Pbar swinging modelling

AEgIS Collaboration Meeting
CERN
18/12/2024

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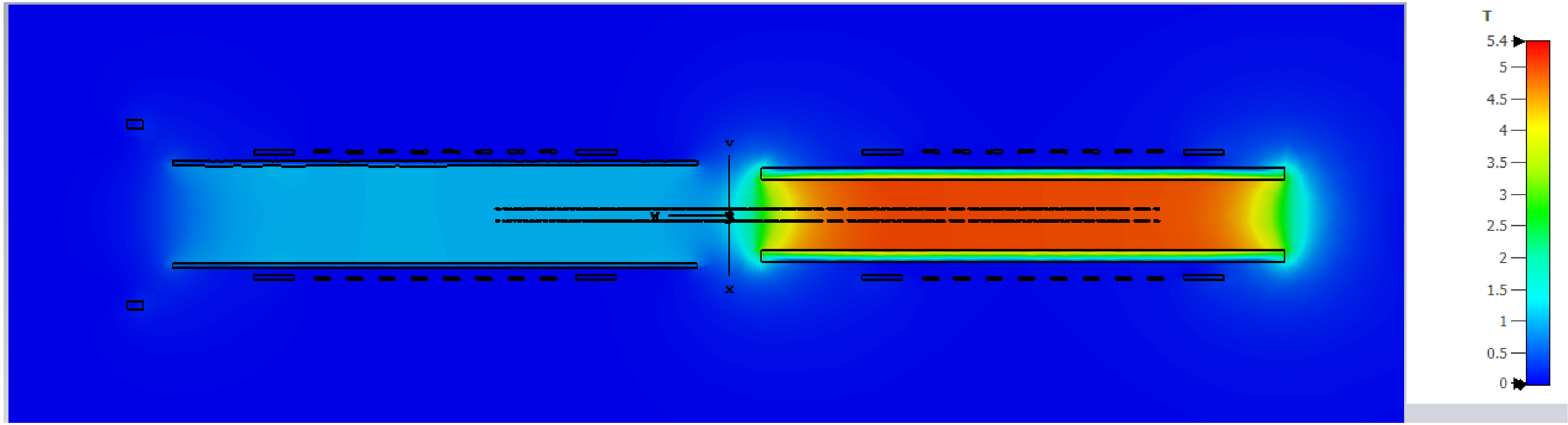
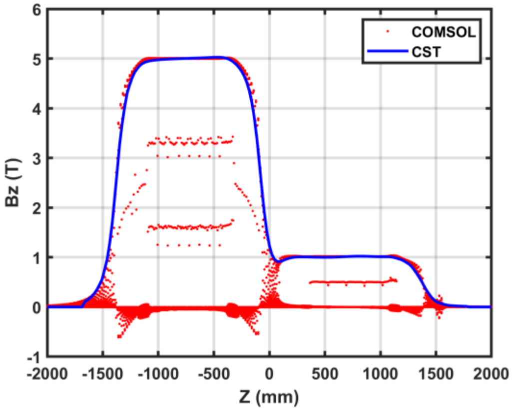
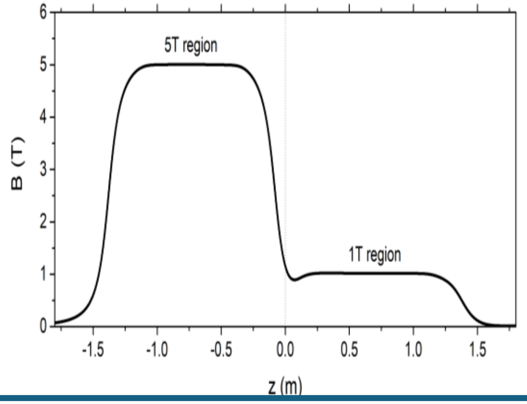
Simulated magnetic field map of AEgIS trap (2024 values-with corrector coils)

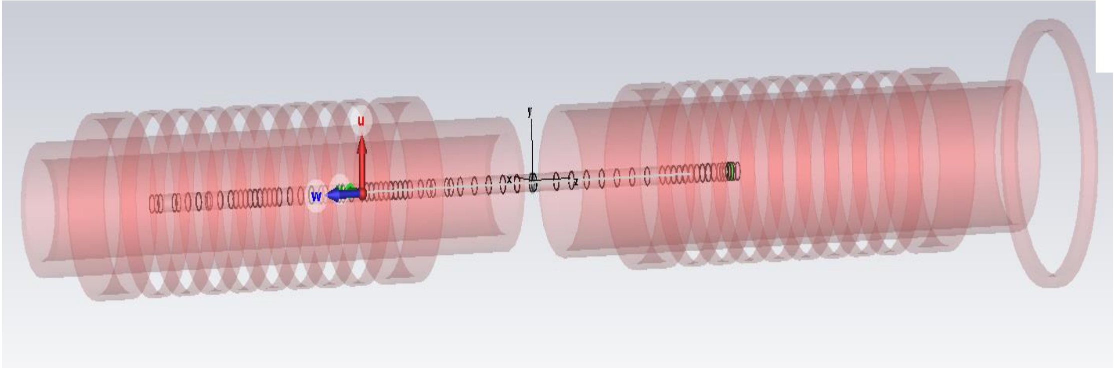


Comparison of axial magnetic field simulated in COMSOL and CST.



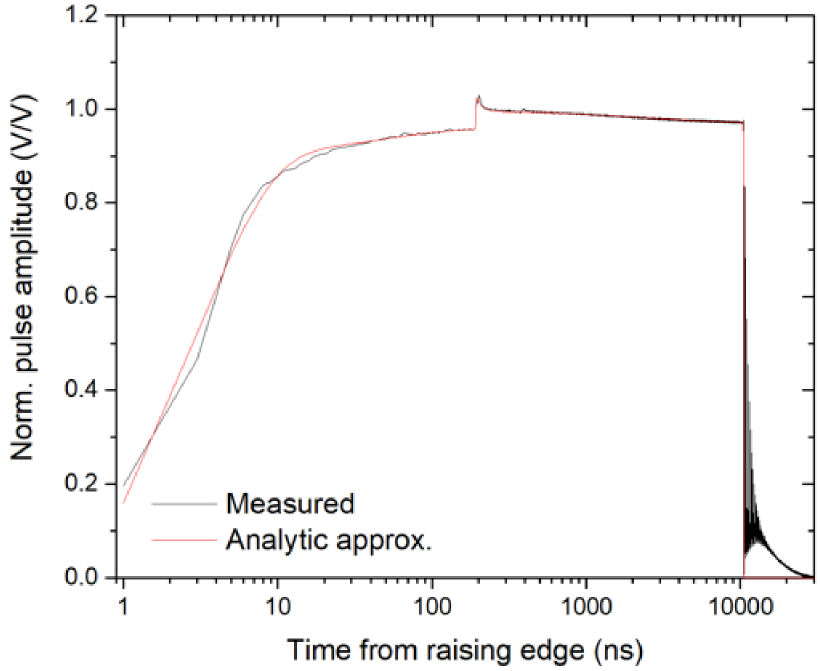


3D model of the AEgIS trap

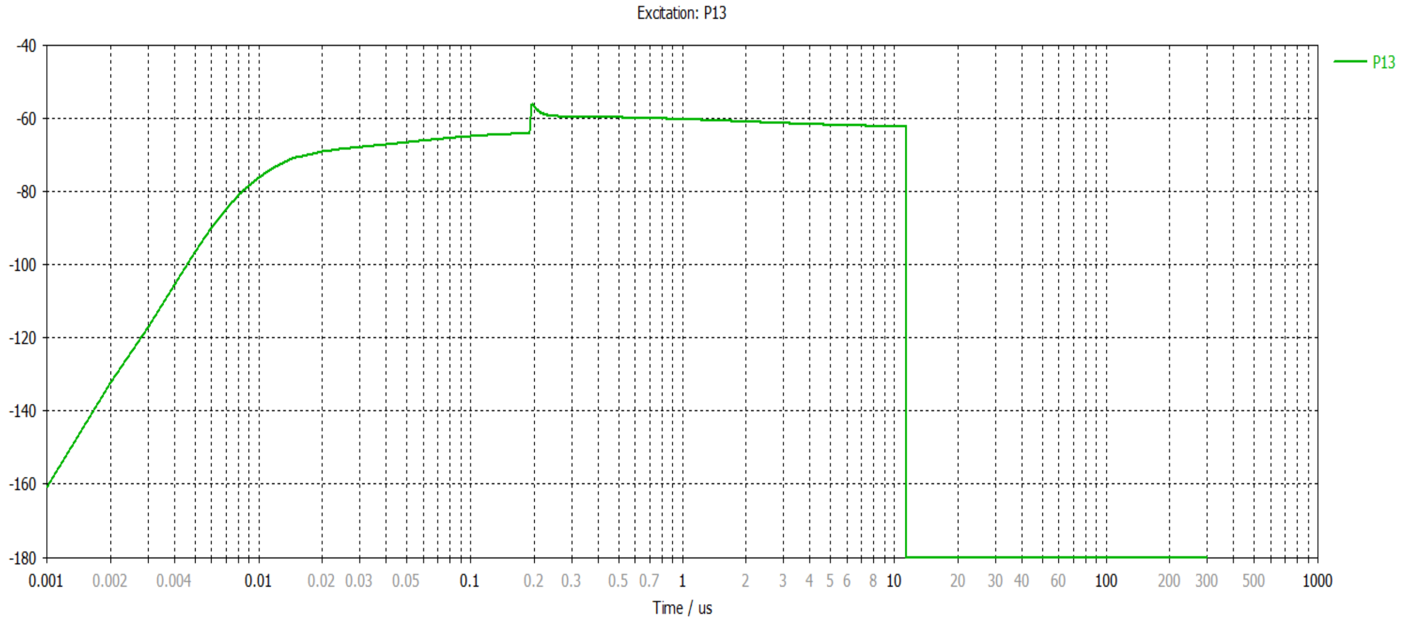


The P9 electrode input signal

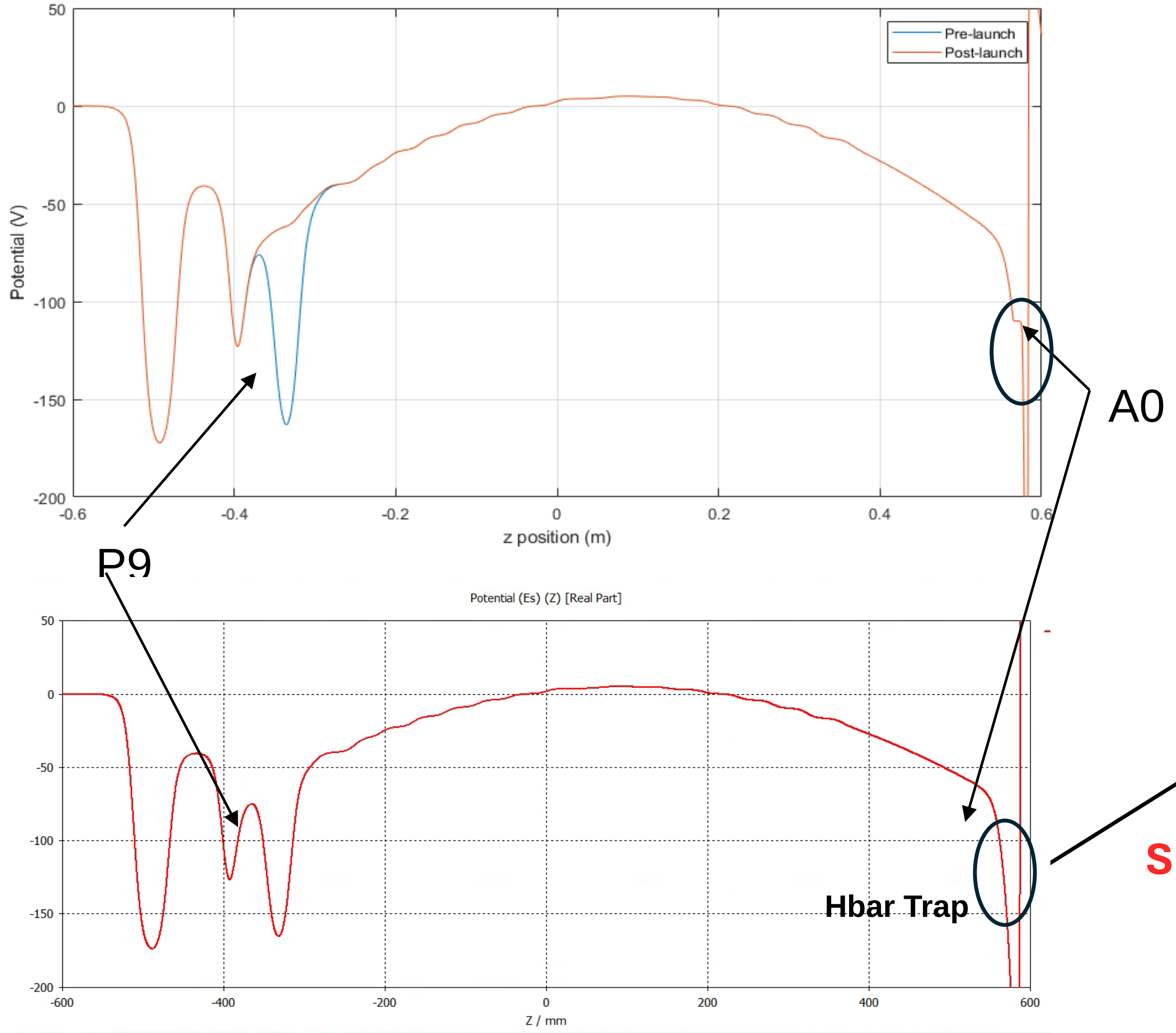
P9 signal and its analytical approximation



P9 input reproduced for CST



The P9 electrode input signal



Experiment

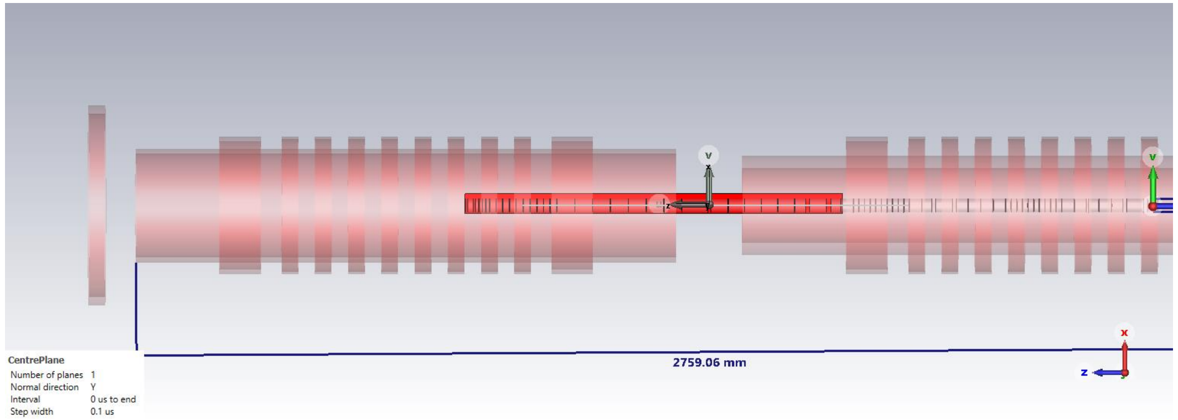
Ref: Rugg's slides

The wire grids (G1,G2) are modelled as planar discs ,perforated disk and as with meshed wires.

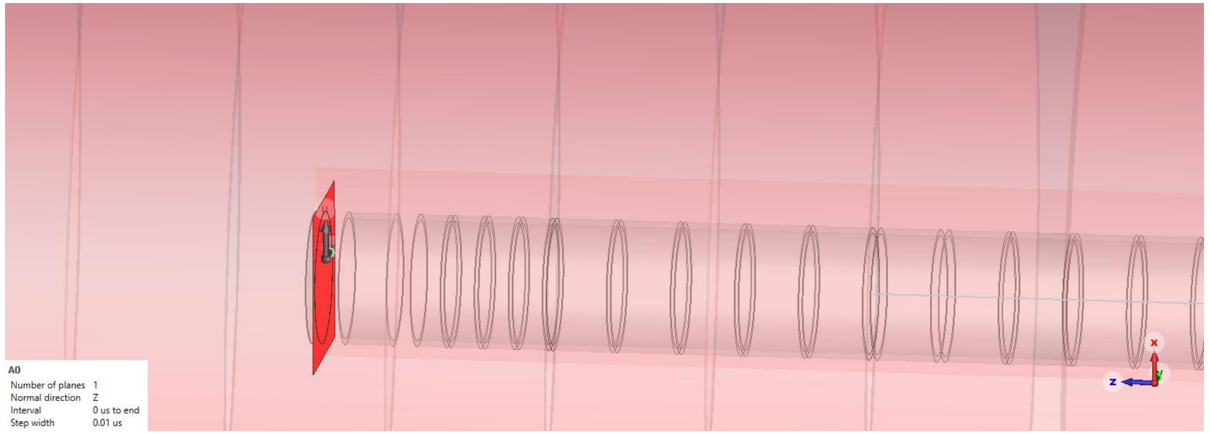
Simulation

Observation planes

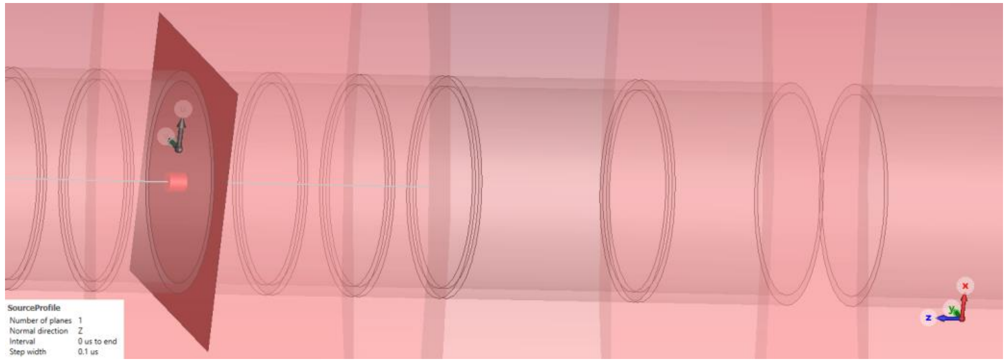
For tracking particles along the axis



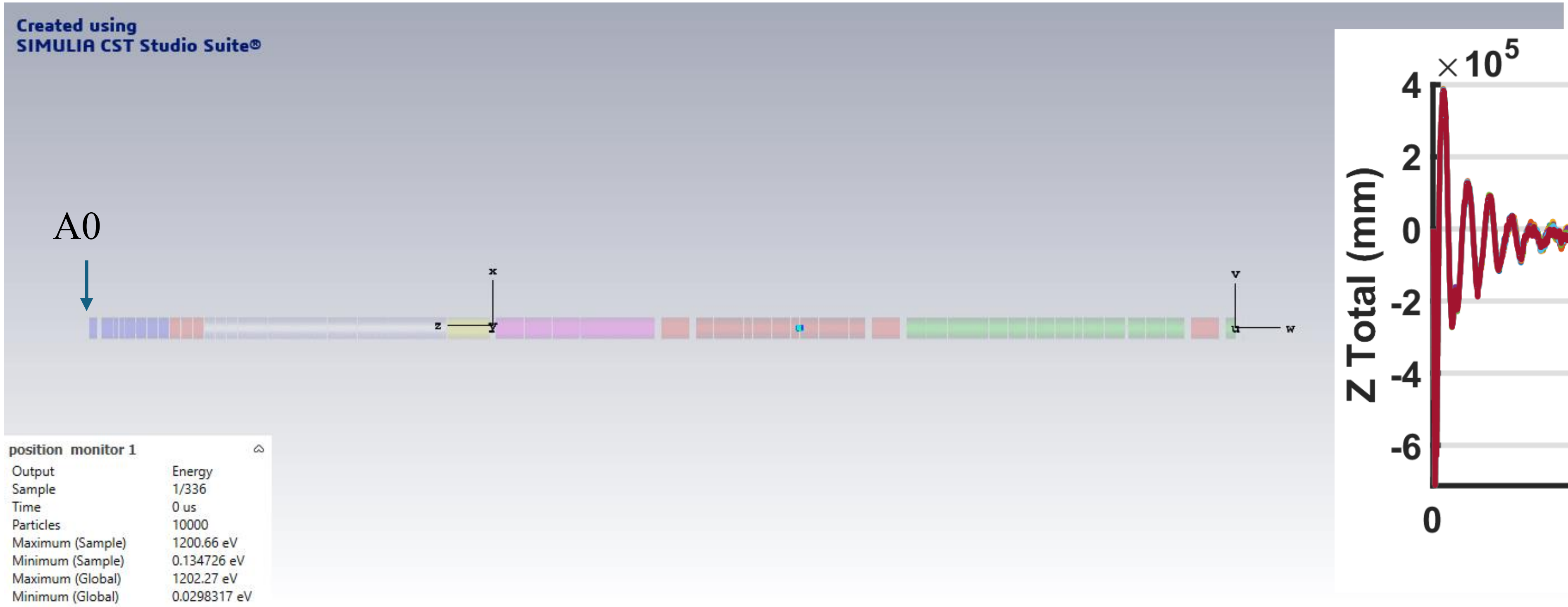
For counting hits on G1

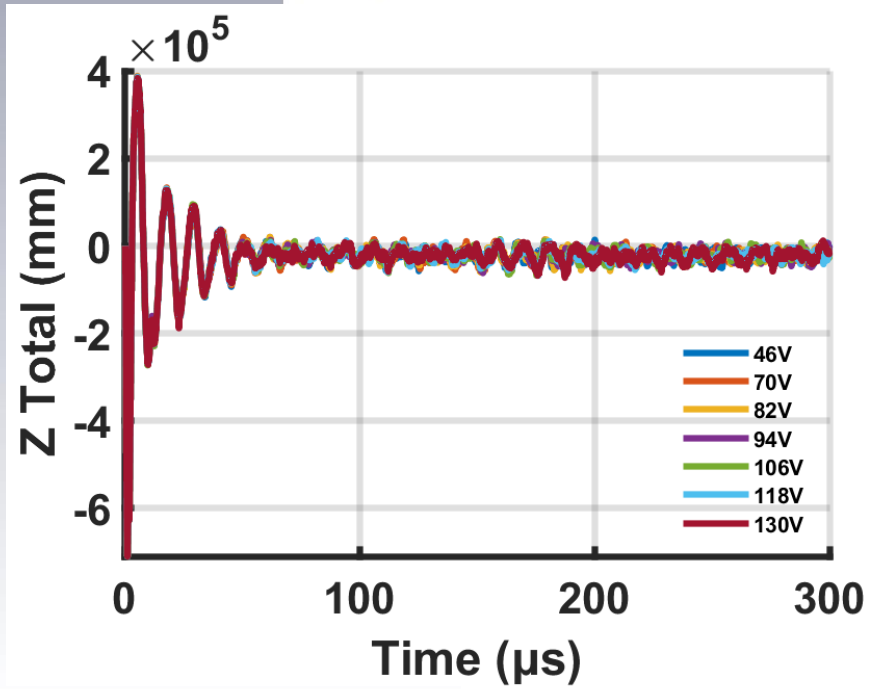


For the initial source profile

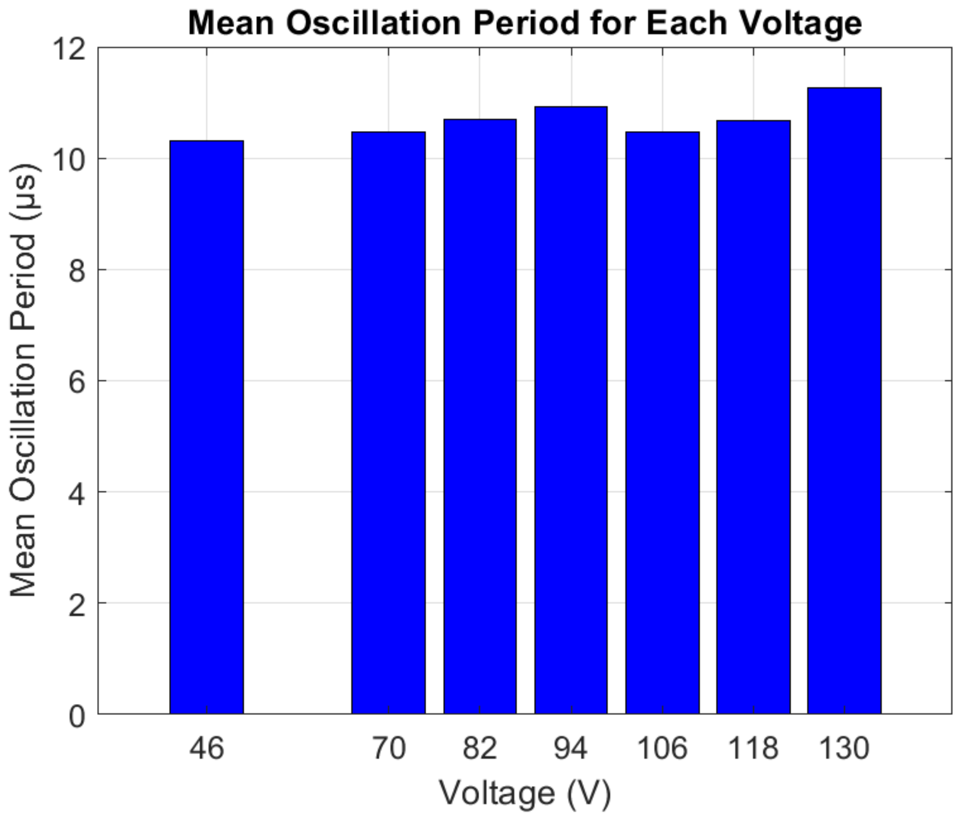


Typical Swinging simulation (A0= -34V)





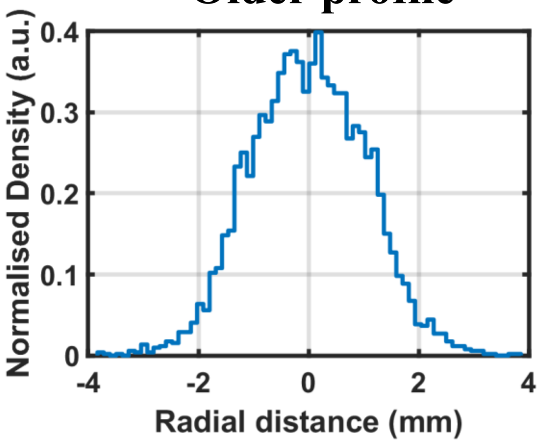
From the last update

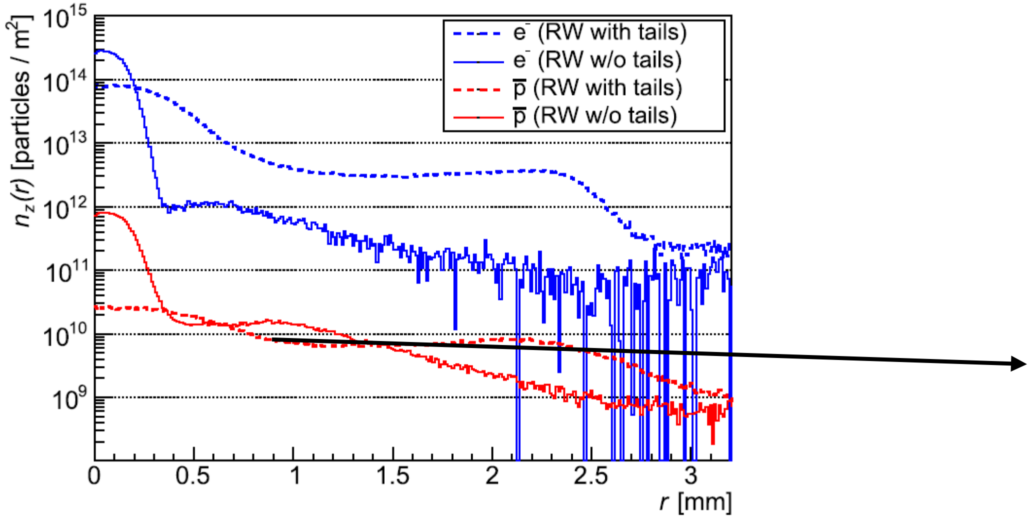


- **Wrong energy of the source antiprotons and very simplistic modelling of the G1 grid.**

Maxwellian source but with 3mm radius

Older profile

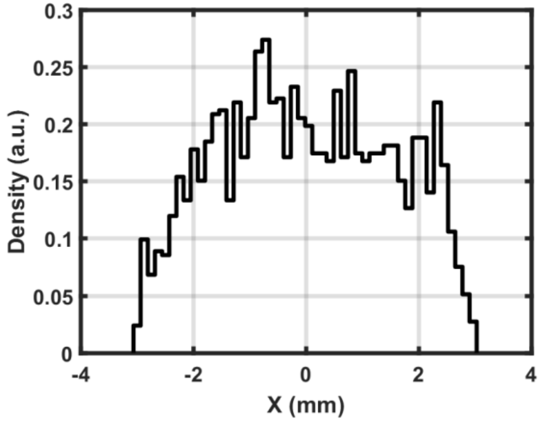


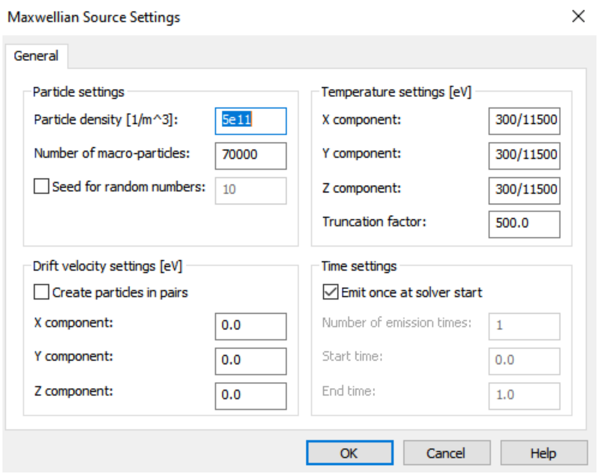


pbar profile with tails

Ref: Eur. Phys. J. D (2018) 72: 76 https://doi.org/10.1140/epjd/e2018-80617-x

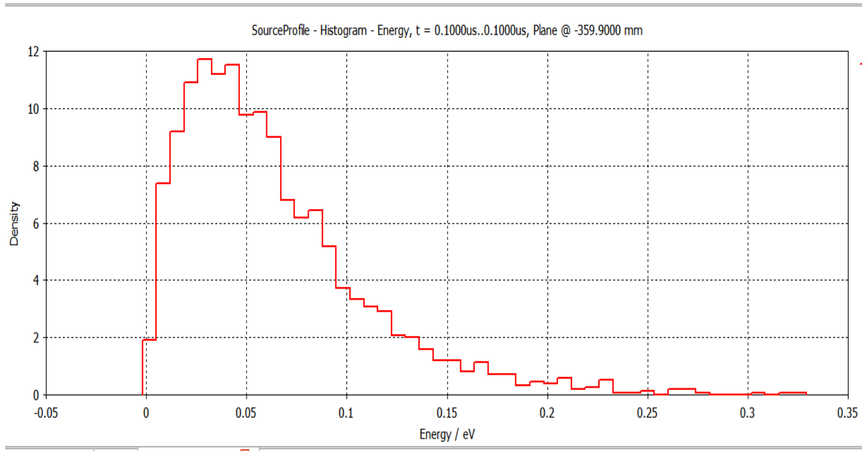
Flatter profile





Around 1 macro particle per real particle in the given source volume.

Initial energy distribution function



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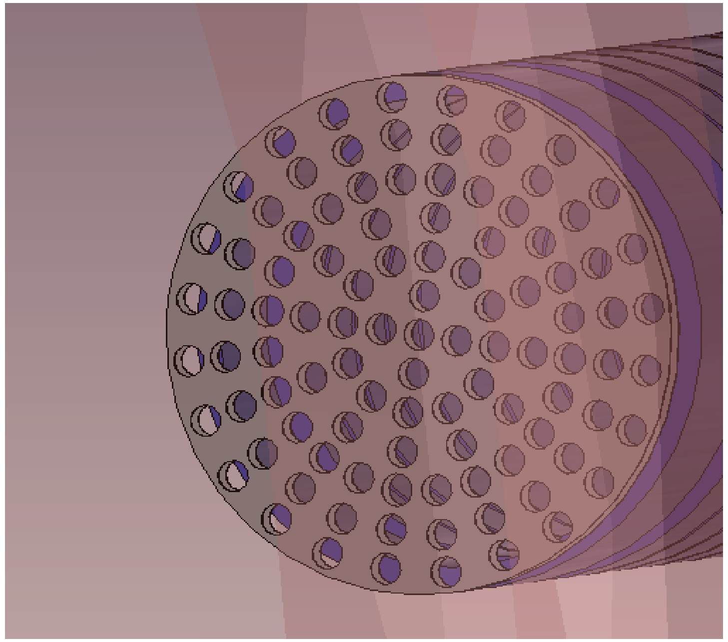
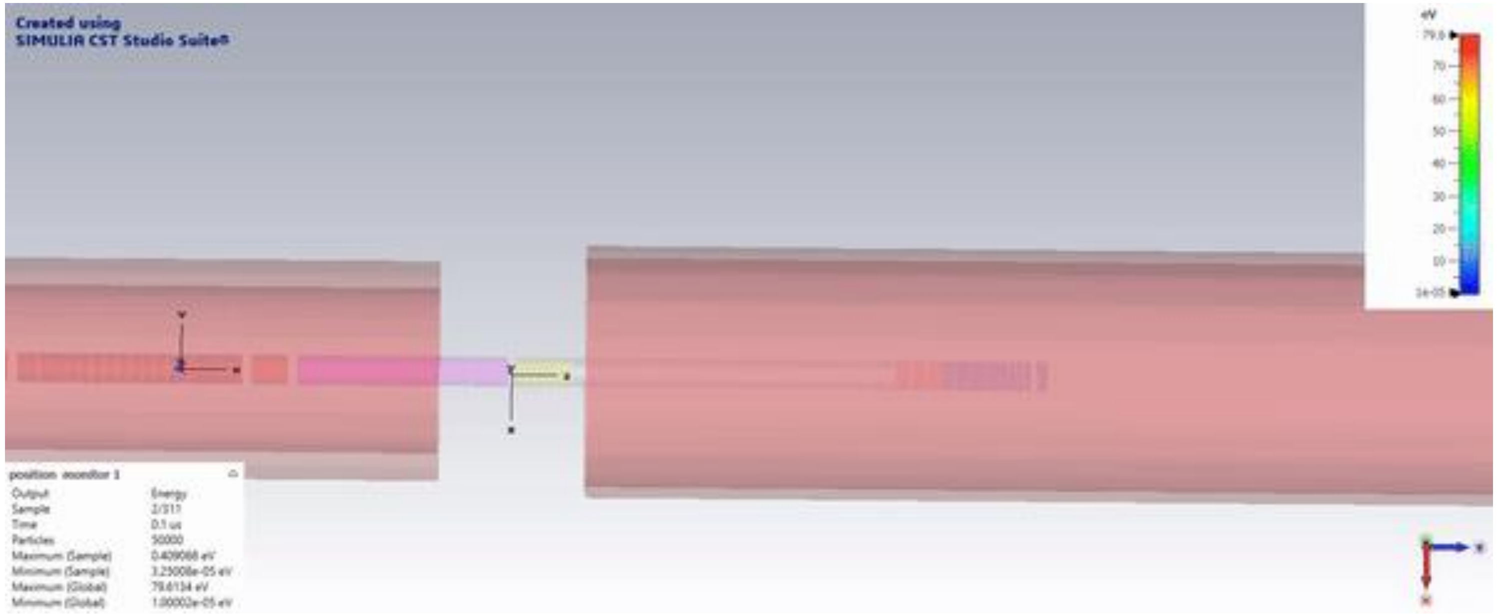
Perforated G1



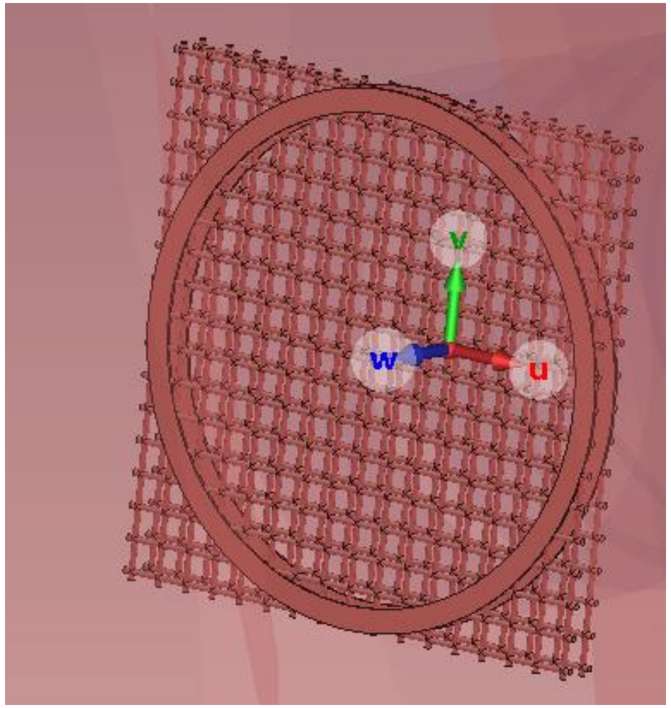
How does a typical pbar swing look?



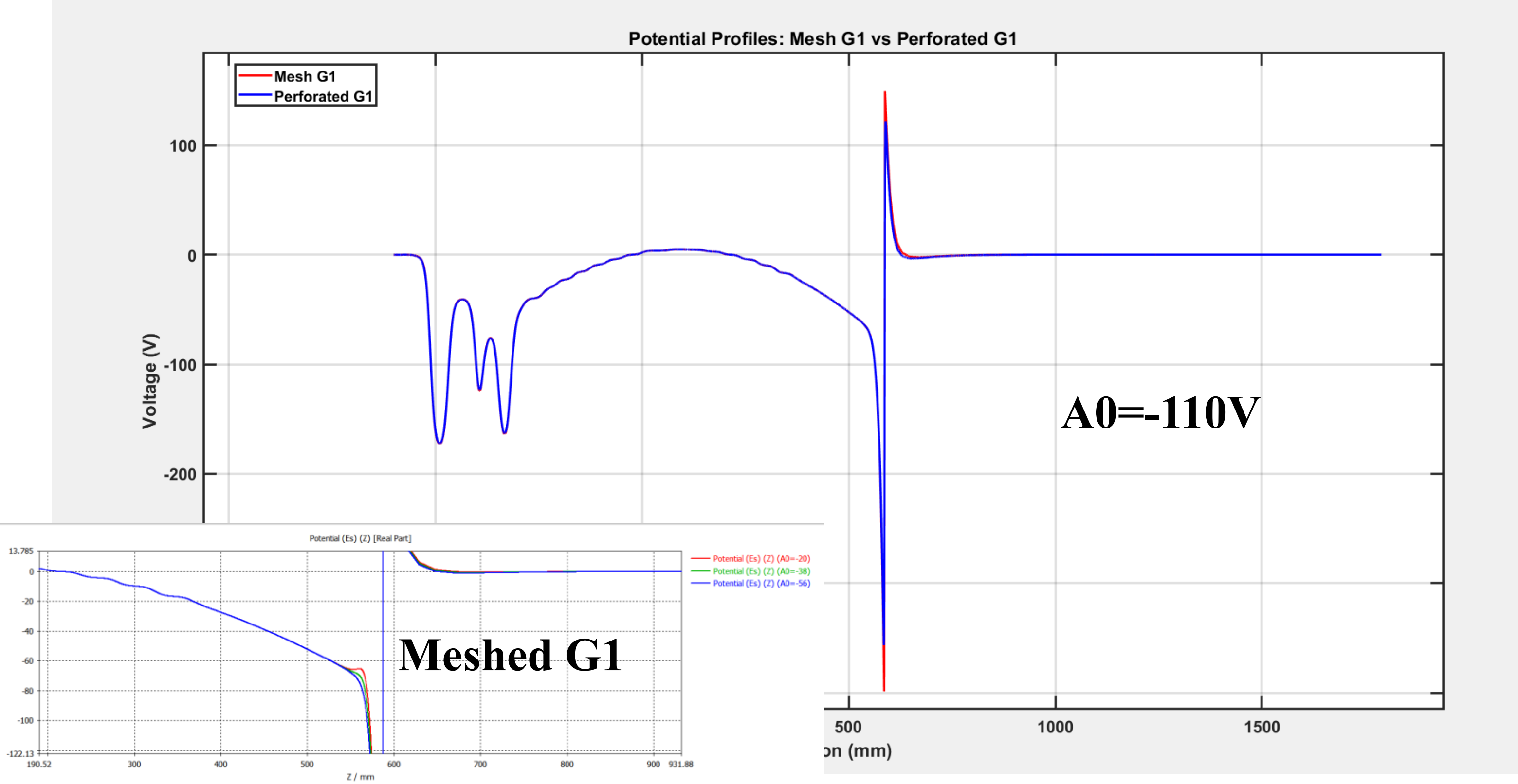
- **More accurate representation than the planar disk G1 with 30% transparency but the meshing has to be more refined due to the multiple apertures.**
- **Source is still Maxwellian but with 3mm radius.**

Meshed G1

Same dimensions of wires and pitch as experiment



Comparison of axial potential meshed G1 and perforated G1



- **Better representation than the perforated version , still need to remove the edges.**
- **But one scan of 200micro seconds with meshed G1 takes around 24 hours on the local PC with 32GB ram.**

User defined source modelling

Inputs needed in CST for source definition

```
Gauss - Notepad
File  Edit  Format  View  Help
% Use always SI units.
% The momentum (mom) is equivalent to beta * gamma.
% The data need not to be chronological ordered.
%
% Columns: pos_x  pos_y  pos_z  mom_x  mom_y  mom_z  mass  charge  charge(macro)  time

-4.20752e-03  -2.81951e-03  -3.60288e-01  -3.45454e-23  5.72219e-24  -3.61660e-23  1.67262e-27  -1.60218e-19  2.55507e-23  0.00000e+00
-3.55508e-03  -3.48792e-03  -3.59261e-01  3.06398e-23  2.25865e-23  2.64524e-24  1.67262e-27  -1.60218e-19  2.61329e-23  0.00000e+00
-3.34689e-03  -3.92642e-03  -3.59664e-01  -1.64767e-23  -1.55492e-24  -1.95954e-23  1.67262e-27  -1.60218e-19  2.44939e-23  0.00000e+00
-4.48256e-03  -4.40580e-03  -3.60723e-01  -3.15411e-23  2.37413e-23  1.05895e-23  1.67262e-27  -1.60218e-19  1.95706e-23  0.00000e+00
-4.20748e-03  -2.90069e-03  -3.59773e-01  2.94844e-23  -7.23705e-24  -1.95030e-23  1.67262e-27  -1.60218e-19  2.19157e-23  0.00000e+00
-5.74906e-03  -3.86889e-03  -3.58308e-01  2.84228e-23  8.26694e-24  8.48480e-24  1.67262e-27  -1.60218e-19  1.66066e-23  0.00000e+00
-3.48921e-03  -3.01622e-03  -3.60194e-01  2.55655e-23  -1.31610e-23  1.85104e-23  1.67262e-27  -1.60218e-19  2.16226e-23  0.00000e+00
-3.91657e-03  -3.05611e-03  -3.60504e-01  -1.31451e-23  4.27007e-23  3.44448e-24  1.67262e-27  -1.60218e-19  2.47916e-23  0.00000e+00
-3.48778e-03  -4.35796e-03  -3.59381e-01  -1.42651e-23  2.67673e-23  3.29805e-24  1.67262e-27  -1.60218e-19  2.32018e-23  0.00000e+00
-5.53387e-03  -4.56987e-03  -3.59550e-01  -8.50322e-24  5.53642e-25  -2.07336e-23  1.67262e-27  -1.60218e-19  1.84868e-23  0.00000e+00
-5.21572e-03  -3.04988e-03  -3.57942e-01  -2.17101e-23  -4.17875e-23  -1.46610e-23  1.67262e-27  -1.60218e-19  2.30736e-23  0.00000e+00
-4.09283e-03  -2.42941e-03  -3.59025e-01  1.03716e-23  7.84590e-24  -4.19740e-24  1.67262e-27  -1.60218e-19  2.46590e-23  0.00000e+00
-3.97841e-03  -4.43295e-03  -3.62083e-01  2.99417e-23  -4.24985e-23  -1.17787e-24  1.67262e-27  -1.60218e-19  2.09132e-23  0.00000e+00
```

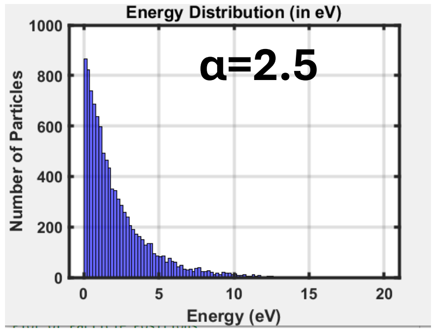
Modelling of the momentum

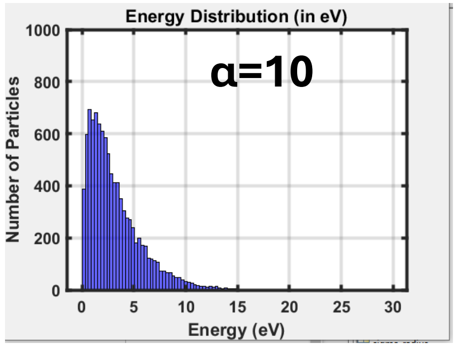
1) $p = p_{\max} U^{1/\alpha}$ The power-law exponent $\alpha = 2.5$.

2) The maximum momentum $p_{\max} = 10\, p_{\text{rms}}$, where $p_{\text{rms}} = \sqrt{m k_B T}$.

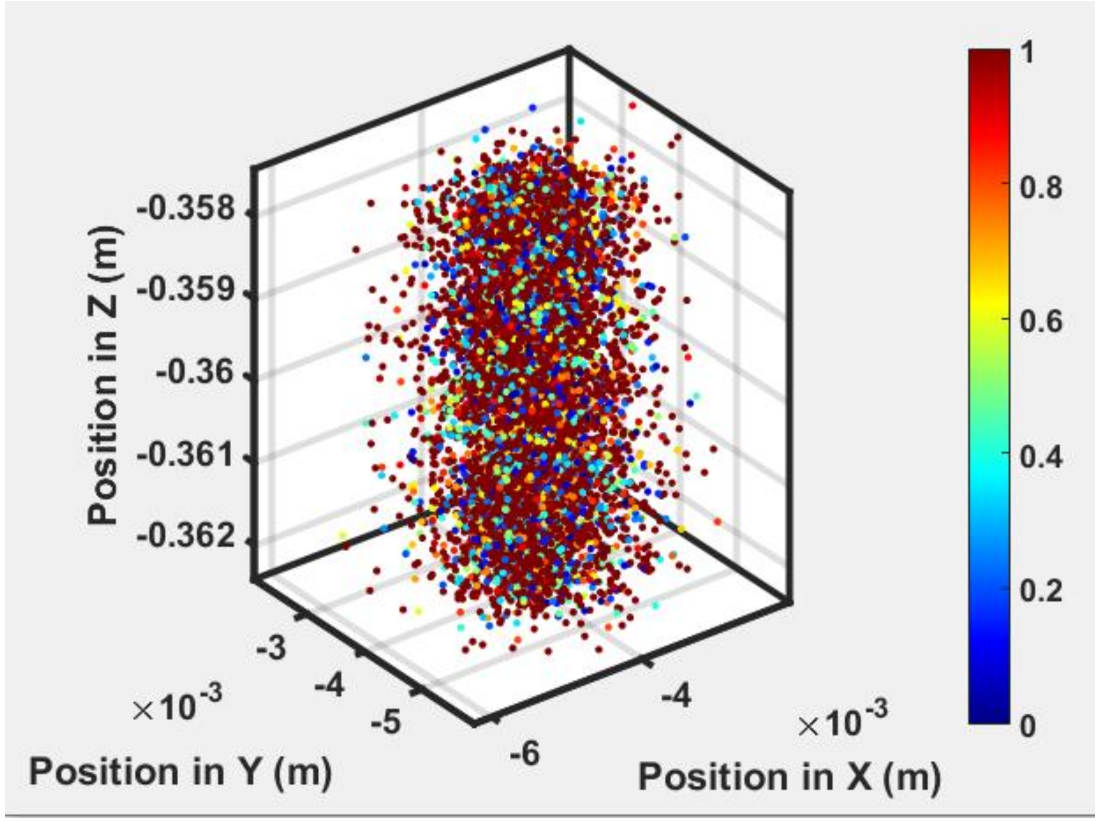
3) $p_x = p\cos(\phi)\sin(\psi), \quad p_y = p\sin(\phi)\sin(\psi), \quad p_z = p\cos(\psi)$

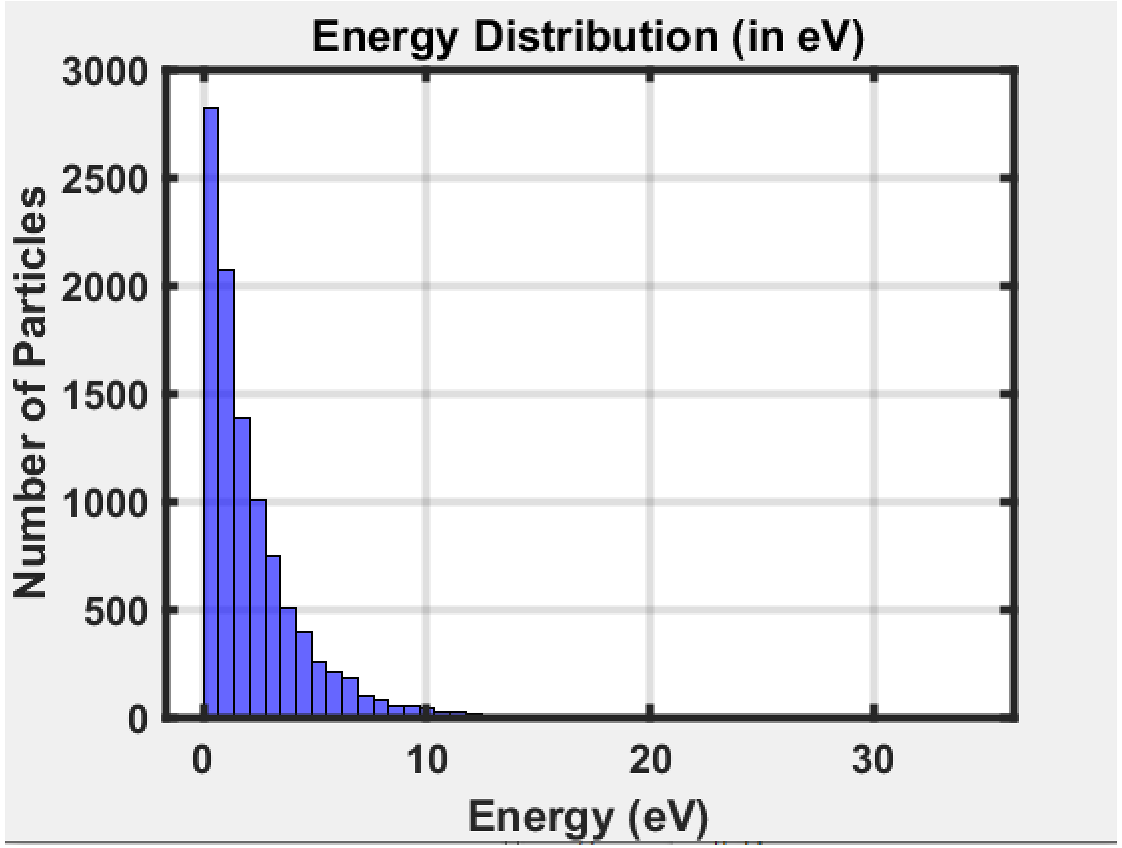
Effect of α on initial EDF



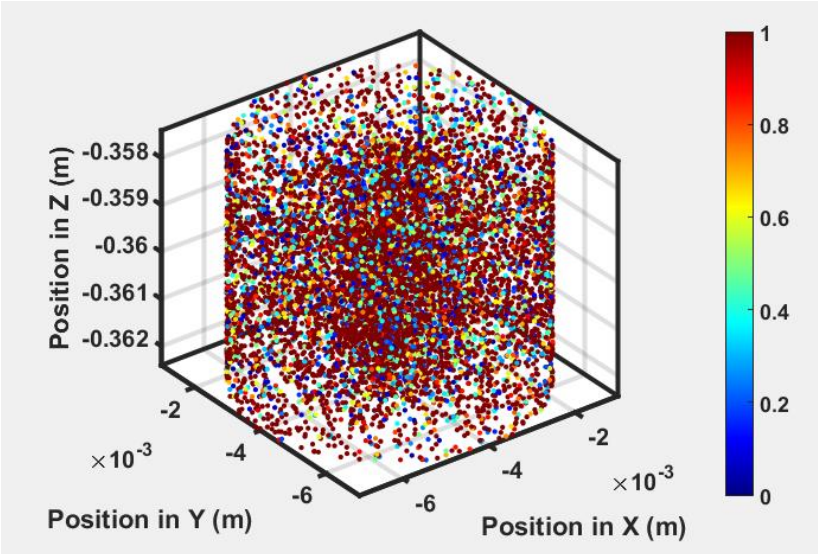


User defined source modelling

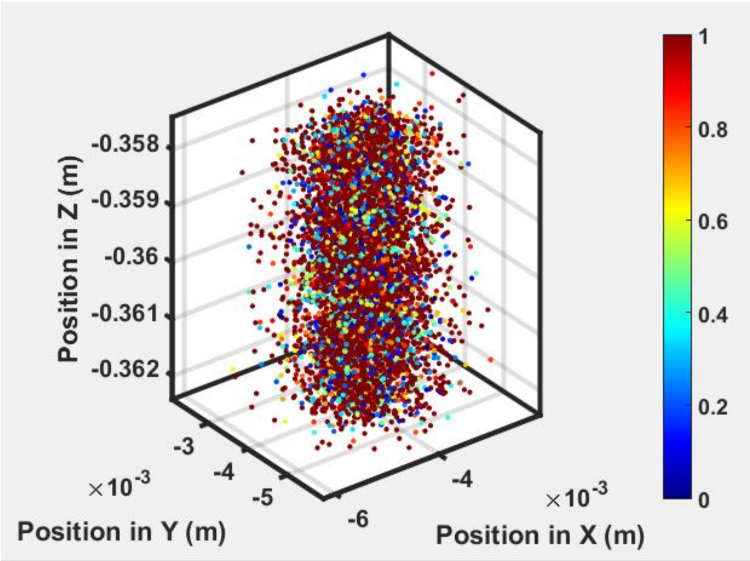




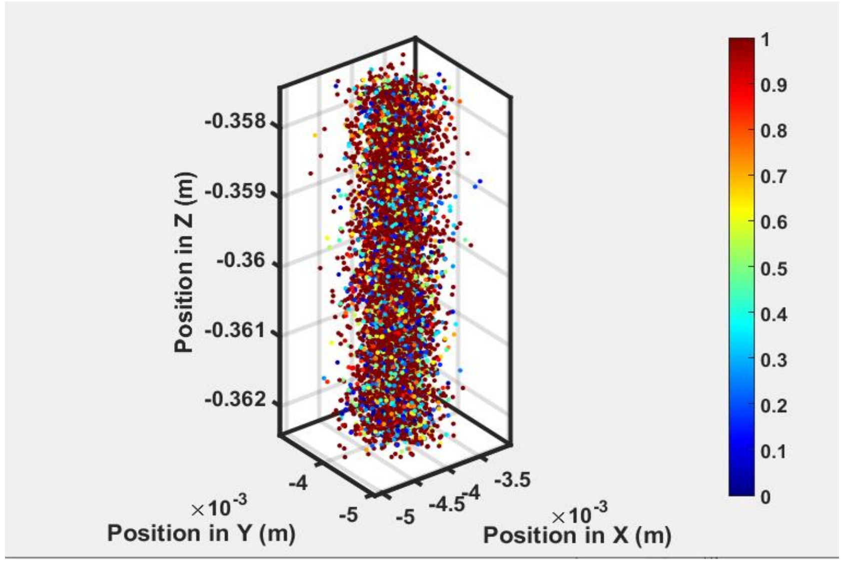
Initial source distribution



SD=radius



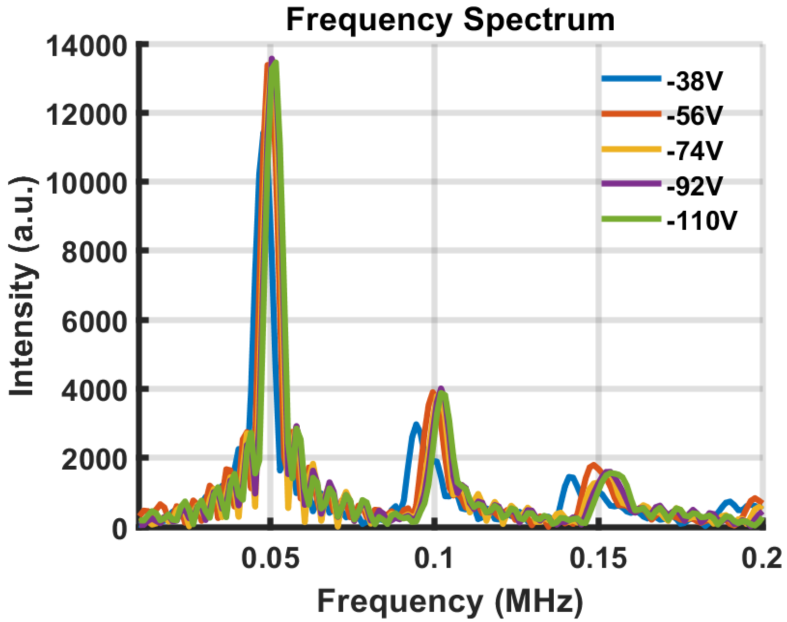
SD=radius/5



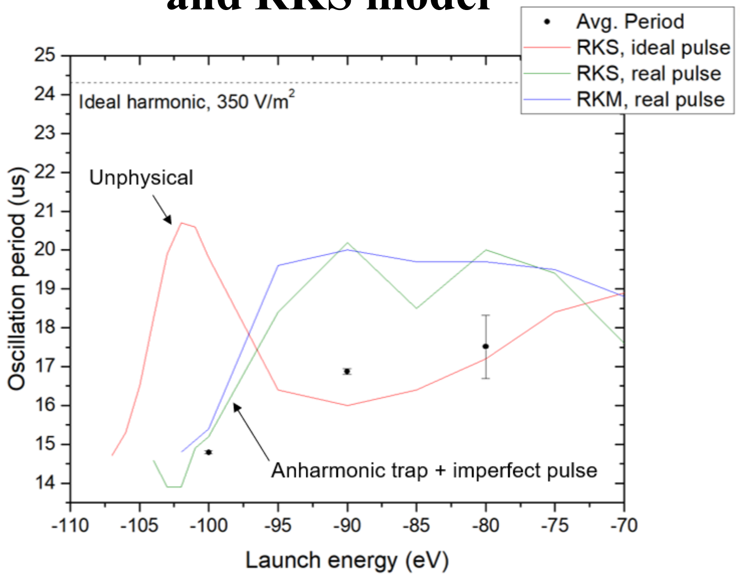
SD=radius/10

Results

Meshed G1 with r=3mm (Maxwellian, T=300K).
FFT of mean energy of antiprotons

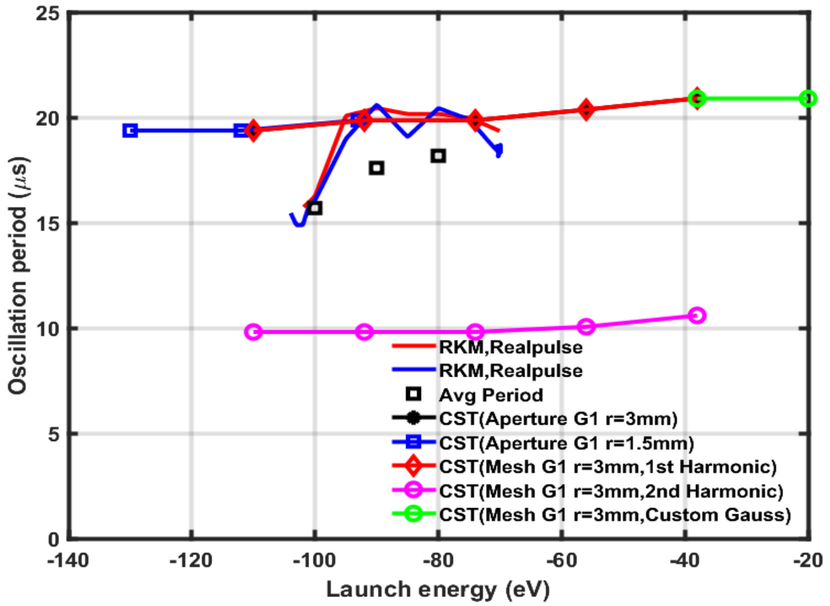


Experimental data and RKS model



Ref:Rugg's Presentation

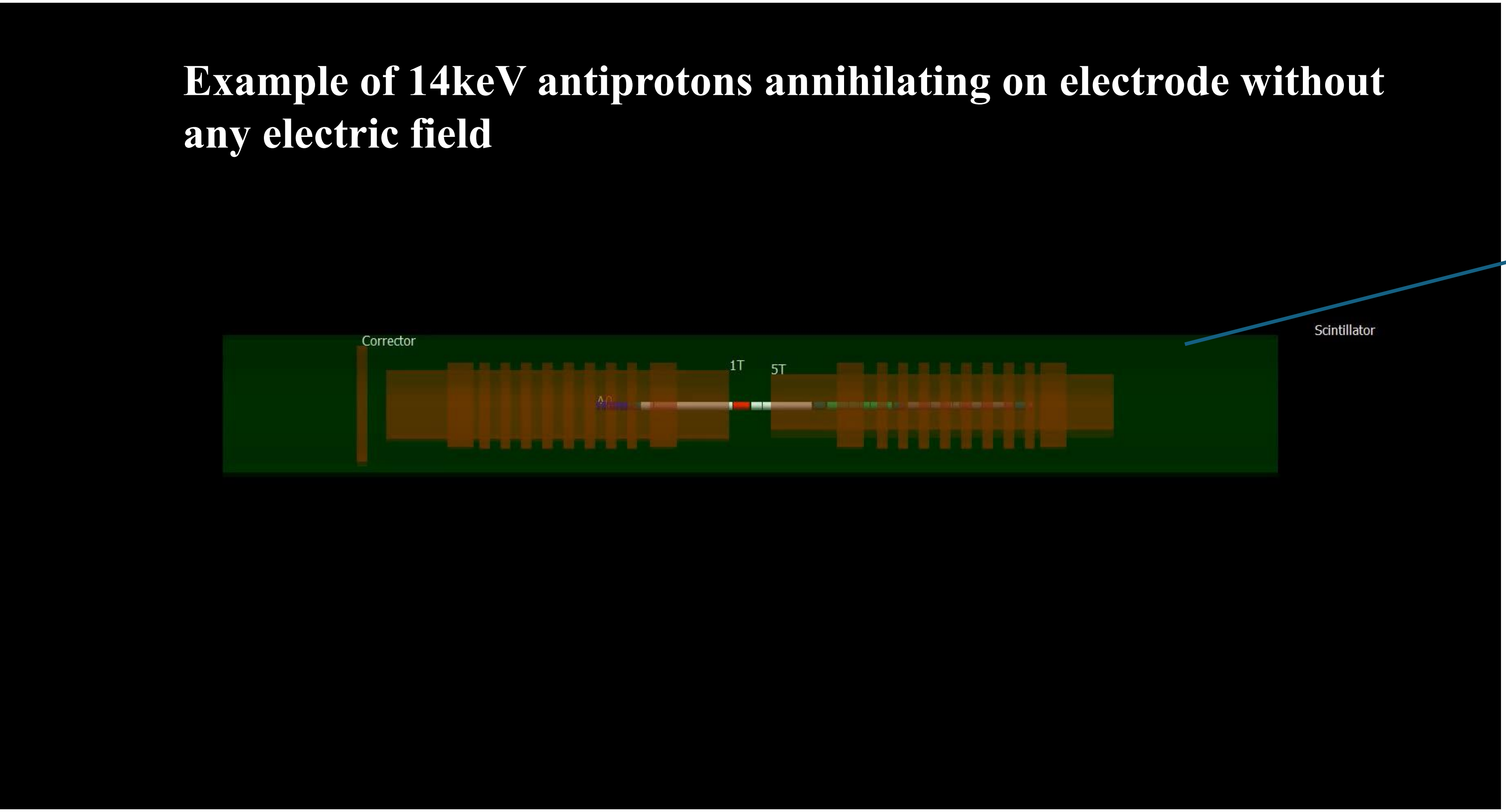
Comparison of the oscillation period

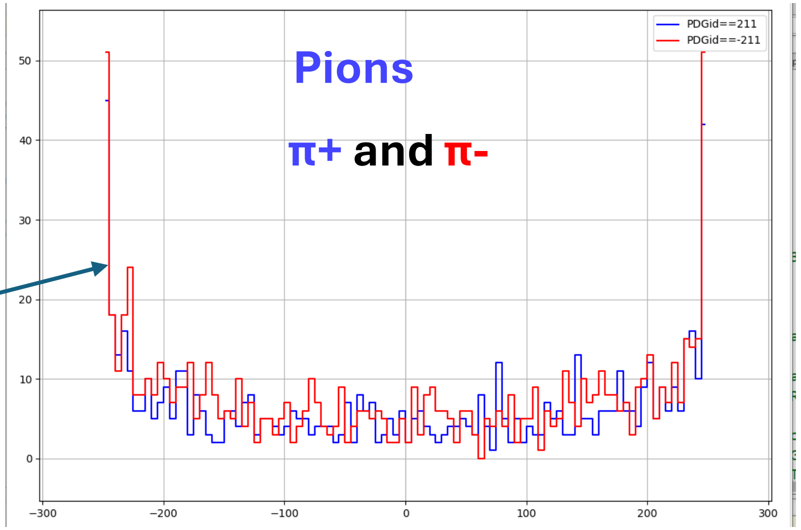


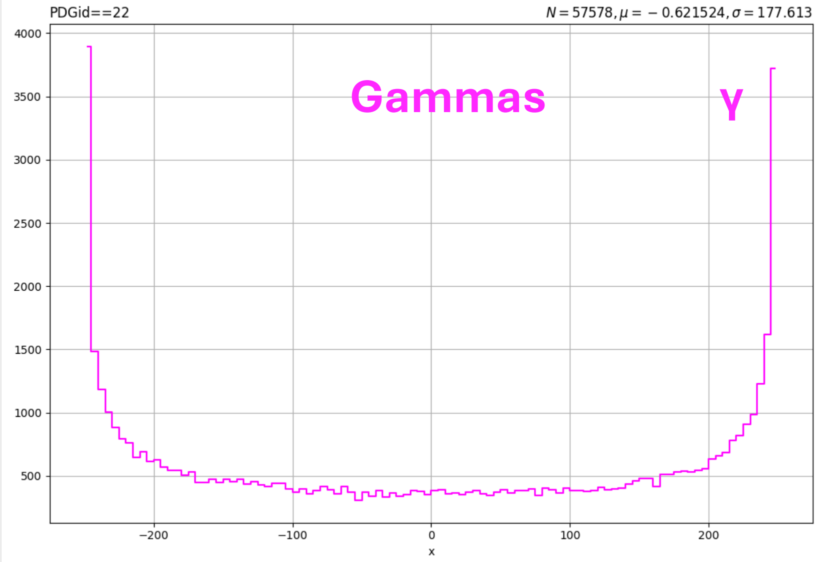
- Still don't see annihilations or losses with the distribution simulated so far.
- However, see a weak dependence of the oscillation period on A0 with different source distribution.

Another parallel development

G4Beamline model of AEgIS experiment







- **Studies related to antiproton annihilation events on electrode surfaces.**

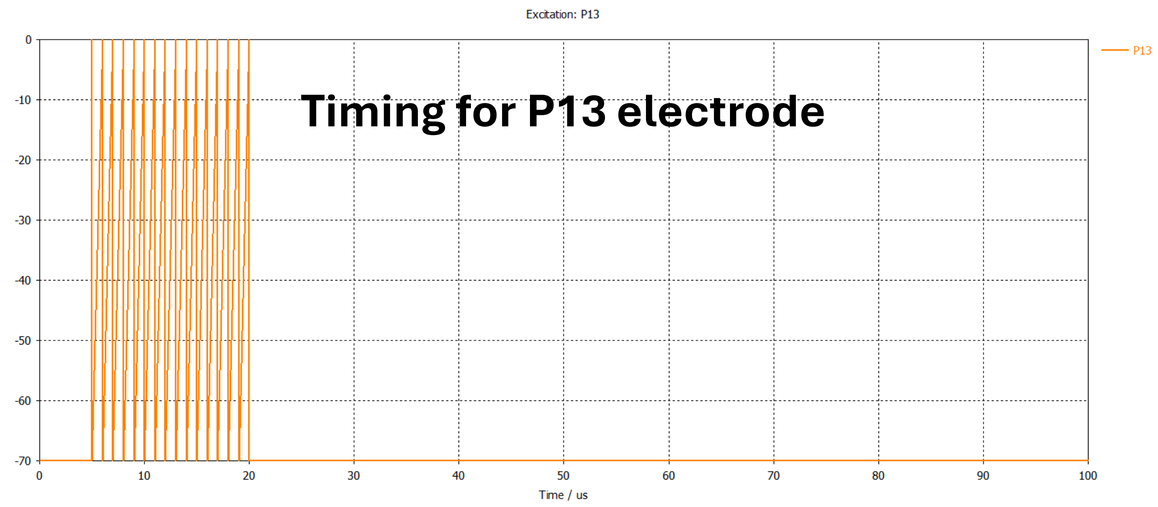
Conclusion and task to be done

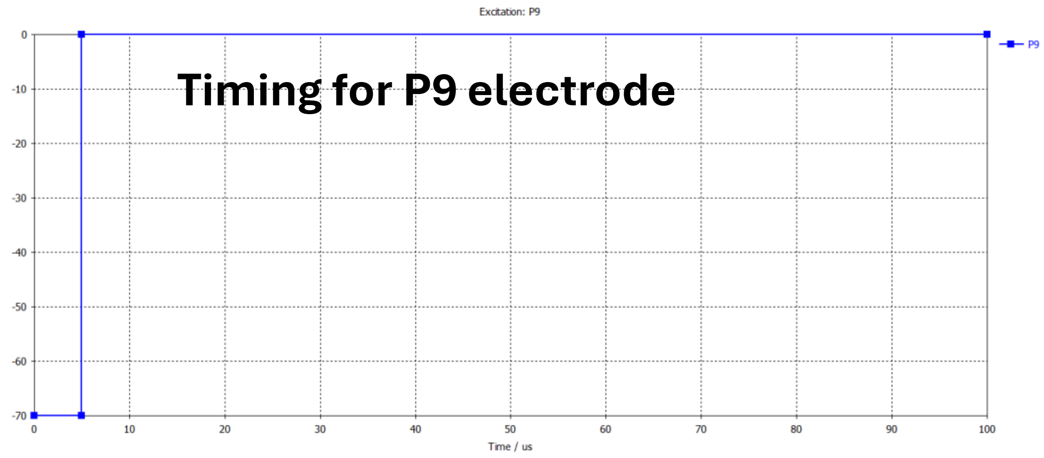
- The modeling was conducted using different versions of **G1**:
  - Planar
  - Perforated
  - Meshed
- A weaker dependence of the **oscillation period** on A0 was observed in the simulations.
- Most efforts are focused on accurately modeling the **initial distribution** using a **user-defined input**, as both **annihilation/loss** and **oscillation periods** appear to be strongly influenced by it. Still looking to figure out the accurate initial source distribution of antiprotons before the swinging process to include the tails of the distribution.
- Developing a **G4Beamline model** to study **antiproton annihilations**, which cannot be modeled using CST.
- Once the swinging is properly reproduced using modeling , it can be further used to optimize the parabolic potential profile to better values.

Thank you

Merry Christmas and Happy New year!

Wesołych Świąt!
Frohe Weihnachten!
Buon Natale!
veselé Vánoce!
Priecīgus Ziemassvētkus!
god jul!





Initial Loading conditions:

Number of pbar : 20000

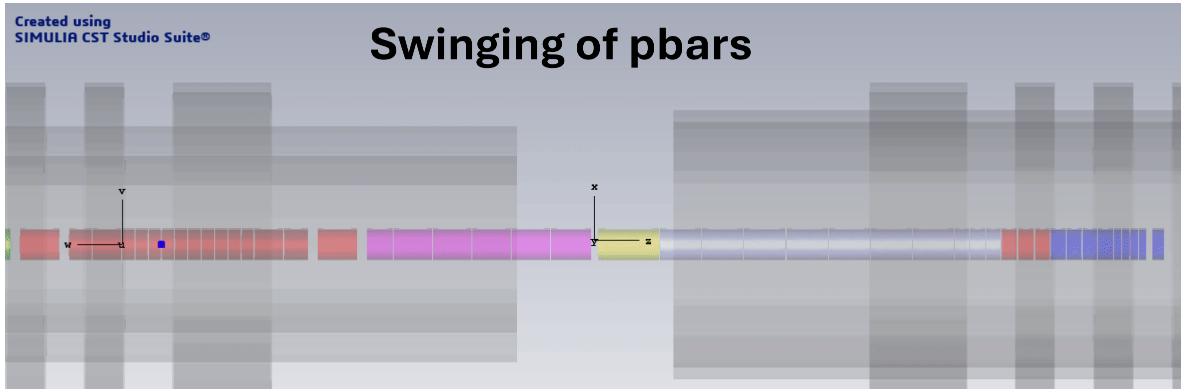
Density: 1×10^{12} m^{-3}

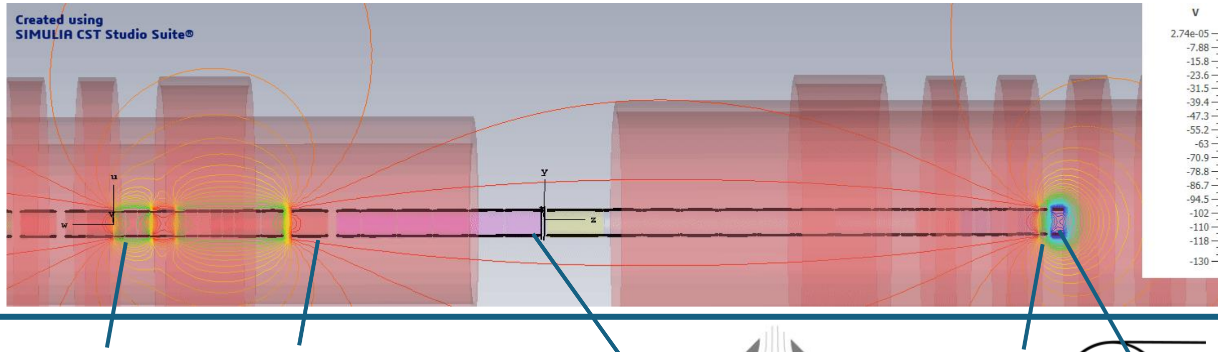
Temperature: 55K (x,y,z)

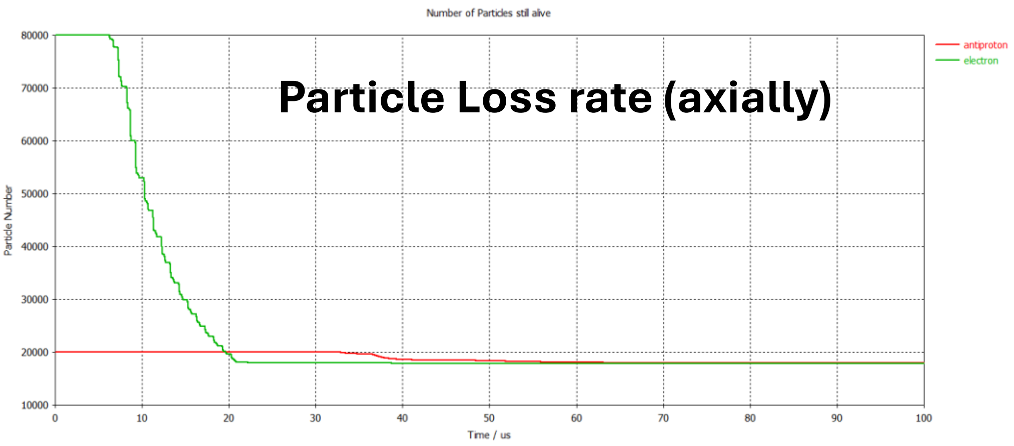
Number of electrons : 80000

Density: 1×10^{10} m^{-3}

Temperature: 55K (x,y,z)







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