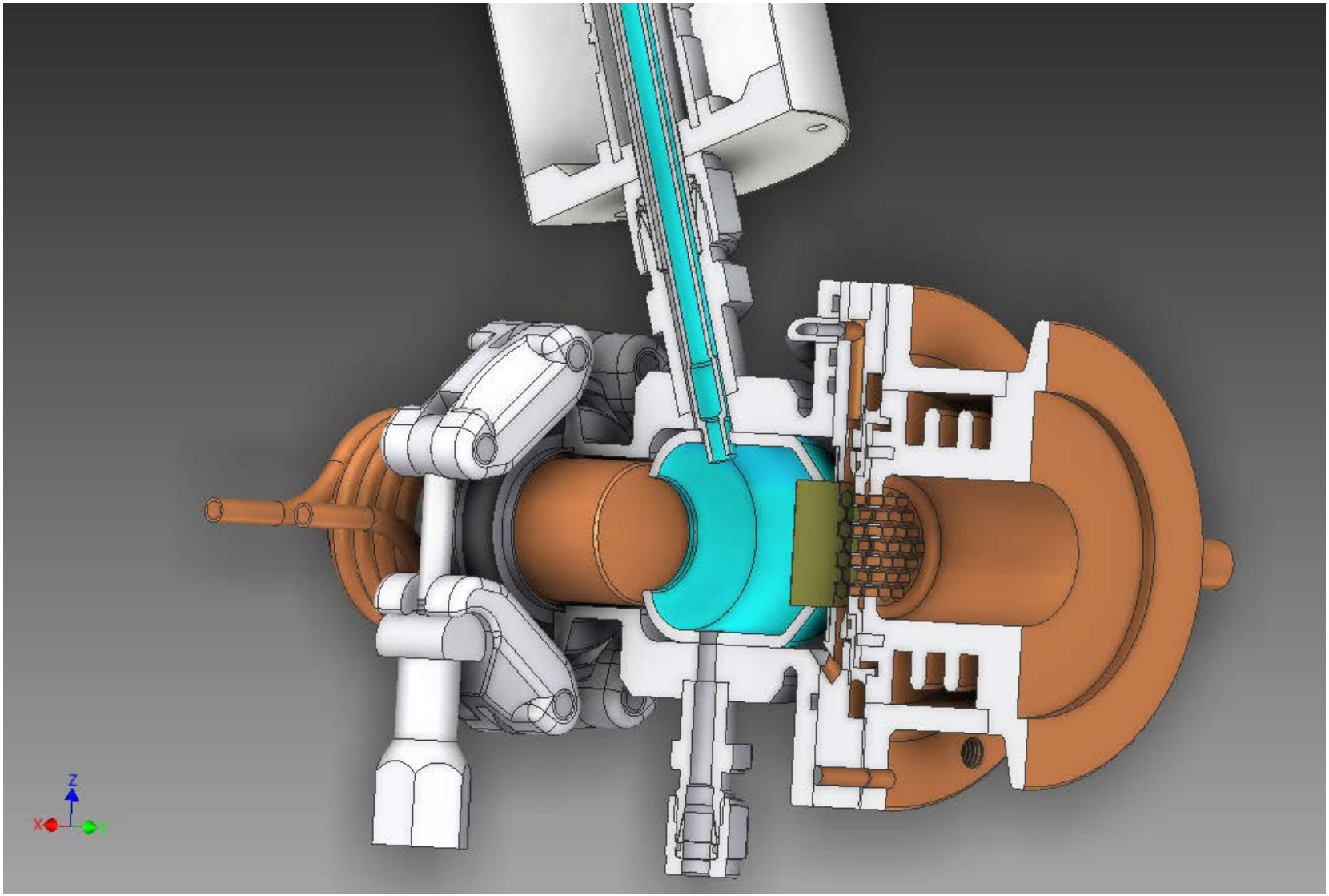
58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Pure & Appl. Chem. 69 (1997) 2471; 75 (2003) 1613; 76 (2004) 2101; 82 (2010) 753

Insitu-Volatilization and On-line detection apparatus

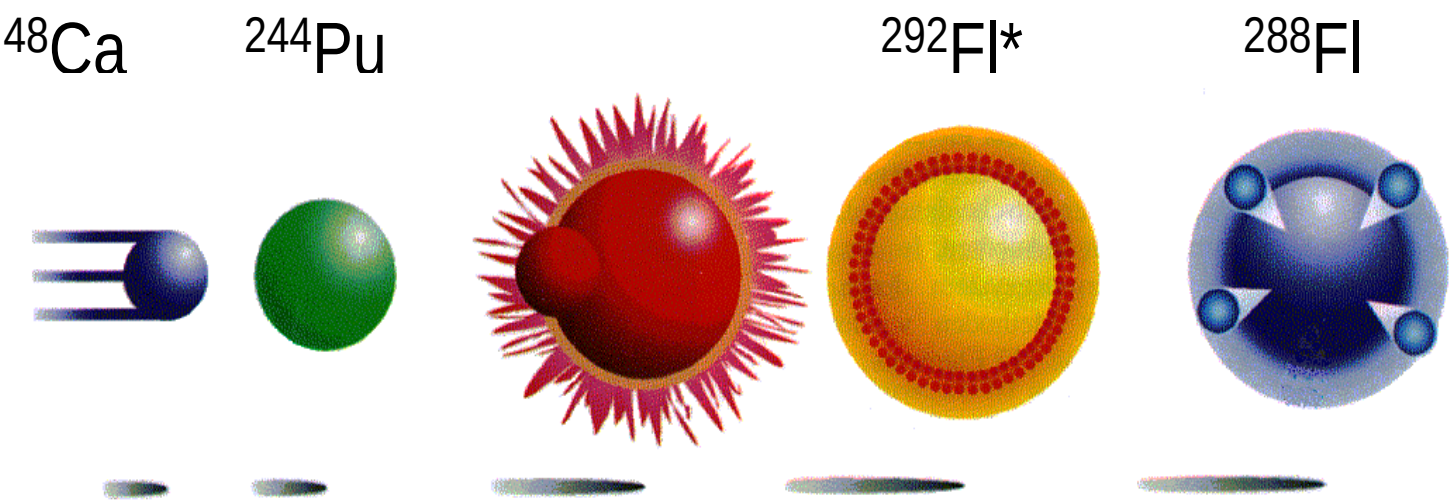


PSI - recoil chamber



Synthesis of element Flerovium (*Z*=114)

$^{244}Pu(^{48}Ca, 4n)^{288}Fl$



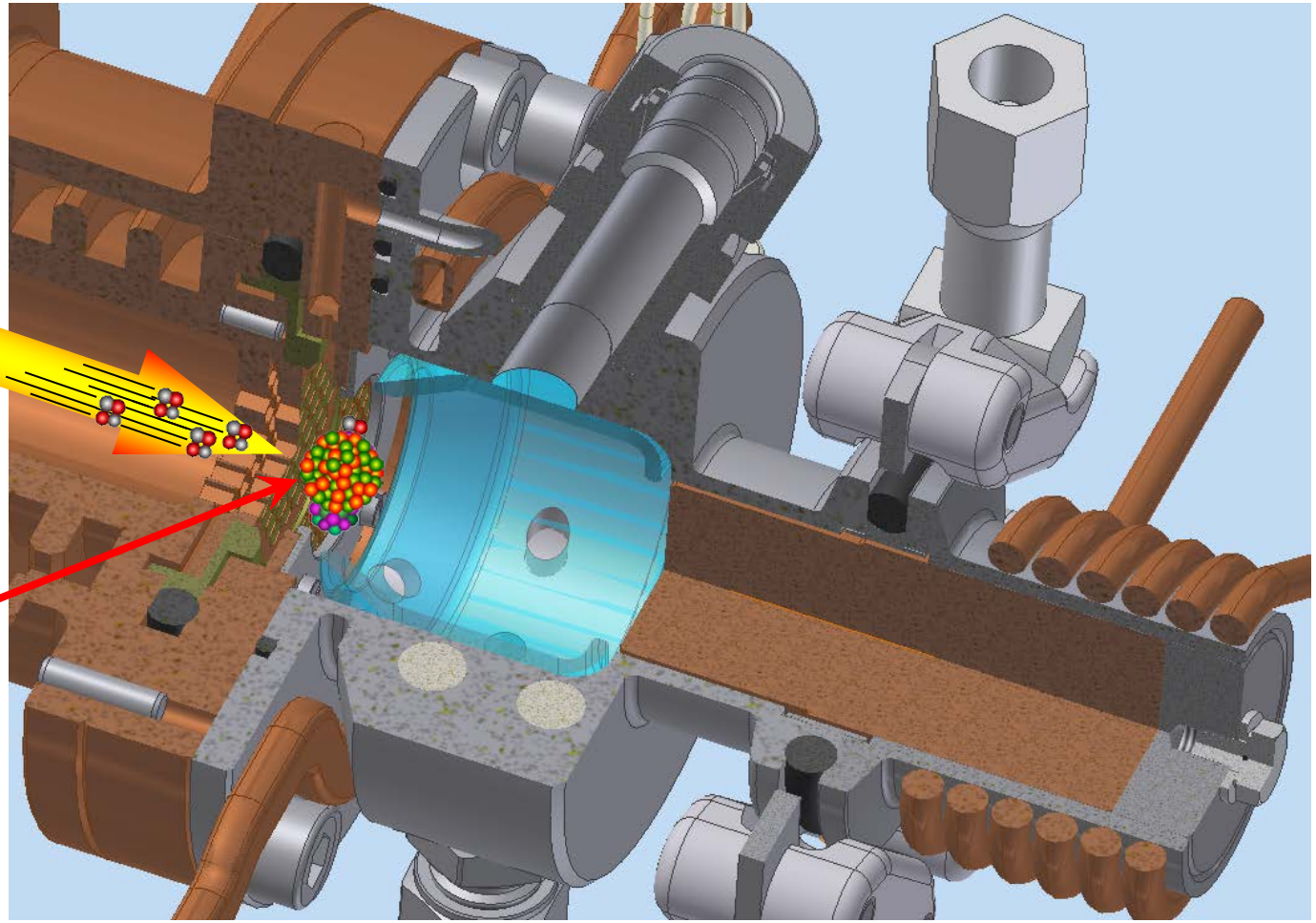
2×10^{17} ions per day

1×10^{19} atoms in target → 5×10^{8} compound nuclei per day → 7 atoms produced per day

Nuclear synthesis in PSI - recoil chamber

^{48}Ca beam

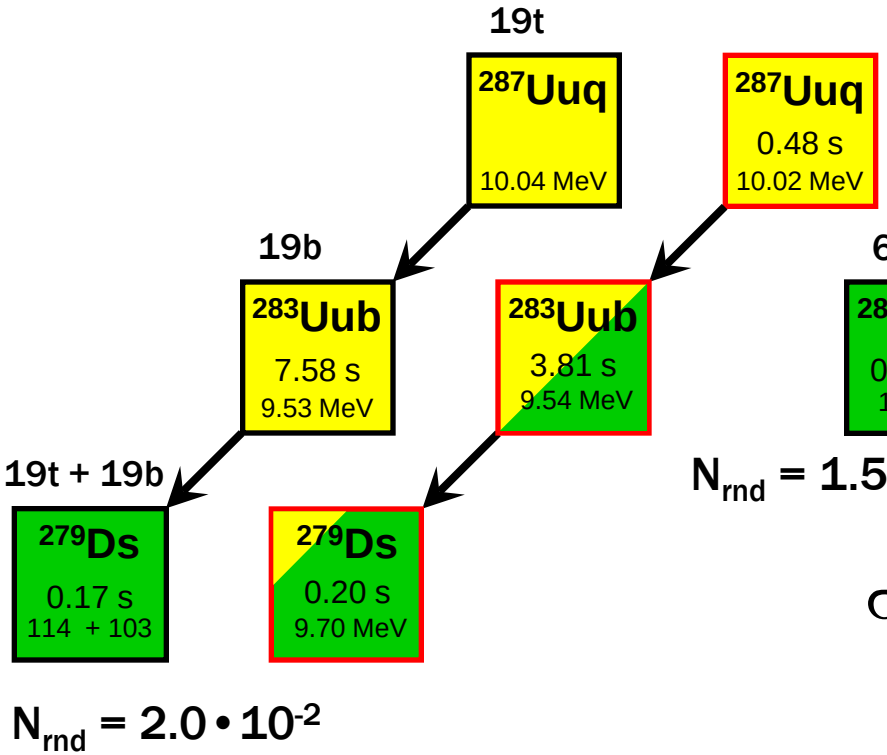
^{244}Pu target



Observed decay chains

$^{242}Pu + {}^{48}Ca$

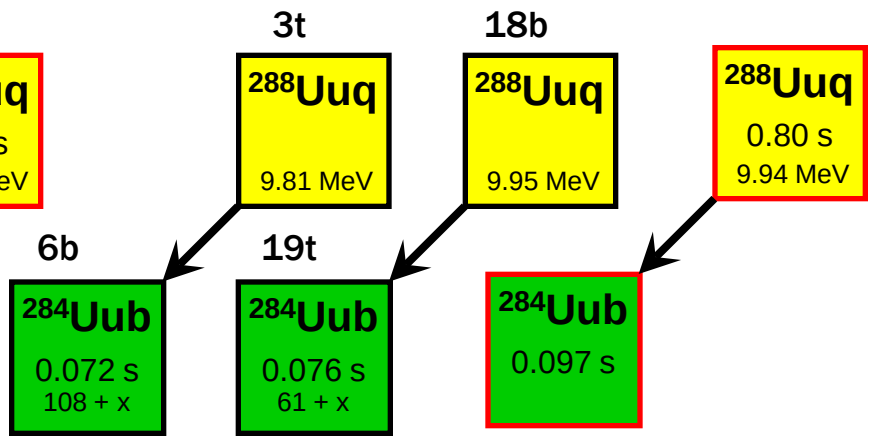
$3.1 \cdot 10^{18}$ ^{48}Ca during 16 days



$N_{rnd} = 2.0 \cdot 10^{-2}$

$^{244}Pu + {}^{48}Ca$

$4.5 \cdot 10^{18}$ ^{48}Ca during 16 days



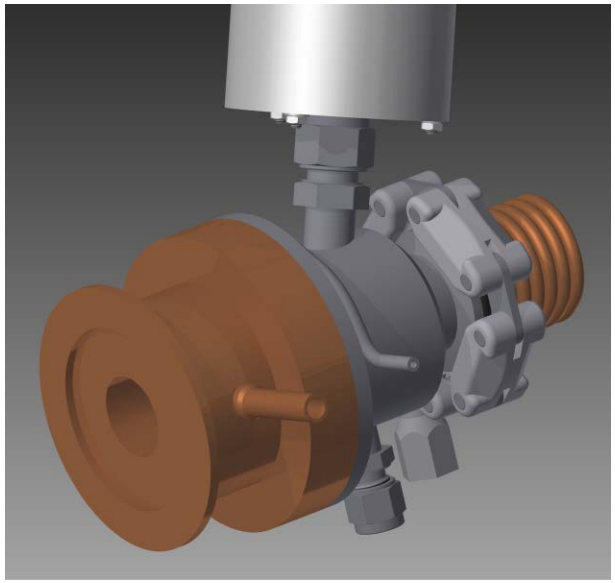
$N_{rnd} = 1.5 \cdot 10^{-3}$ $N_{rnd} = 1.1 \cdot 10^{-2}$

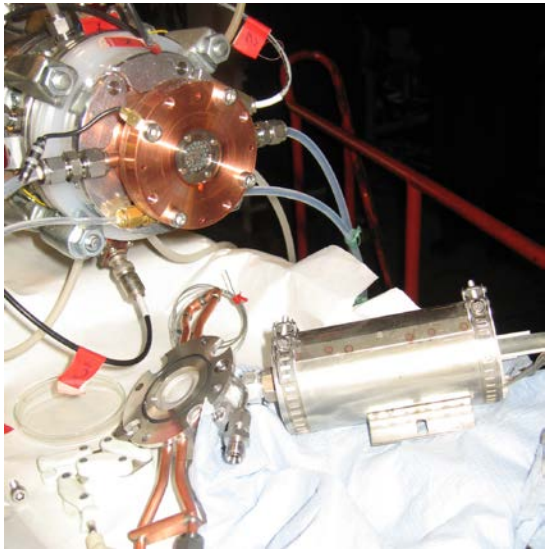
$\sigma_{estimated} = 3.7$ pb

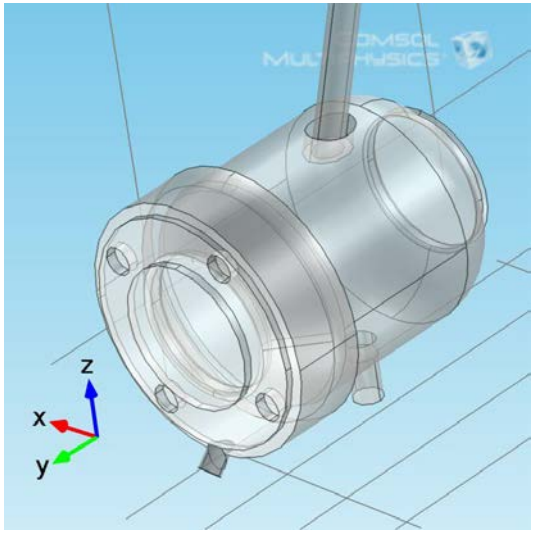
R. Eichler, et al.: Radiochim. Acta 98 (2010) 133

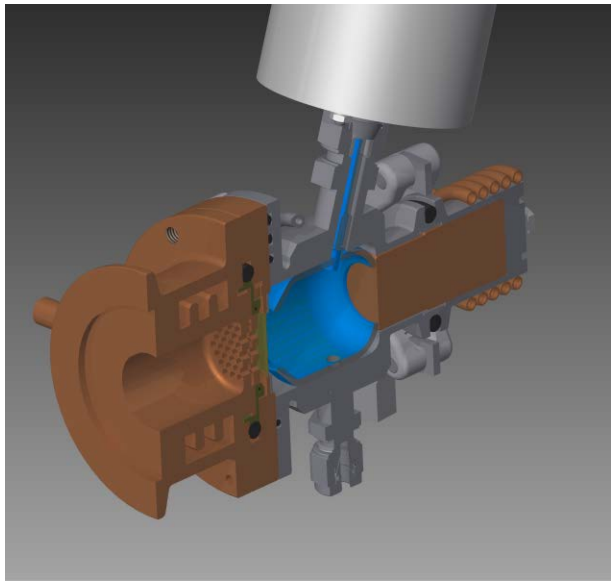
Yu. Oganessian: J. Phys. G 34 (2007) R165

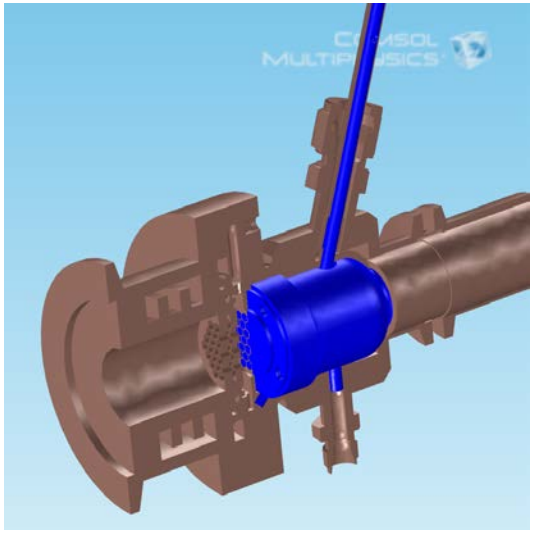
From 3D CAD model to COMSOL® geometry

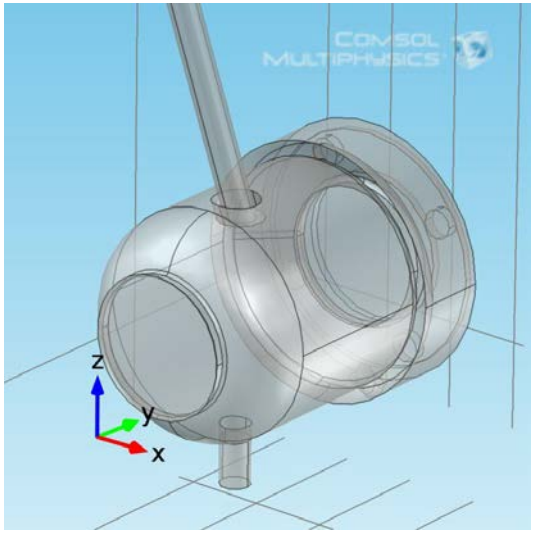




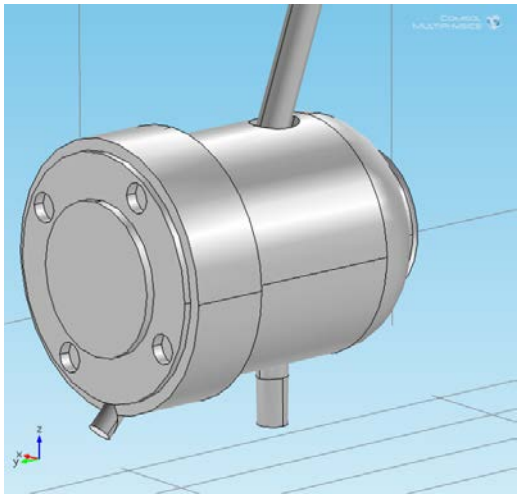


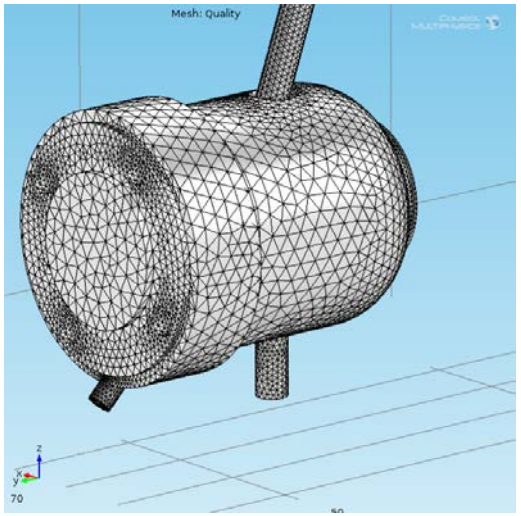


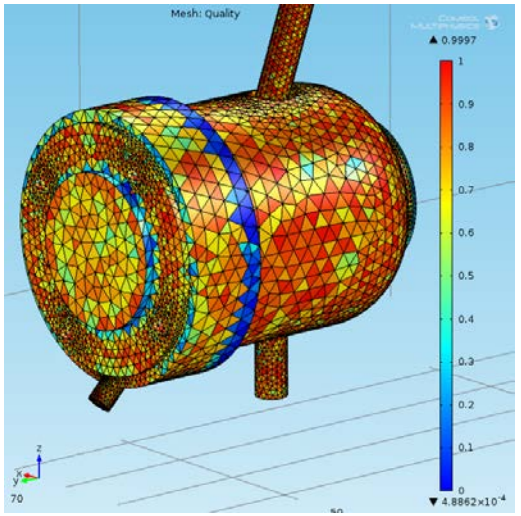




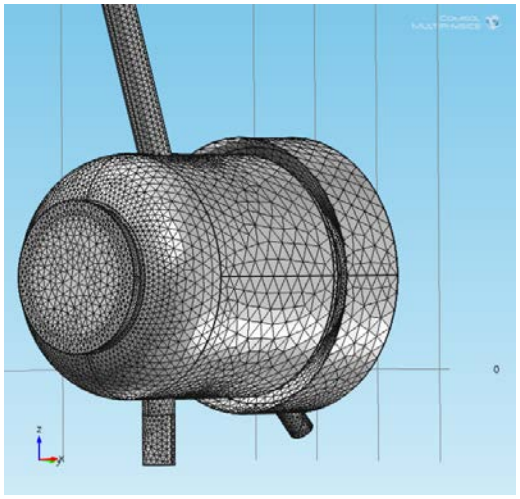
3D modeling & meshing

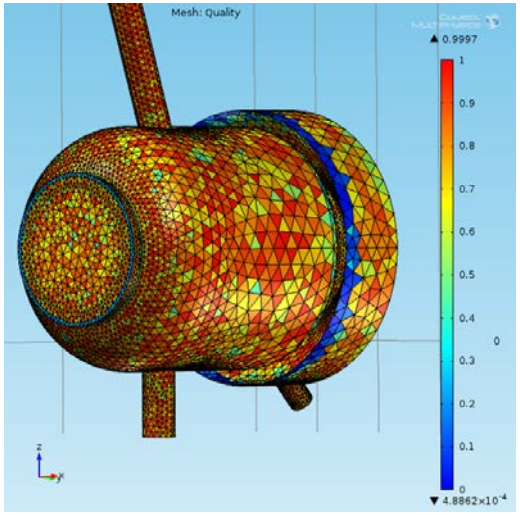




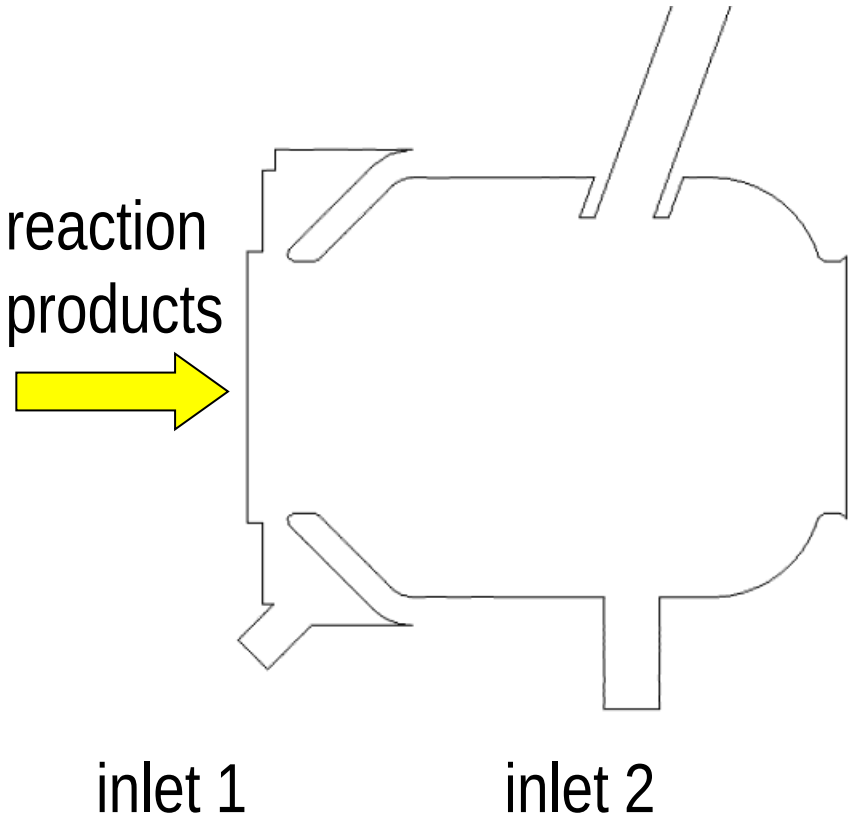


- elements: 504298
- min.quality: 4.886×10^{-4}
- average quality: 0.7592
- degrees of freed.: 466377

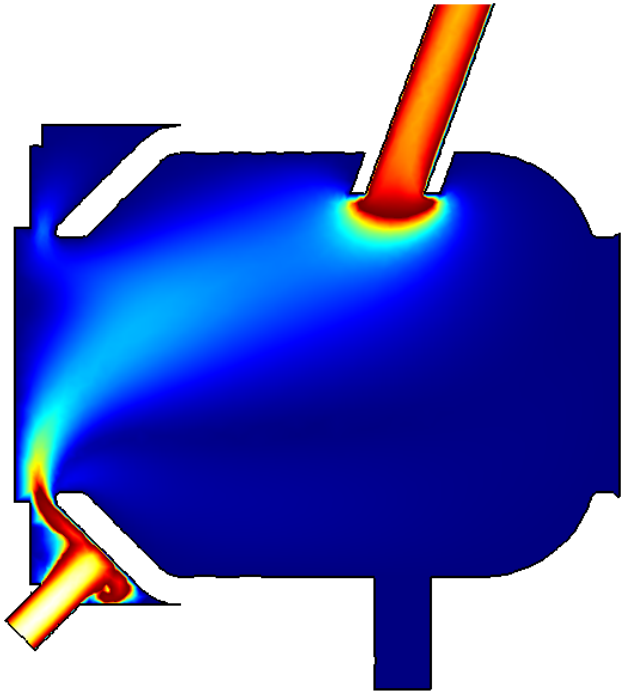




Steady state flow pattern



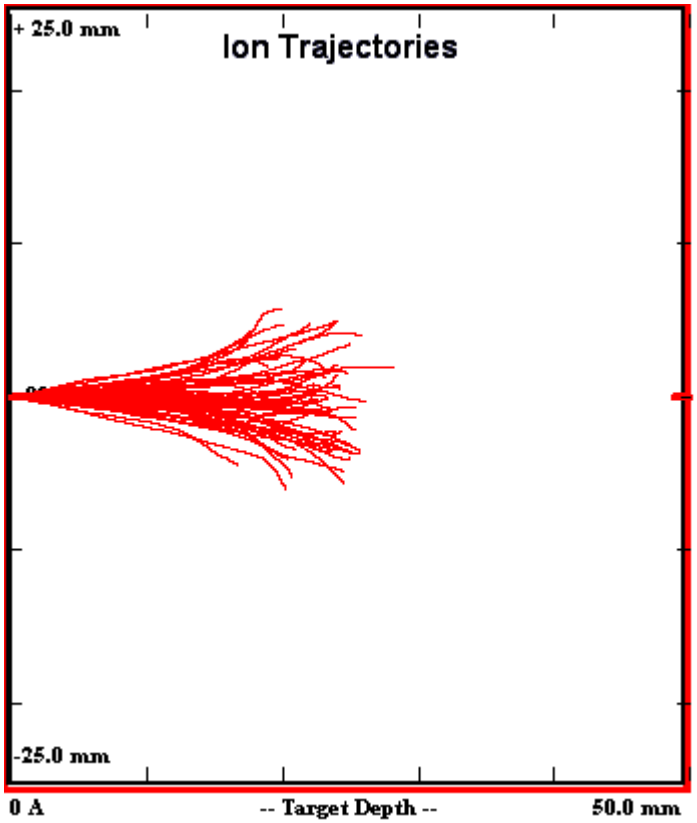
Flow pattern
(velocity magnitude)

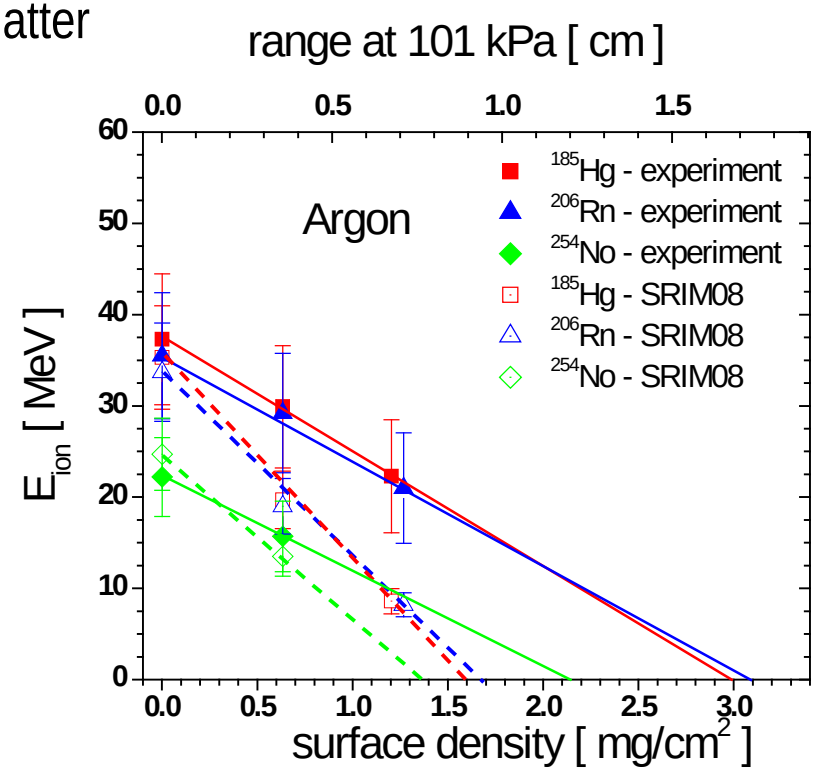


Flow pattern 1.5 l/min 100% inlet 1

Reaction product distribution

SRIM - The Stopping and Range of Ions in Matter
J.F. Ziegler, J.P. Biersack, M.D. Ziegler
http://www.srim.org (Lulu Press Co. 2008)





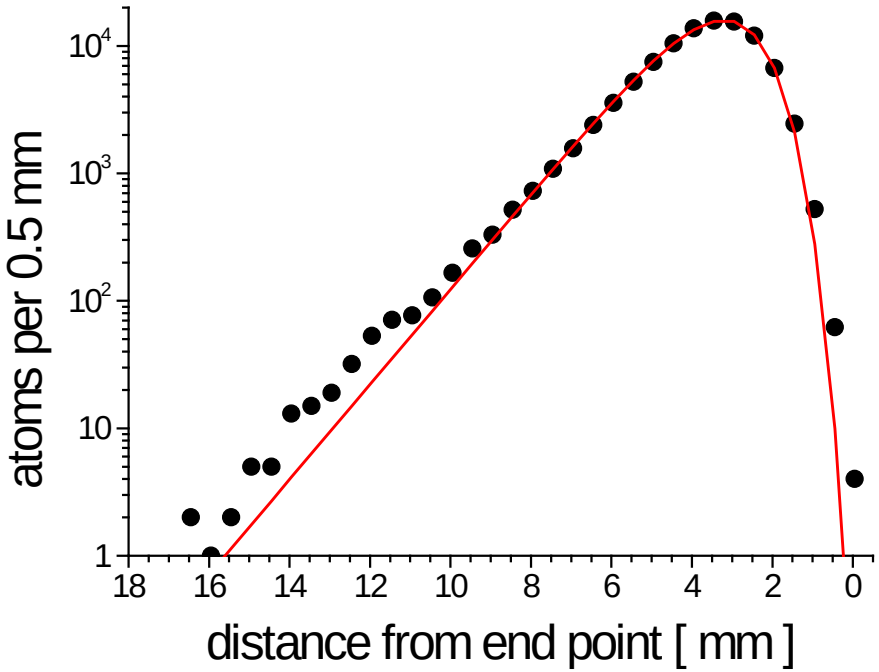
SRIM-2008 over estimates the stopping force of heavy ions in argon about a factor 1.4

D. Wittwer, et al.: Nucl. Instr. and Meth. in Phys. Res. B 268 (2010) 28

Parameterization for reaction products

Lateral distribution

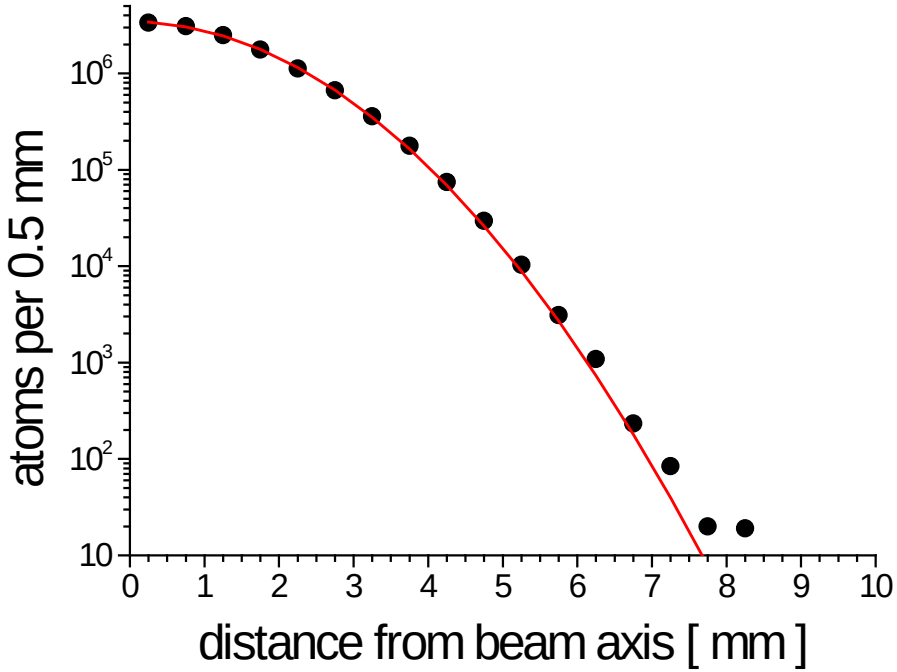
(Rayleigh type)



$$f(x) \propto \frac{1}{w_l} \cdot \mathrm{Exp}\left(\frac{x - x_p}{w_l} - \left(1 - \mathrm{e}^{-\frac{x}{w_l}}\right) \cdot \mathrm{e}^{-\frac{x - x_p}{w_l}} \right)$$

Radial distribution

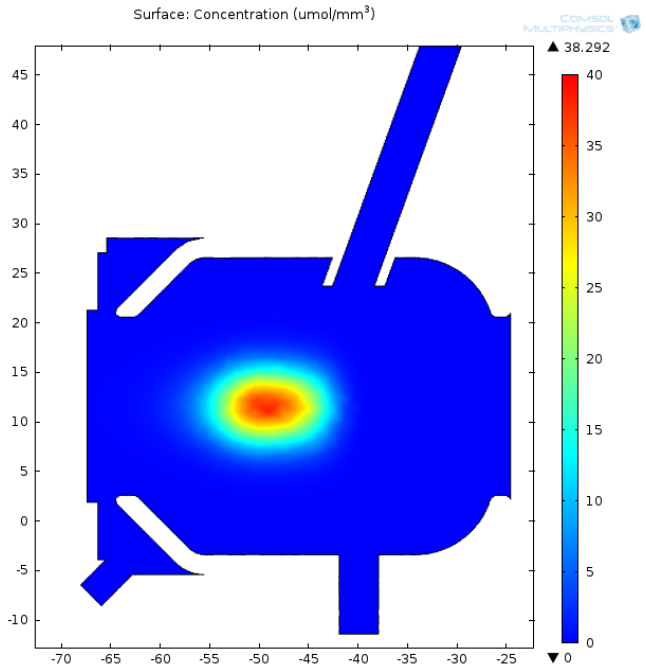
(Gauss type)



$$f(r) \propto \frac{1}{\sqrt{2\pi} \cdot \sigma} \cdot \mathrm{Exp}\left(- \frac{r^2}{2 \cdot \sigma^2} \right)$$

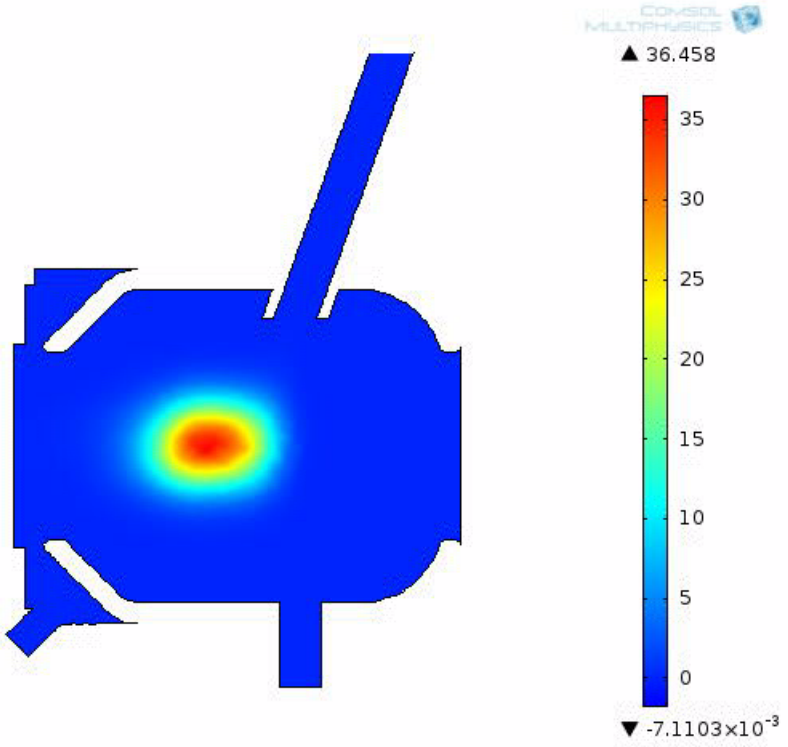
Flush out of reaction products

Initial space distribution

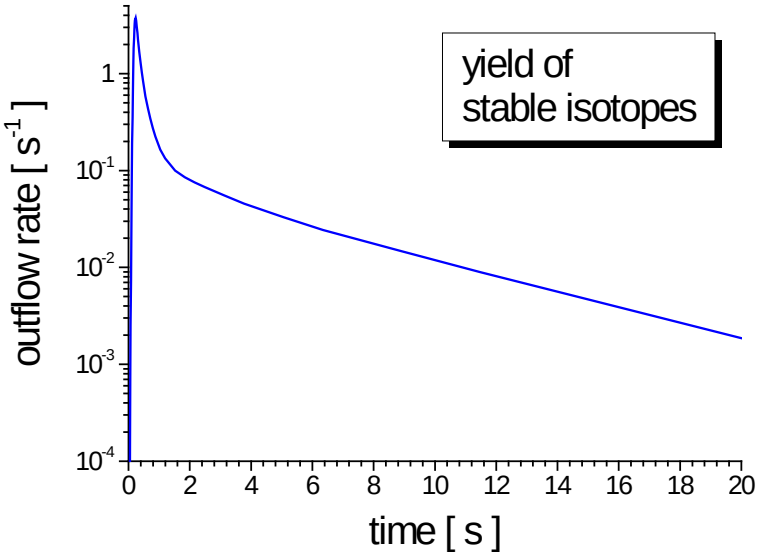


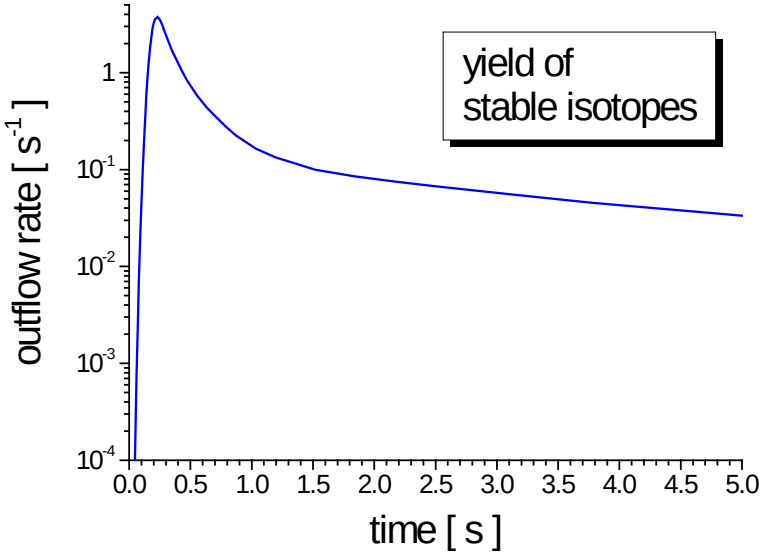
- transport of diluted species
- coupling to flow pattern
- SRIM parameterization as initial value
- time dependent flush out

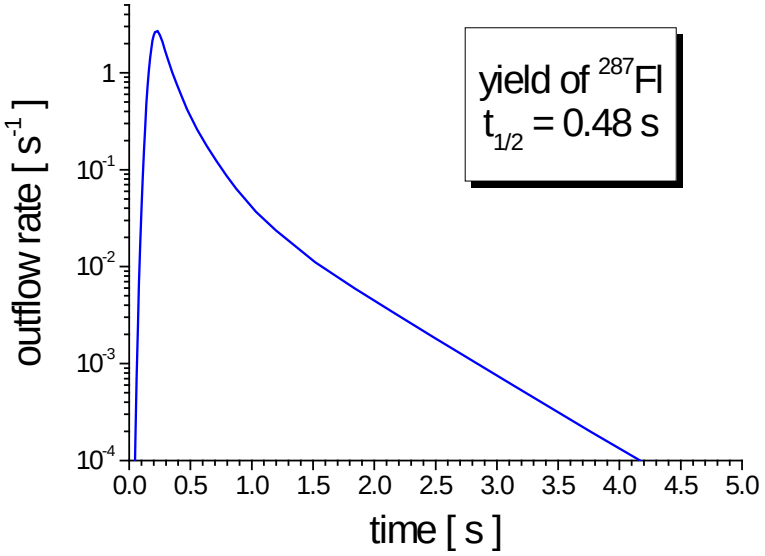
Flush out during 1st second



Yield with 100% flow inlet 1

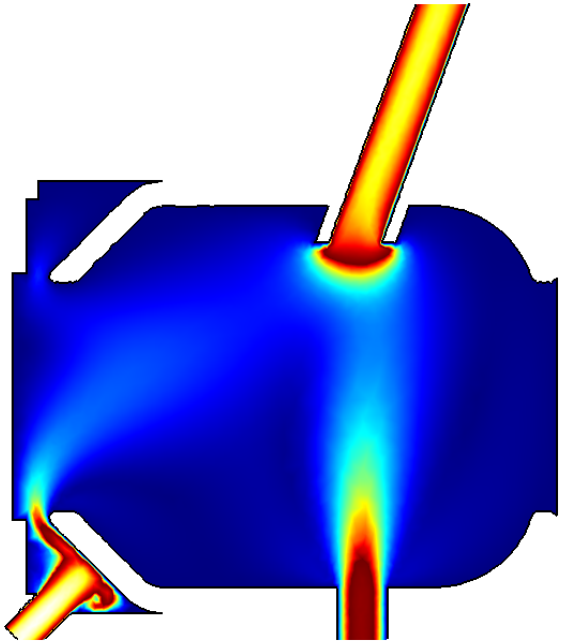




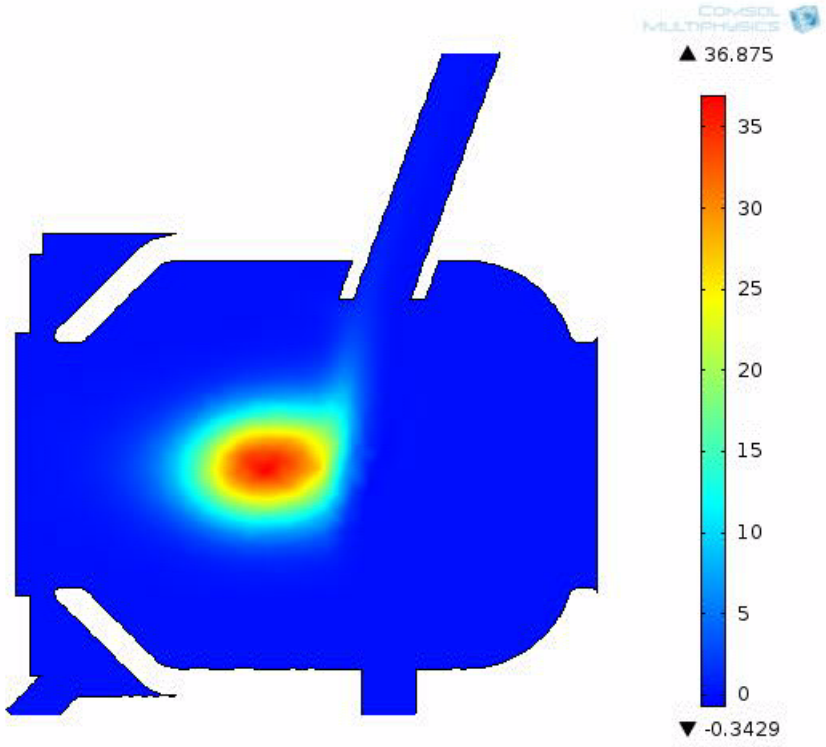


Flow pattern 1.5 l/min 5% inlet 1 / 95% inlet 2

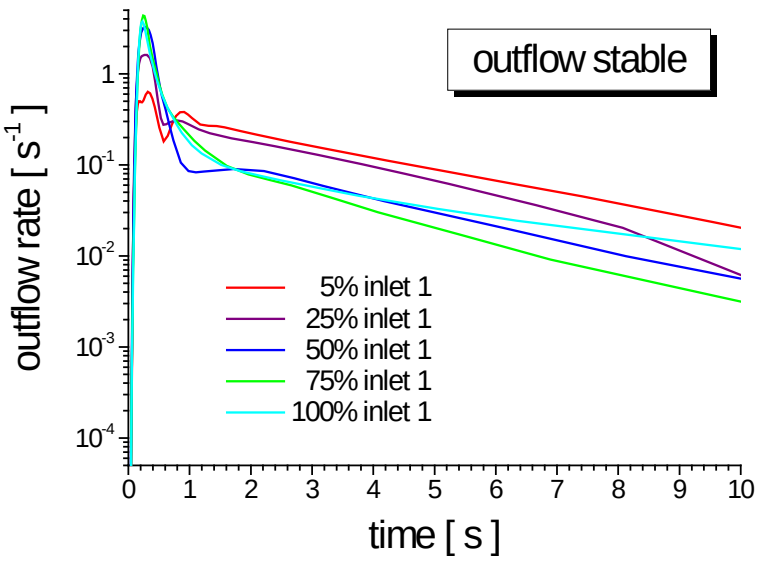
Flow pattern

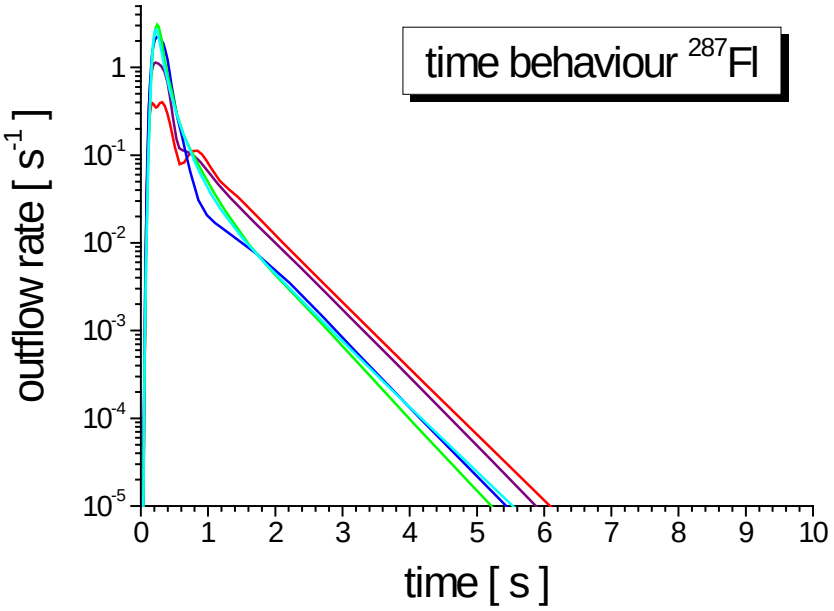


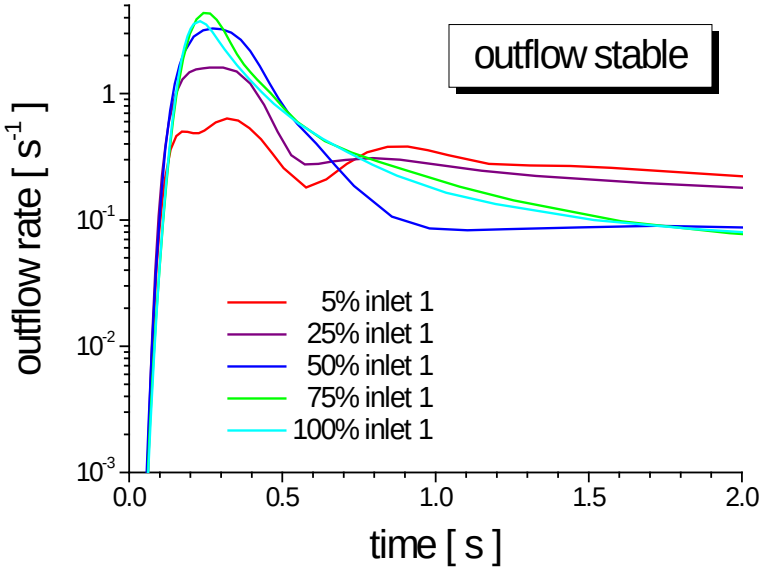
Flush out during 1st second

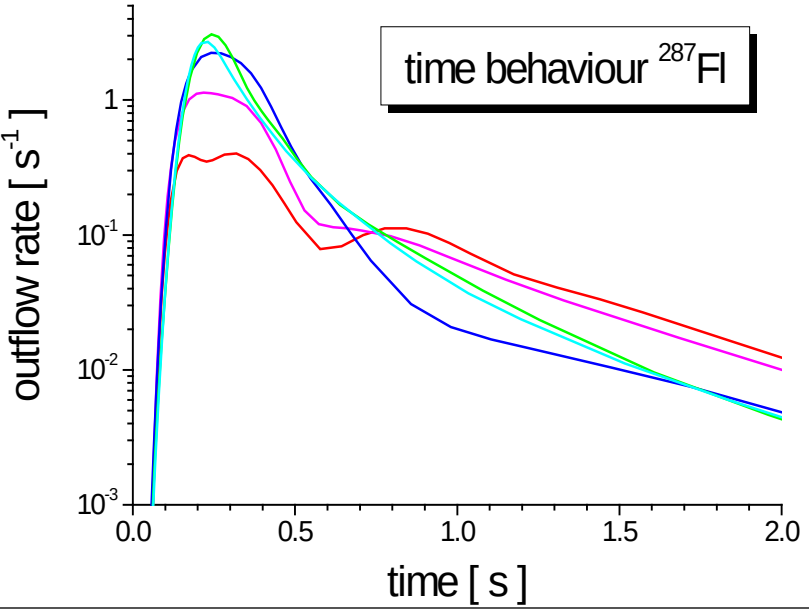


Time dependent yield

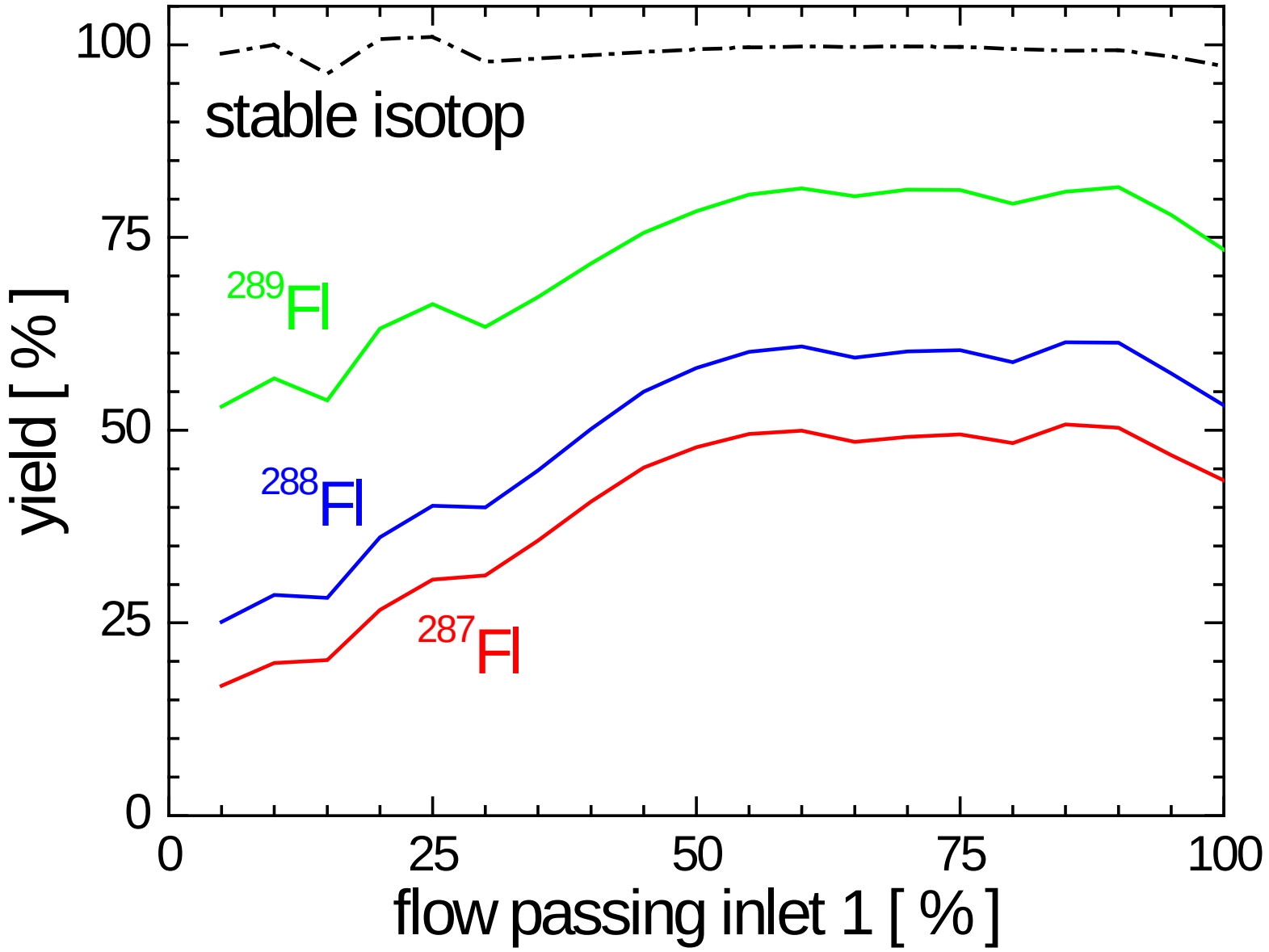




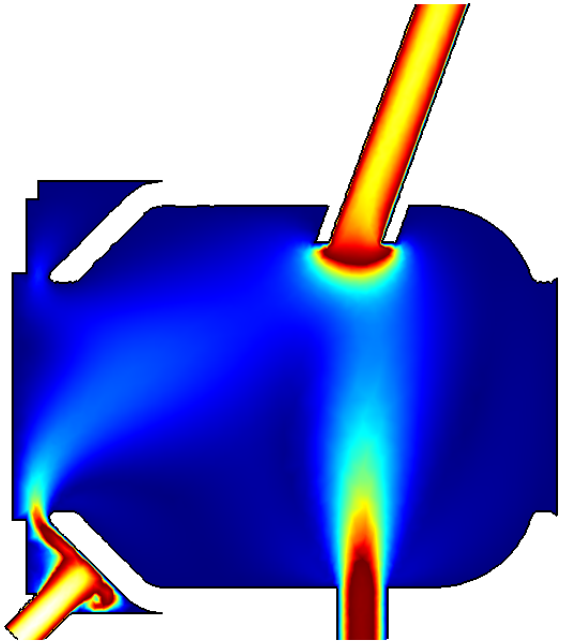




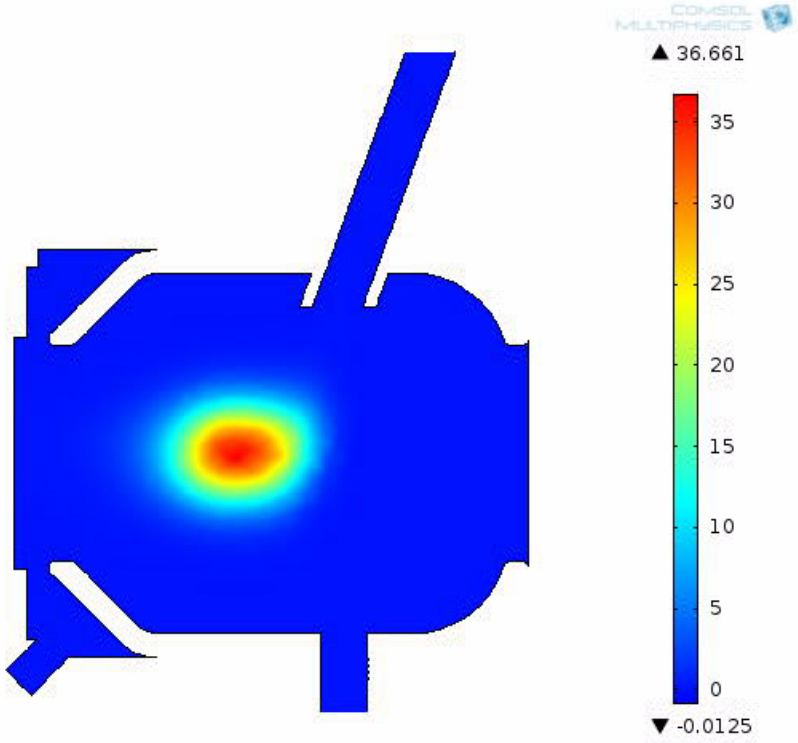
Yield vs. inflow condition



Flow pattern



Flush out during 1st second



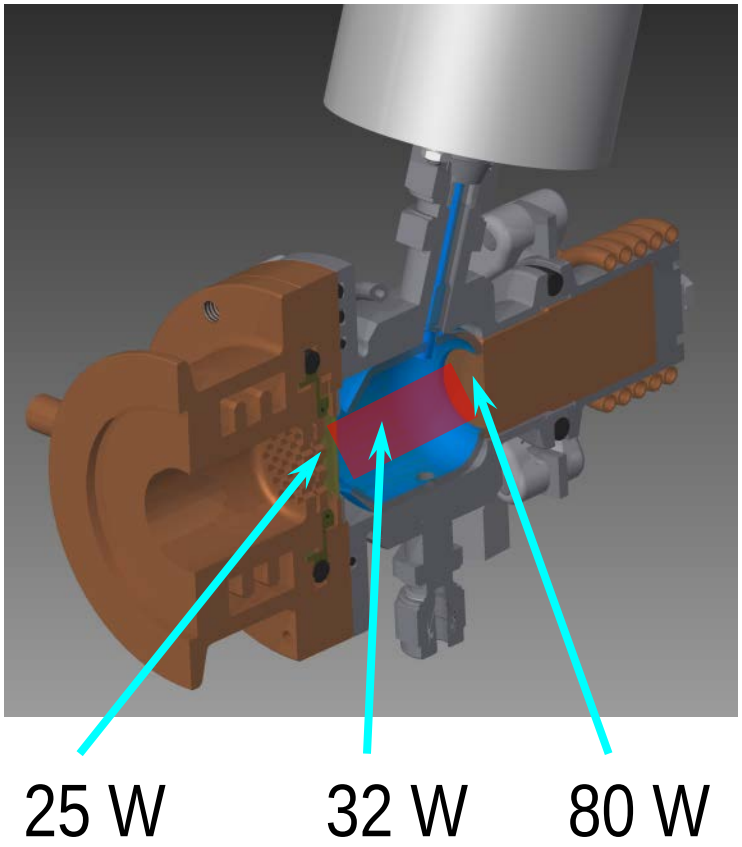
Conclusions

- COMSOL® Multiphysics usable to calculate flow in PSI-RC
- optimum flow condition for transport of super heavy elements obtained

Outlook

- coupling flow with heat transfer
- thermal load by ^{48}Ca beam
- heat transfer to PSI-RC hardware and active cooling parts
- additional momentum due to interaction with ^{48}Ca beam

Heat deposition in materials by ^{48}Ca beam



Thank you for your attention