GATE-RTion

A GATE release for scanned ion beam therapy users

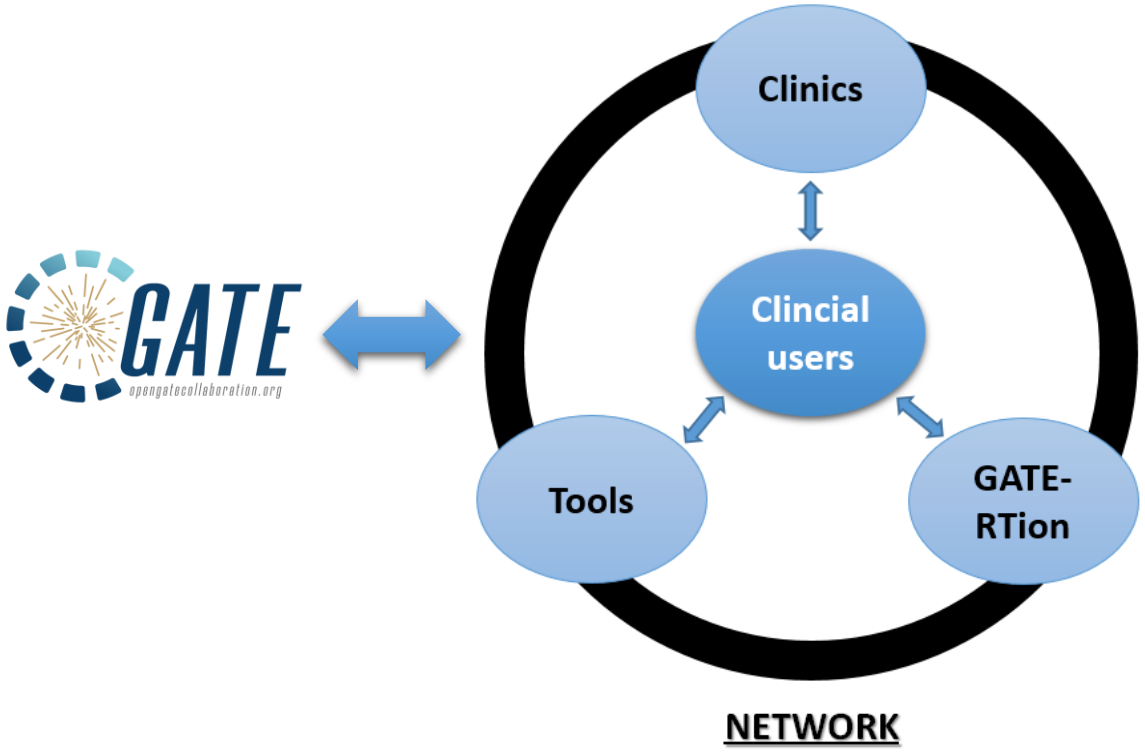
Loïc Grevillot

Purpose

To support the clinical use of GATE in **scanned ion beam therapy** facilities.

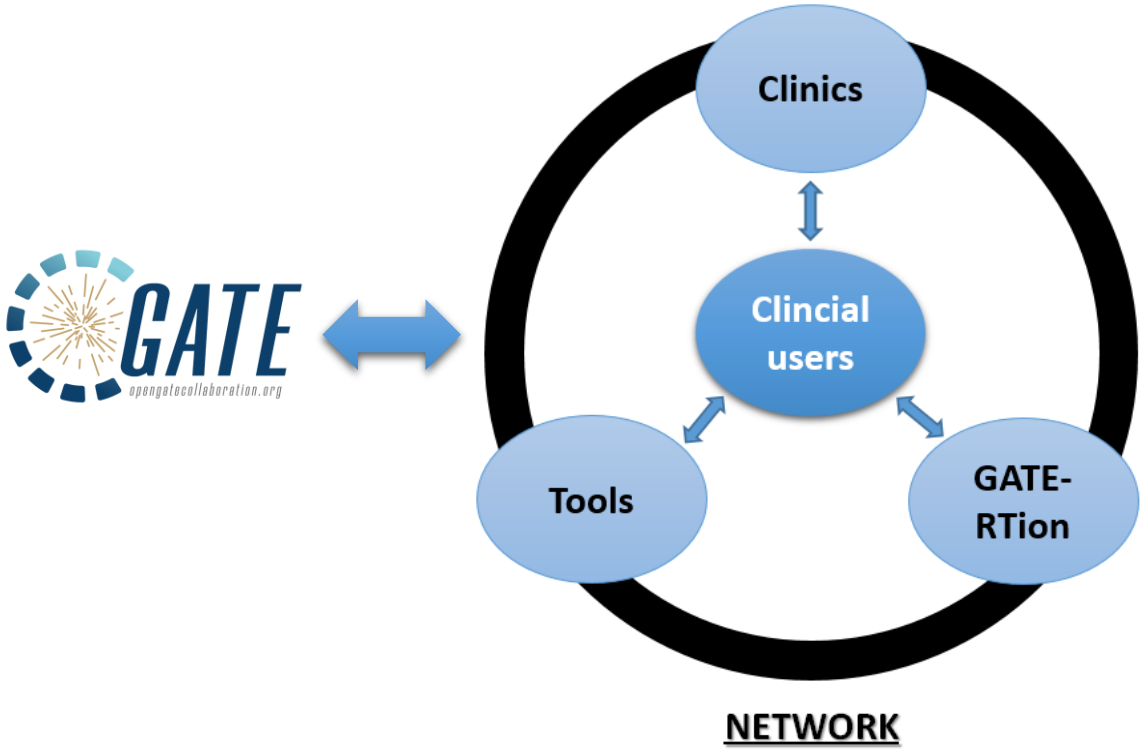
Concept

- Providing a **VALIDATED** and long term GATE release.
- Providing **TOOLS** to interface GATE with the clinics.
- Developing a **NETWORK** of clinical users.



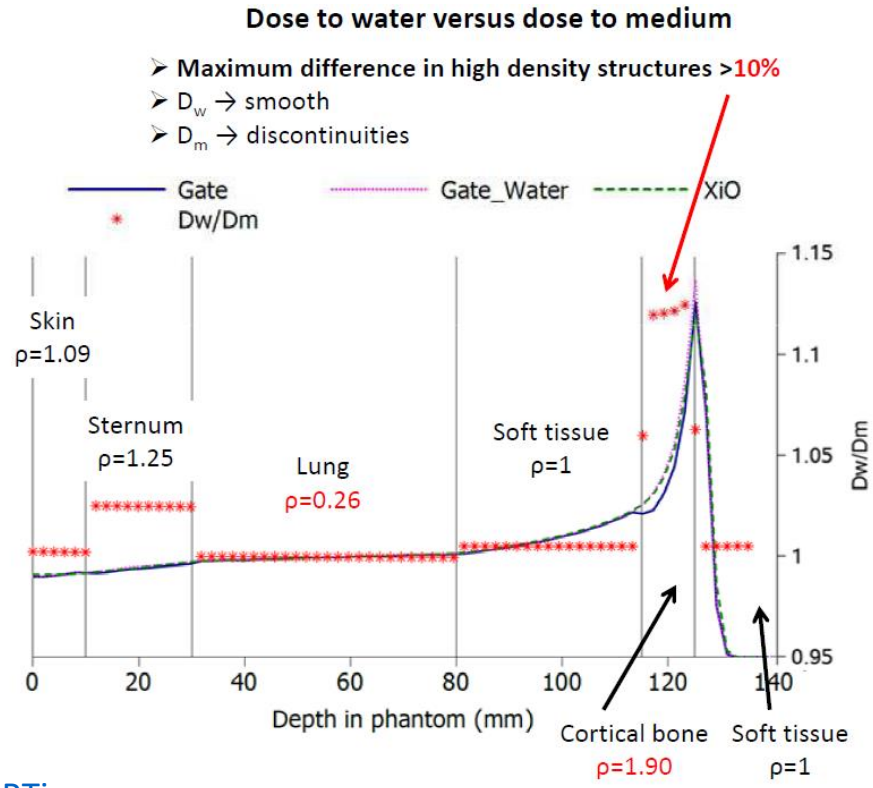
Outline

- Key **functionalities** and **VALIDATION** plans
- Existing **TOOLS** and future plans
- Current **NETWORK** and European projects



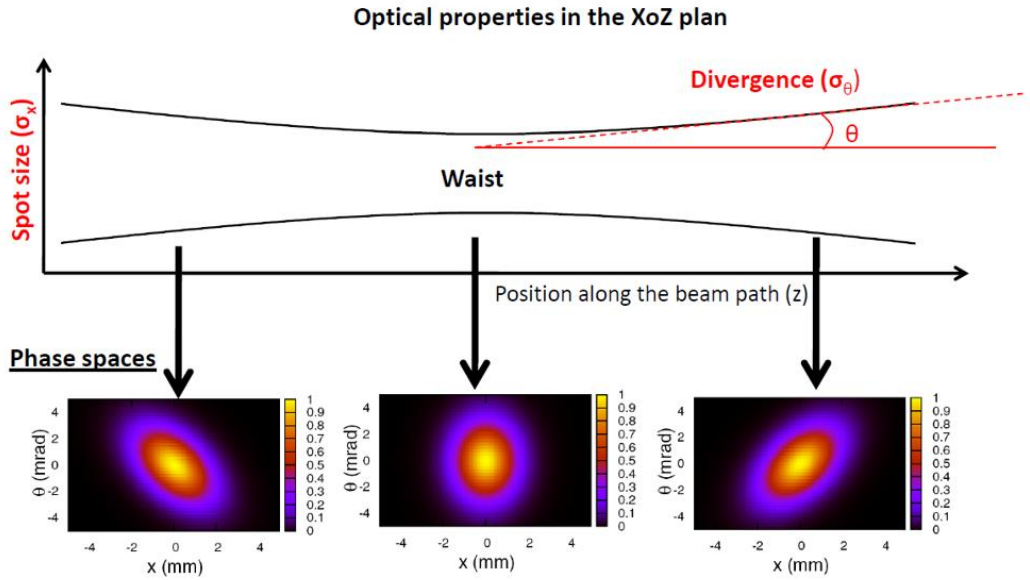
Key functionalities

- **Dose Actor**
  - **Purpose:** To score energy, dose and dose-to-water
  - **Main features:**
    - Scoring of energy and dose deposited
    - In-line conversion of dose into dose-to water
    - Scoring of associated statistical uncertainties
    - Accounting for different CT and scoring resolutions
  - **Validation:**
    - Available on the git repository OpenGate/GateContrib
      https://github.com/OpenGATE/GateContrib/tree/master/GATE-RTion

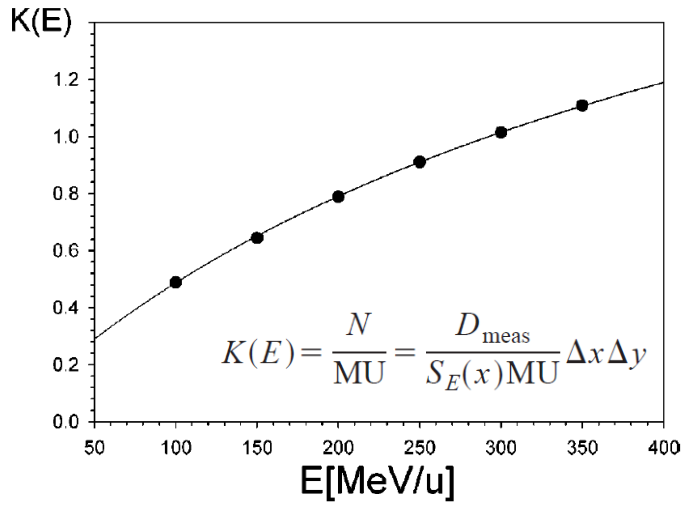


Key functionalities

- **TPS Pencil Beam Source**
  - **Purpose:** To describe a clinical beam line (all energies)
  - **Main features:**
    - DICOM coordinates
    - Any type of ion: ^{1}H, ^{4}He, ^{12}C
    - Polynomial description of all pencil beam parameters (energy, optics) as a function of energy
    - Calibration in number of particles (N/MU)
  - **Validation:**
    - Available on the git repository OpenGate/GateContrib https://github.com/OpenGATE/GateContrib/tree/master/GATE-RTion

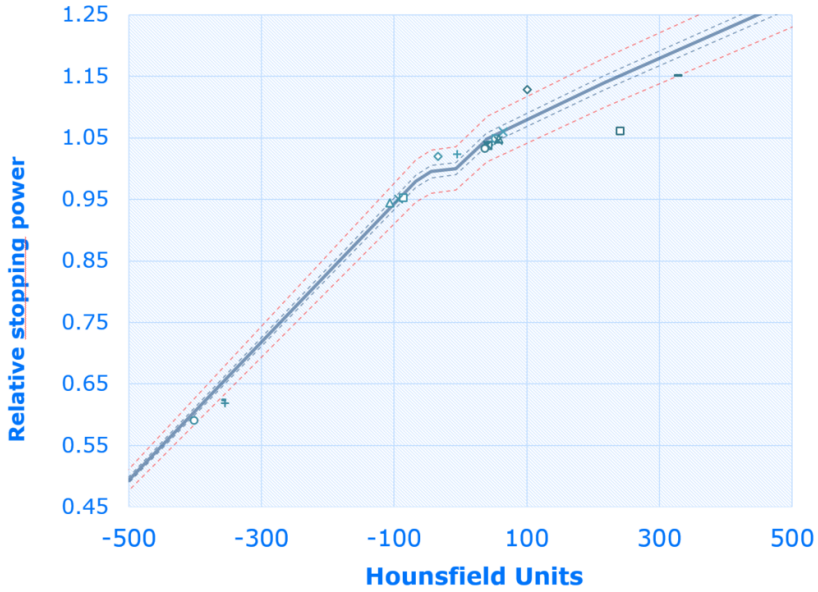


Emittance ($\epsilon_{\theta x}$) = ellipse phase space area



Key functionalities

- **Voxelized geometry**
  - **Purpose:** To define a CT-based simulation geometry
  - **Main features:**
    - DICOM coordinates
    - Integration of CT images
    - Stochiometric calibration (HU to density and composition)
  - **Validation:**
    - To be released before end of 2019



Tools

- **Purpose:** To provide a set of harmonized tools to the users
- **Main functionalities:**
  - Beam modeling
  - DICOM-RT (image, plan, structure) interface
  - Image processing tools
  - Cluster management
- **Current status: OpenReGate**
  - A central repository of Open Source tools
    https://public.kitware.com/open-regate/index.php/Main_Page
- **Future plans: GATE TOOLS**
  - A new Python dedicated toolkit – *starting this summer!*
    https://github.com/OpenGATE/GateTools

Typical Use Scenario:

I am a clinical user and I want to recompute my TPS plan with GATE.

- I need a beam model for GATE
- I have a computer or a cluster and I would like to distribute my computation on it.
- I want to override some structures in the CT image like in the TPS.
- Sometimes I need to resample the output dose distribution…
- Etc.

Network

- **Purpose:** To develop a network of clinical users
- **Main outcomes?**
  - To develop harmonized guidelines for clinical users
  - To increase the level of confidence in the software
  - To apply for common clinical research projects
- **Current status: OpenReGate**
  - A central repository of Open Source tools
    https://public.kitware.com/open-regate/index.php/Main_Page
- **Future plans:**
  - To be defined by the users !!

Typical Use Scenario:

I am a clinical user and I want to recompute my TPS plan with GATE.

- Can you tell me how you did the beam model?
- I found a 3% difference with range shifter when the air gap is more than 10 cm, did you observe something similar?
- The simulation is running slow when….
- Which statistical uncertainty do you consider for comparing with the TPS, do you thing 2% is too large?
- Which voxel size do you consider in your center?
- Which simulation parameters do you use…
- Etc.

Network

6 Ion Therapy Centers:

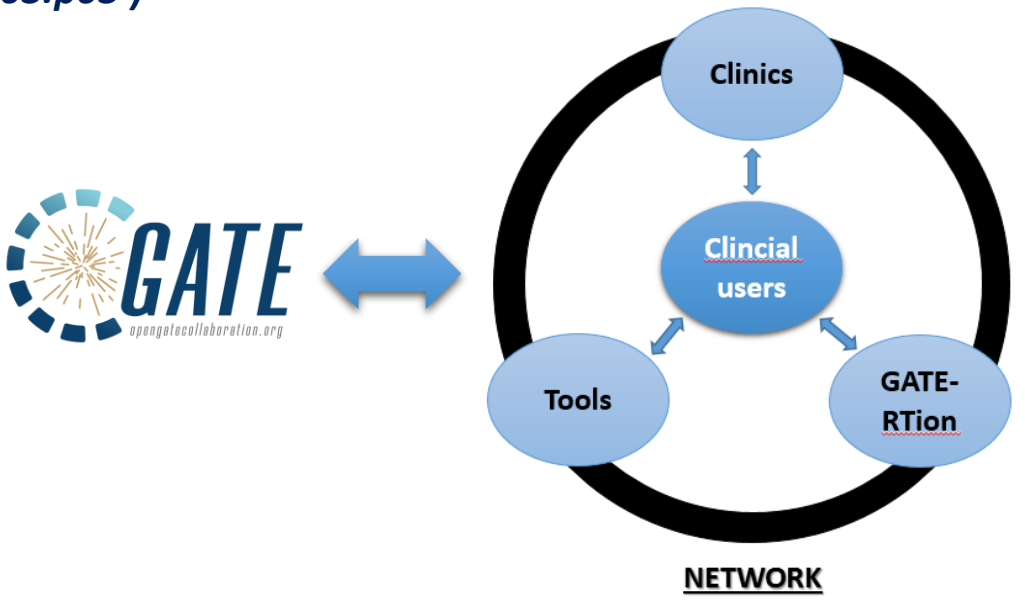
- *MedAustron (Austria)*
- *The Christie (United Kingdom)*
- *UCLH (United Kingdom)*
- *CAL (France)*
- *CPO (France)*
- *Skandion (Sweden)*

5 Partners:

- *University of Lyon (France)*
- *University of Clermont-Ferrand (France)*
- *Medical university of Vienna (Austria)*
- *University of Krakow (Poland)*
- *ACMIT (Austria)*

The GATE-RTion recipe

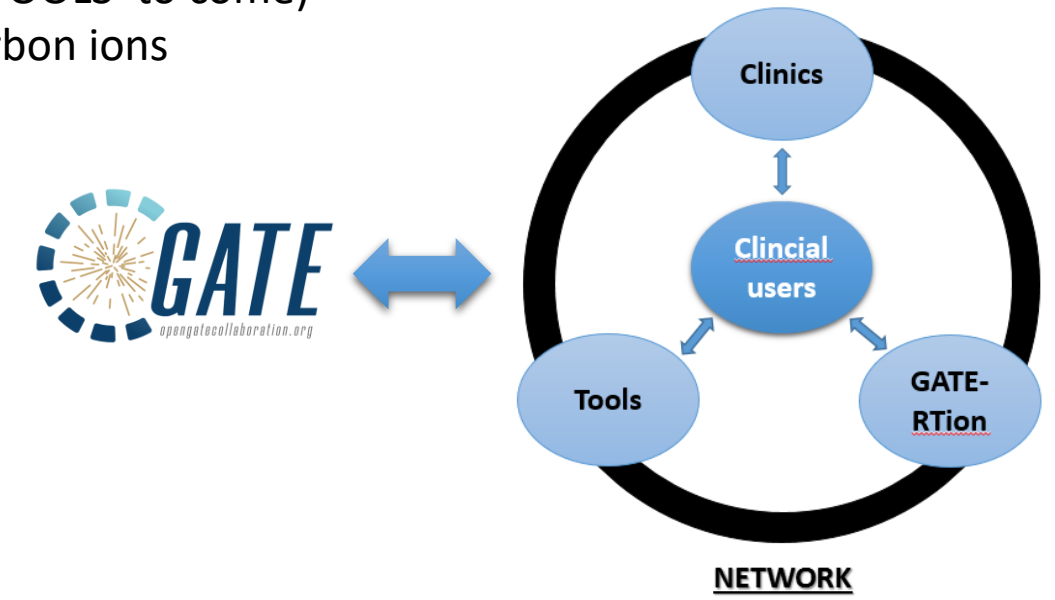
- **Ingredients:**
  - One **VALIDATED** GATE/GEANT4 version
    e.g. GATE-RTion 1.0 (i.e. GATE 8.1 with GEANT4 10.03.p03)
  - A set of common **GATE-TOOLS**
  - A **NETWORK** of clinical users



Summary

GATE-RTion 1.0 released since May 2018

- **Validation** of key functionalities are available (more to come)
- **Tools** are available (new Python-based 'GATE-TOOLS' to come)
- **Network** of European users for proton and carbon ions



http://www.opengatecollaboration.org/GateRTion

The IDEAL Perspective!

Independent DosE cAlculation for Light ion beam radiotherapy (IDEAL)

- Based on GATE-RTion dose engine
- CE-marked
- First release plan for 2020

In development at EBG MedAustron GmbH in collaboration with ACMIT Gmbh (both in Wiener Neustadt, Austria) and the Medical University of Vienna. Funding within the scope of the Austrian COMET - Competence Centers for Excellent Technologies program and funded by the federal government (BMVIT and BMDW) and the governments of Lower Austria and Tyrol.

FFG Österreichische Forschungsförderungsgesellschaft

acmit AUSTRIAN CENTER FOR MEDICAL INNOVATION AND TECHNOLOGY

MedAustron

MEDIZINISCHE UNIVERSITÄT WIEN

GATE-RTion Tutorial

A GATE release for scanned ion beam therapy users

Introduction: Loïc Grevillot
Live demo: David Boersma

MyTreatmentPlanFile.dcm → GATE-TOOLS → MyTreatmentPlanFile.txt

TPS Pencil Beam Source

commented

```
/gate/source/addSource PBS TPSPencilBeam
/gate/source/PBS/setParticleType proton
#/gate/source/PBS/setParticleType GenericIon
#/gate/source/PBS/setIonProperties 6 12 6 0

/gate/source/PBS/setPlan data/MyTreatmentPlan.txt

/gate/source/PBS/setSourceDescriptionFile data/MySource.txt
```

Sample description of MyTreatmentPlan.txt

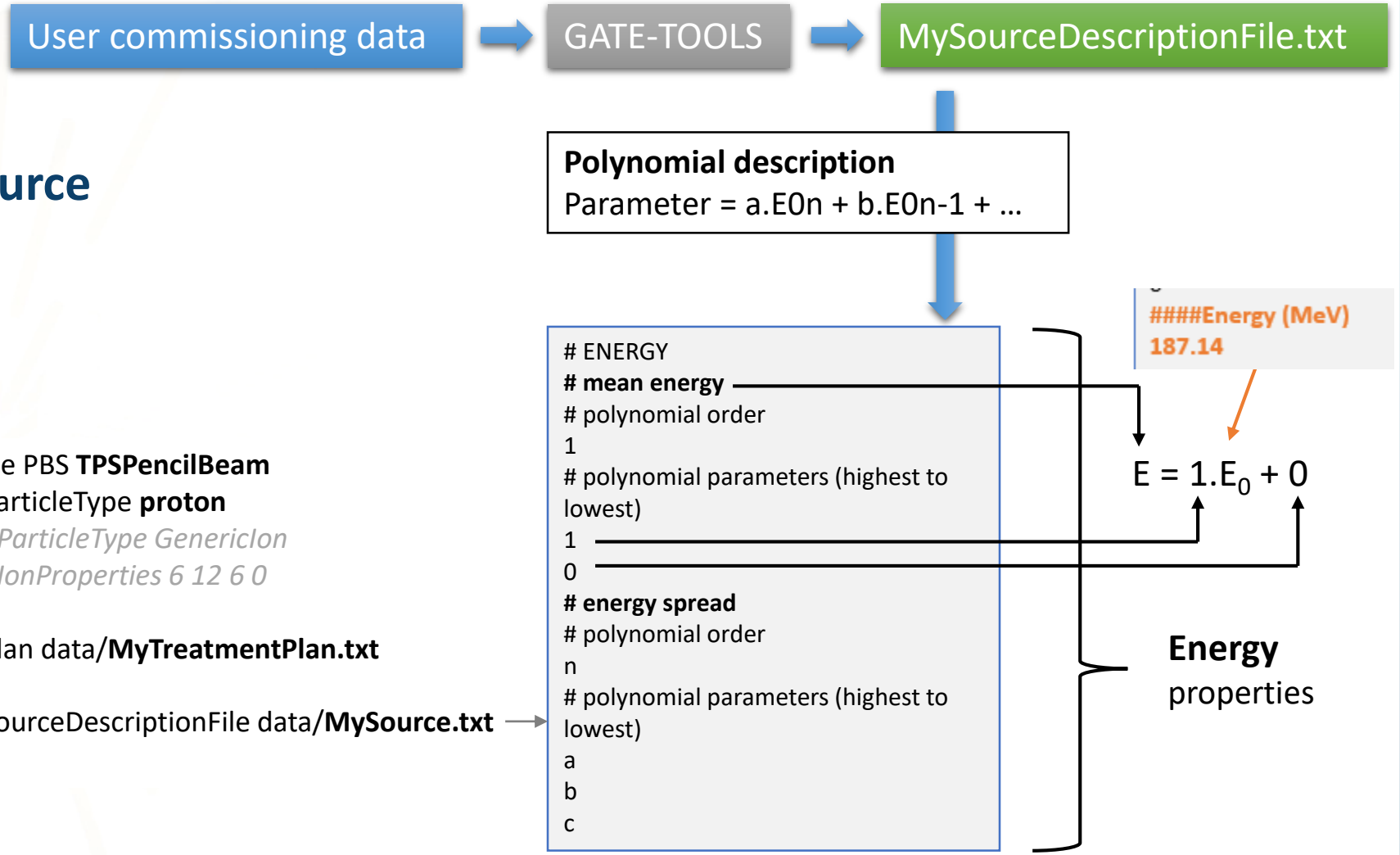
```
###GantryAngle
270
###PatientSupportAngle
0
###IsocenterPosition
4.4 3.8 -1218.5
###NumberOfControlPoints
30
…

####ControlPointIndex
0
####SpotTunnedID
4
####CumulativeMetersetWeight
0
####Energy (MeV)
187.14
####NbOfScannedSpots
17
####X Y Weight
-16 24 26.86
-8 16 26.77
0 16 32.85
…
```

TPS Pencil Beam Source

/gate/source/addSource PBS **TPSPencilBeam**
/gate/source/PBS/setParticleType **proton**
#/gate/source/PBS/setParticleType GenericIon
#/gate/source/PBS/setIonProperties 6 12 6 0

/gate/source/PBS/setPlan data/**MyTreatmentPlan.txt**

/gate/source/PBS/setSourceDescriptionFile data/**MySource.txt**



Sample description of MySource.txt

User commissioning data → GATE-TOOLS → MySourceDescriptionFile.txt

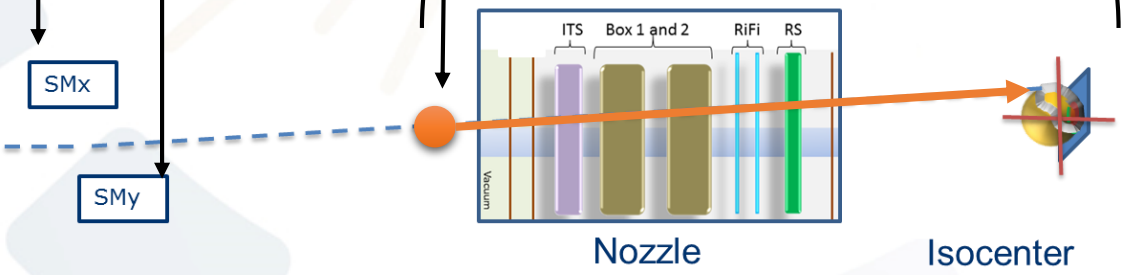
TPS Pencil Beam Source

```
# Source to Isocenter distance (SID)
1000
# SMX to Isocenter distance
6700
# SMY to Isocenter distance
7420
```

Sample description of MySource.txt

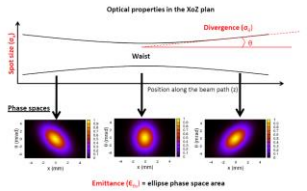
SAD properties

Geometrical properties



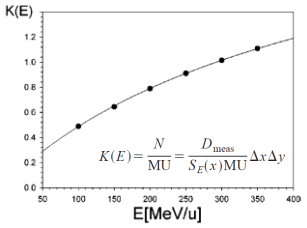
Polynomial description
Parameter = a.E0n + b.E0n-1 + …

```
# x
# polynomial order
2
# polynomial parameters
a
b

# Theta
…

# x-theta emmittance
…
```



Optics properties

```
# Beam monitor calibration
# N/MU
# polynomial order
n
# polynomial parameters
a'
b'
 …
```



Calibration (N/MU)

Sample description of MySource.txt

Geometry

```
# WORLD
/gate/world/setMaterial                 Air
/gate/world/geometry/setXLength    5.0 m
/gate/world/geometry/setYLength    5.0 m
/gate/world/geometry/setZLength    5.0 m

# CT IMAGE
/gate/world/daughters/name                          patient
/gate/world/daughters/insert                        ImageNestedParametrisedVolume

/gate/patient/geometry/setHUToMaterialFile  data/patient-HU2mat.txt
/gate/geometry/setMaterialDatabase          data/patient-HUmaterials.db
/gate/patient/geometry/setImage             data/MyCT-image.mhd
```

```
-1050 -950 Air_0
-950 -852.884 Lung_1
-852.884 -755.769 Lung_2
…
19 80 SoftTissus_15
…
```

Sample description of Patient-HU2mat.txt

```
# Material 1 corresponding to H=[ -950;-852.884 ]
Lung_1: d=102.695 mg/cm3; n=9;
+el: name=Hydrogen; f=0.103
+el: name=Carbon; f=0.105
+el: name=Nitrogen; f=0.031
+el: name=Oxygen; f=0.749
+el: name=Sodium; f=0.002
+el: name=Phosphor; f=0.002
+el: name=Sulfur; f=0.003
+el: name=Chlorine; f=0.003
+el: name=Potassium; f=0.002
```

Sample description of Patient-HUmaterials.db

Dose scoring

GATE-TOOLS → MyDoseOutput.dcm

Can be re-imported in the TPS for comparison

```
# SCORING the DOSE
/gate/actor/addActor                                  DoseActor  doseDistribution
/gate/actor/doseDistribution/save                     output/MyDoseOutput.mhd
/gate/actor/doseDistribution/attachTo                 patient
/gate/actor/doseDistribution/stepHitType              random
/gate/actor/doseDistribution/setVoxelSize             2 2 2 mm
/gate/actor/doseDistribution/enableDose               true
/gate/actor/doseDistribution/enableDoseToWater        true
/gate/actor/doseDistribution/enableUncertaintyDose    true
```