

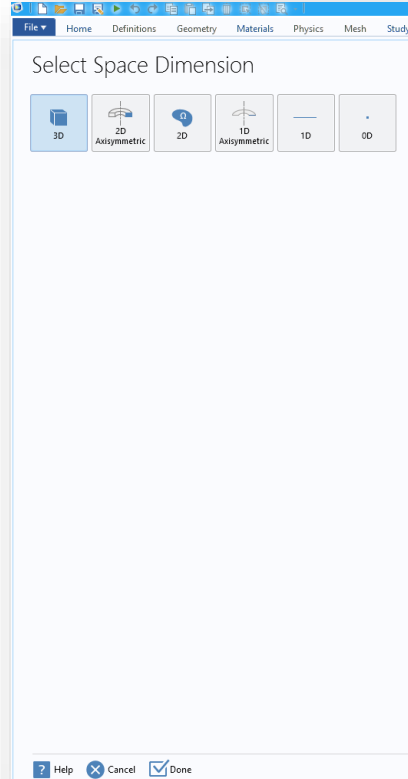
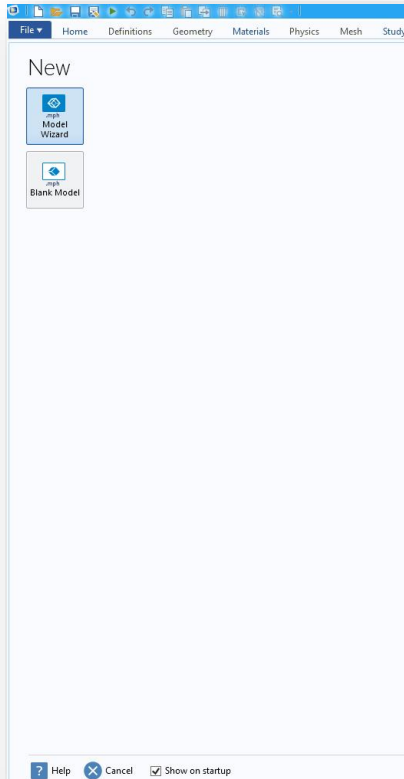
# Van Allenovy radiační pásy

Martin Kožíšek

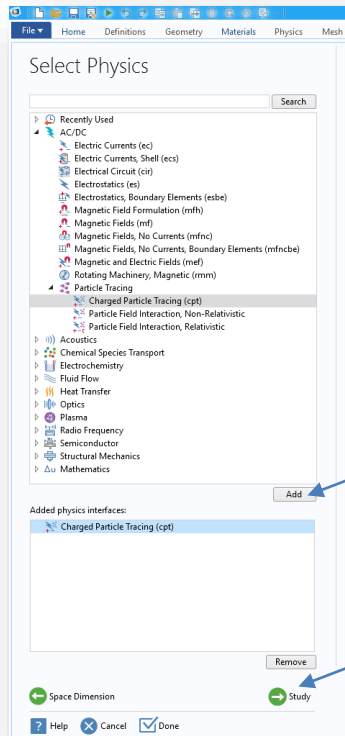
kozisek@humusoft.cz

+420 284 011 745

# 1) Model Wizard / 3D



## 2) AC/DC / Particle Tracing / Charged Particle Tracing (cpt)



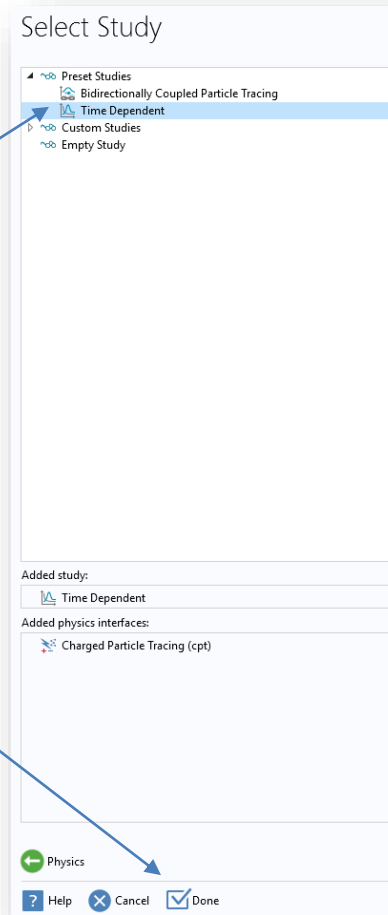
Fyzikální rozhraní se přidá kliknutím na „Add“

K výběru studie se přejde stiskem „Study“

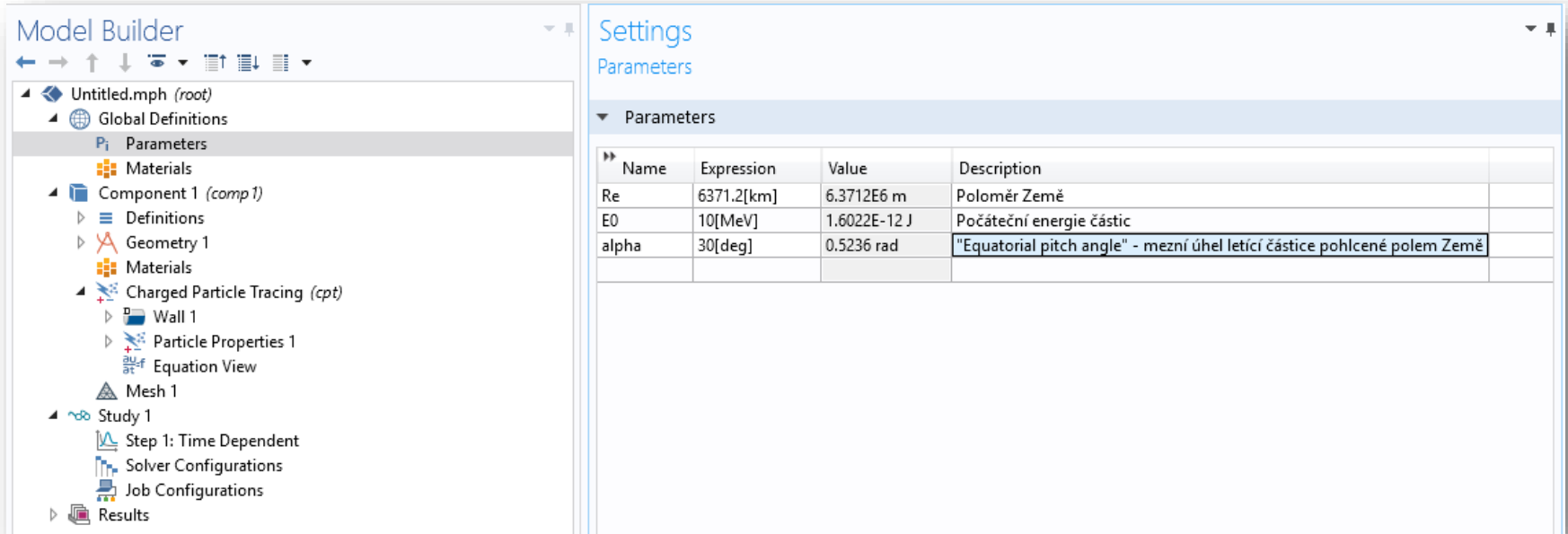
### 3) Select Study -> Time Dependent

Studie se vybere označením

Dokončit základní nastavení  
Model Wizard



## 4) Global Definitions / Parameters



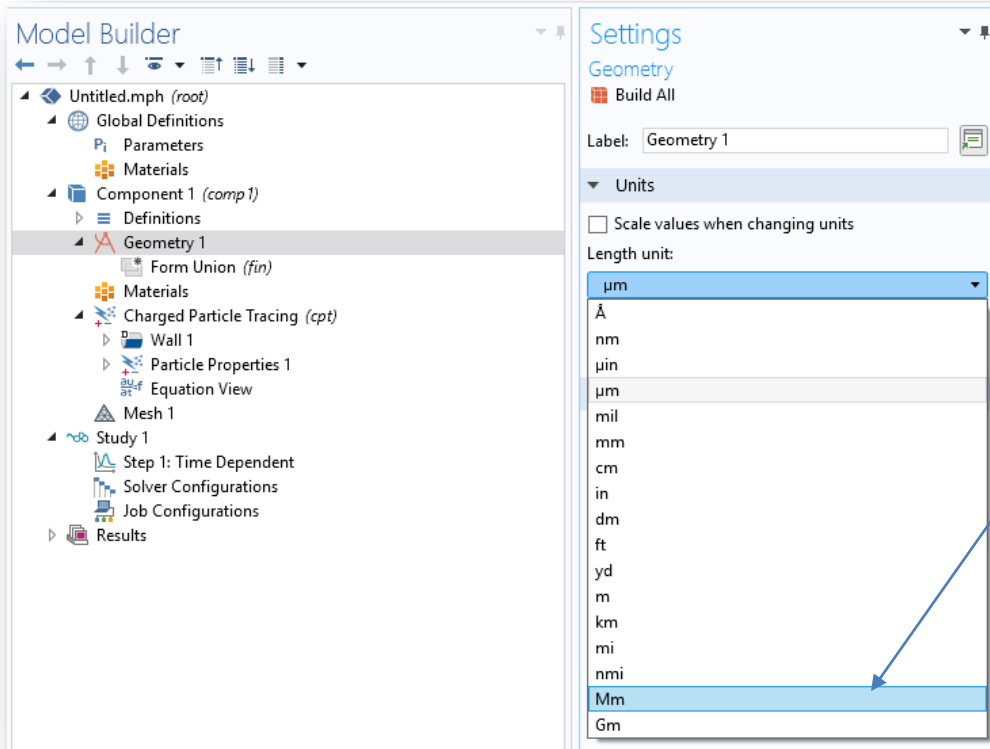
The screenshot displays the COMSOL Multiphysics Model Builder interface. The left pane shows the Model Builder tree with the following structure:

- Untitled.mph (root)
  - Global Definitions
    - Parameters
    - Materials
  - Component 1 (comp 1)
    - Definitions
    - Geometry 1
      - Materials
    - Charged Particle Tracing (cpt)
      - Wall 1
      - Particle Properties 1
      - Equation View
    - Mesh 1
  - Study 1
    - Step 1: Time Dependent
    - Solver Configurations
    - Job Configurations
  - Results

The right pane shows the Settings window for Parameters, containing a table with the following data:

Name	Expression	Value	Description
Re	6371.2[km]	6.3712E6 m	Poloměr Země
E0	10[MeV]	1.6022E-12 J	Počáteční energie částic
alpha	30[deg]	0.5236 rad	"Equatorial pitch angle" - mezní úhel letící částice pohlcené polem Země

## 5) Component 1 / Geometry – Length unit Mm



The screenshot shows the COMSOL Model Builder interface. On the left is the Model Builder tree, and on the right is the Settings panel for the selected 'Geometry 1' component.

**Model Builder Tree:**

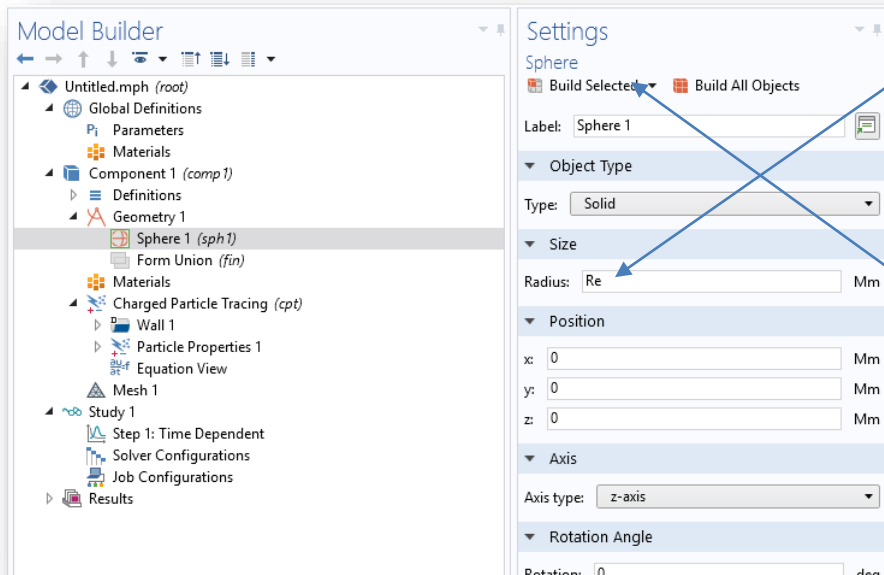
- Untitled.mph (root)
  - Global Definitions
    - Parameters
    - Materials
  - Component 1 (comp 1)
    - Definitions
    - Geometry 1 (selected)
      - Form Union (fin)
      - Materials
      - Charged Particle Tracing (cpt)
        - Wall 1
        - Particle Properties 1
          - Equation View
      - Mesh 1
    - Study 1
      - Step 1: Time Dependent
      - Solver Configurations
      - Job Configurations
    - Results

**Settings Panel (Geometry):**

- Build All
- Label: Geometry 1
- Units
  - Scale values when changing units
  - Length unit:
    - $\mu\text{m}$  (highlighted)
    - Å
    - nm
    - $\mu\text{in}$
    - $\mu\text{m}$
    - mil
    - mm
    - cm
    - in
    - dm
    - ft
    - yd
    - m
    - km
    - mi
    - nmi
    - Mm** (highlighted)
    - Gm

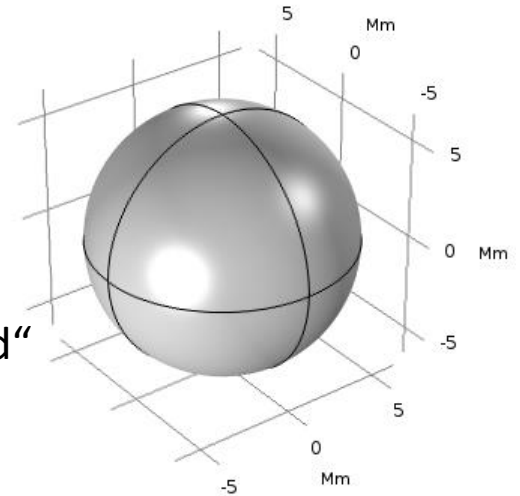
Měřítko blízkého vesmíru

## 6) Component 1 / Sphere 1

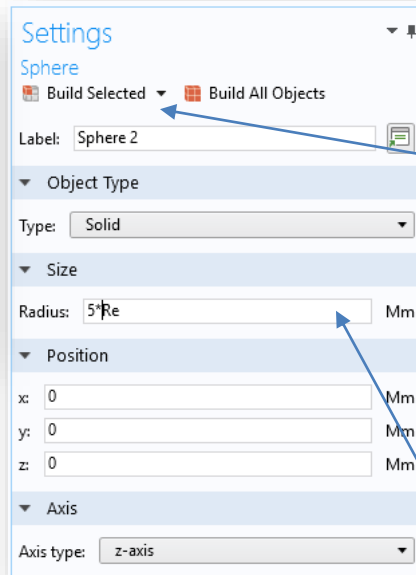
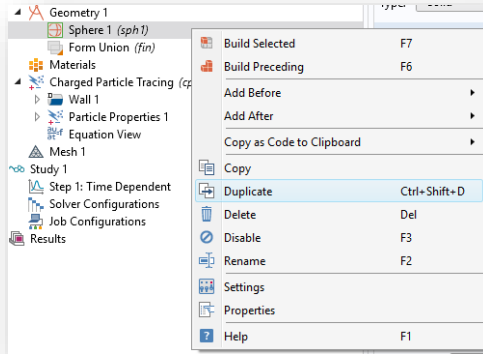


Poloměr Země

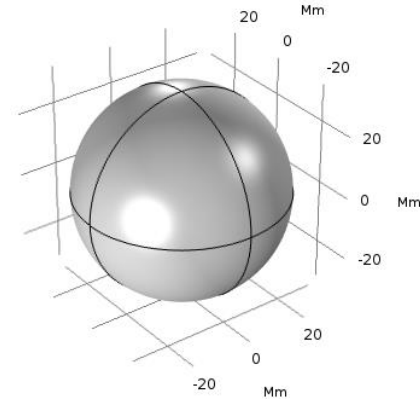
Stisknutím  
„Build Selected“  
se provede:



## 7) Component 1 / Geometry 1 / Sphere 2



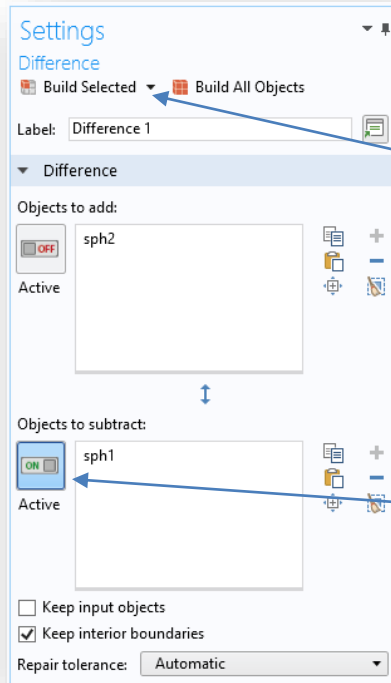
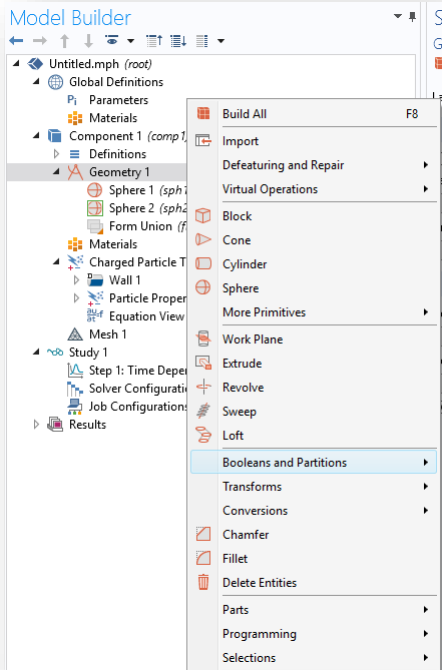
Stisknutím „Build Selected“ se provede úkol:



Výpočetní doména s poloměrem  $5 \cdot Re$



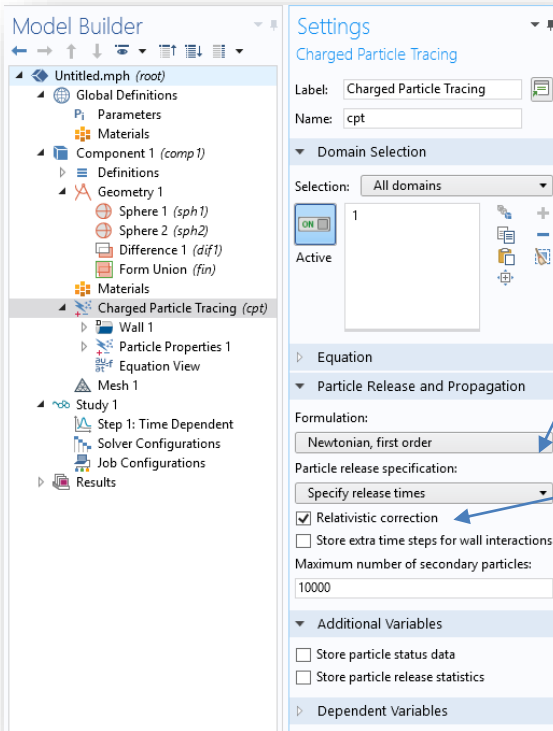
## 8) Component 1 / Geometry 1 / Booleans and Partitions / Difference



Stisknutím „Build Selected“ se provede diference

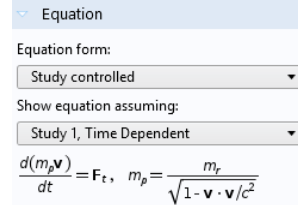
Nejprve se zapne označovací režim (ON) a poté se přímo v geometrii klikne na doménu „sph1“ (pomocí skrolování)

## 9) Component 1 / Charged Particle Tracing (cpt)



Newtonian, first order

Musíme brát v potaz rychlosti blížící se rychlosti světla (nárůst hmotnosti částice)



## 10) Component 1 / Charged Particle Tracing (cpt) / Particle Properties

Model Builder

Settings

Particle Properties

Label: Particle Properties 1

Equation

Particle Rest Mass

Particle rest mass:

$m_r$  mp\_const kg

Charge Number

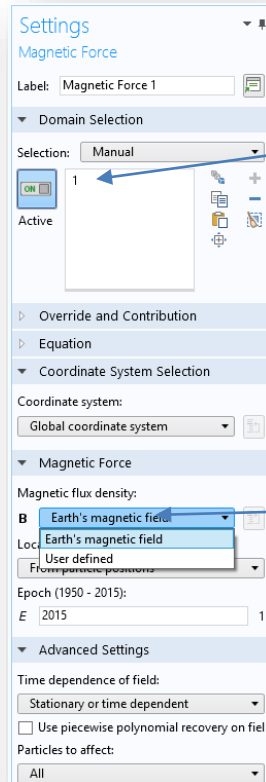
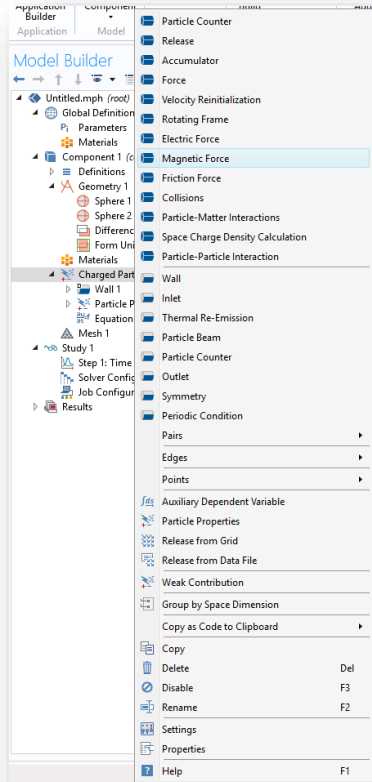
Charge number:

Z 1

Počítám s hmotností protonu

Musí se změnit polarita nabití na +1

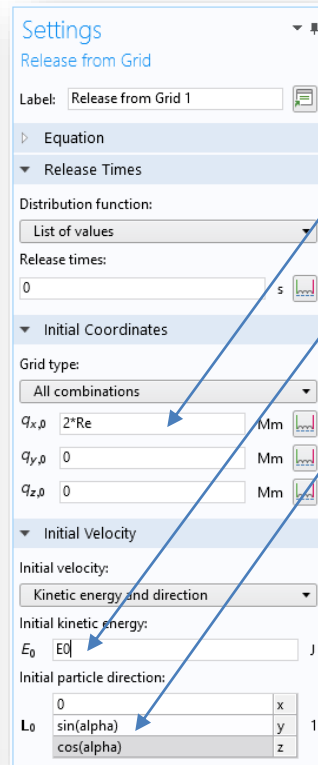
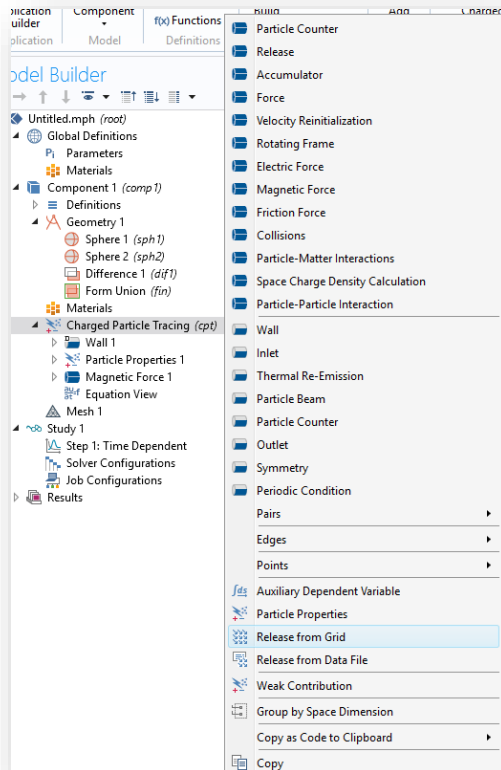
# 11) Component 1 / Charged Particle Tracing (cpt) / Magnetic Force



Magnetická síla působí všude v doméně

COMSOL má vestavěnou databázi „International Geomagnetic Reference Field (IGRF)“ a dokáže počítat s magnetickým polem kdekoli na Zemi měřeném v pětiletém intervalu od roku 1950

## 12) Component 1 / Charged Particle Tracing (cpt) / Release from Grid



Na poloměru  $2 \cdot R_e$  se objeví částice

Částice bude mít počáteční energii

Poletí pod mezním úhlem potřebným pro  
uvěznění částice v pásu kolem Země

## 13) Component 1 / Study 1 / Step 1: Time Dependent

The screenshot shows the COMSOL Multiphysics interface. On the left is the Model Builder tree, and on the right is the Settings panel for the selected study step.

**Model Builder (Left Panel):**

- Untitled.mph (root)
  - Global Definitions
    - Parameters
    - Materials
  - Component 1 (comp 1)
    - Definitions
    - Geometry 1
      - Sphere 1 (sph1)
      - Sphere 2 (sph2)
      - Difference 1 (dif1)
      - Form Union (fin)
    - Materials
    - Charged Particle Tracing (cpt)
      - Wall 1
      - Particle Properties 1
      - Magnetic Force 1
      - Release from Grid 1
      - Equation View
    - Mesh 1
  - Study 1
    - Step 1: Time Dependent (selected)
    - Solver Configurations
    - Job Configurations
    - Results

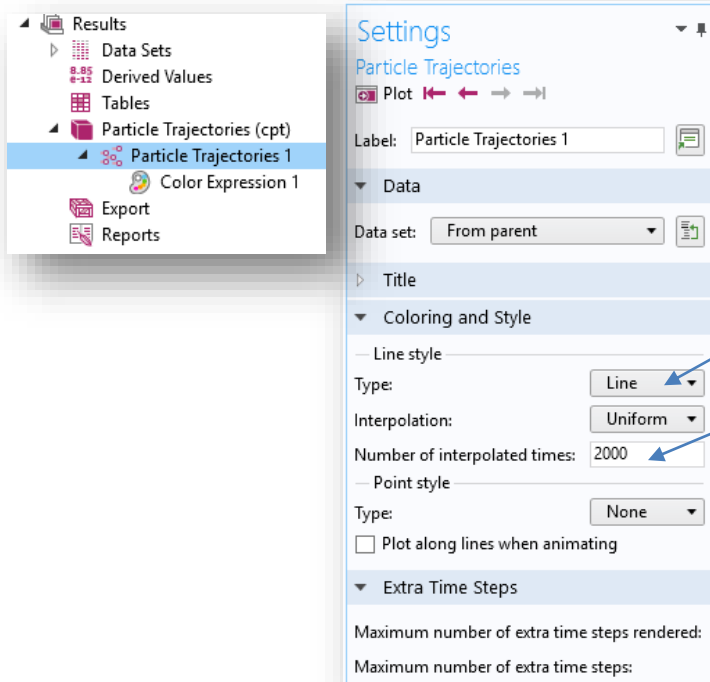
**Settings Panel (Right Panel):**

- Time Dependent
  - Compute
  - Label: Time Dependent
  - Study Settings
    - Time unit: s
    - Times: range(0,0.005,3) s
    - Tolerance: Physics controlled
  - Results While Solving
  - Physics and Variables Selection
    - Modify model configuration for study step
    - Physics interface | Solve for | Di
    - Charged Particle Tracing |  |
  - Values of Dependent Variables
  - Mesh Selection
  - Study Extensions

Budeme sledovat chování částice od 0  
Do 3 s po pěti tisícinách sekundy

Stiskem „Compute“ se spustí výpočet

# 14) Results / Particle Tracing Trajectories / Particle Trajectories

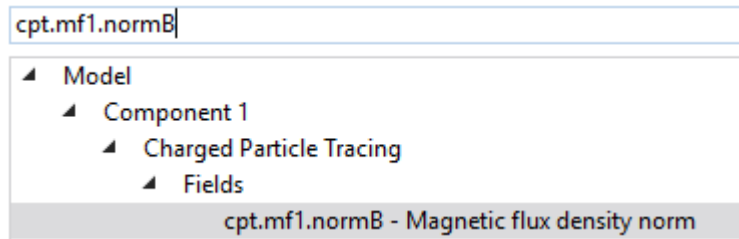


Trajektorie bude čára

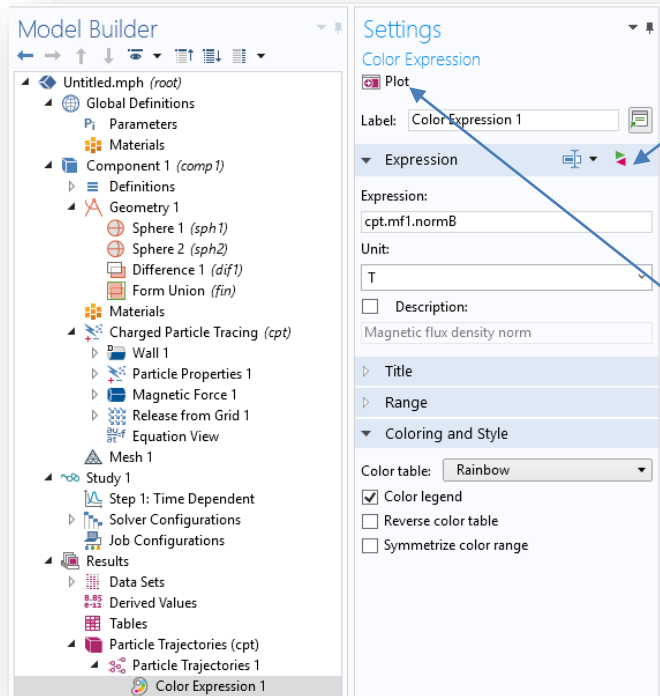
Pokud nastavíme interpolaci, nebude se jednat o lomenou čáru z vypočtených časů.

# 15) Results / Particle Tracing Tracejectories / Particle Trajectories / Color Expression 1

Stiskem tlačítka můžeme vkládat libovolné výrazy, například:

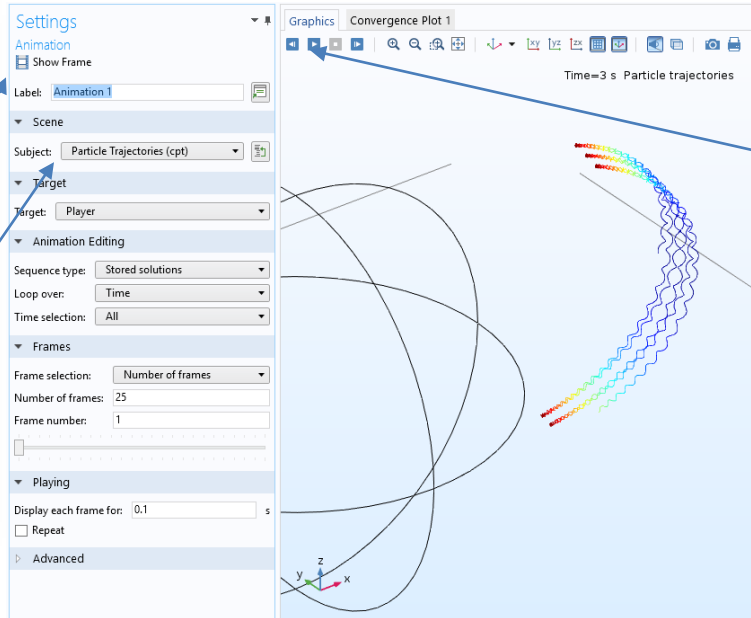
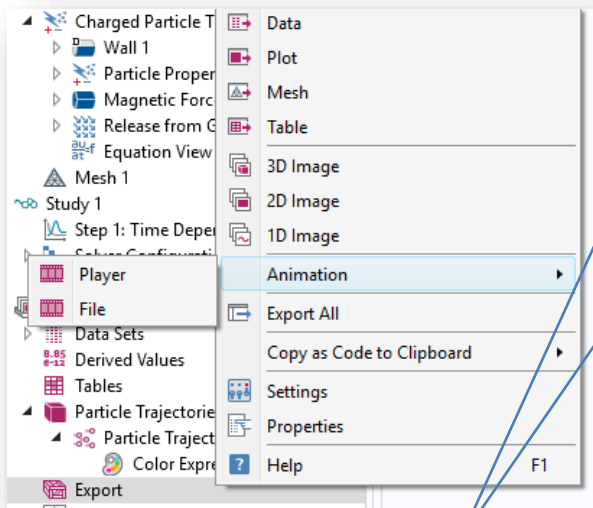


Tlačítkem „Plot“ dojde k vykreslení grafu





## 16) Results / Export / Animation / Player



Animace z grafu Particle Trajectories se připraví kliknutím na „Show Frame“

Video se spustí kliknutím na Tlačítko „Play“