Geant4 simulation of cone shape attenuator for uniform spatial dose distribution for a proton beam generated by fs lasers

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Nuclear Physics

Contents

* Experimental area E5 at ELI-NP
* The aim of simulation
* Why did we need to use Grid
* Simulation and algorithm
* Conclusion

Nuclear Physics

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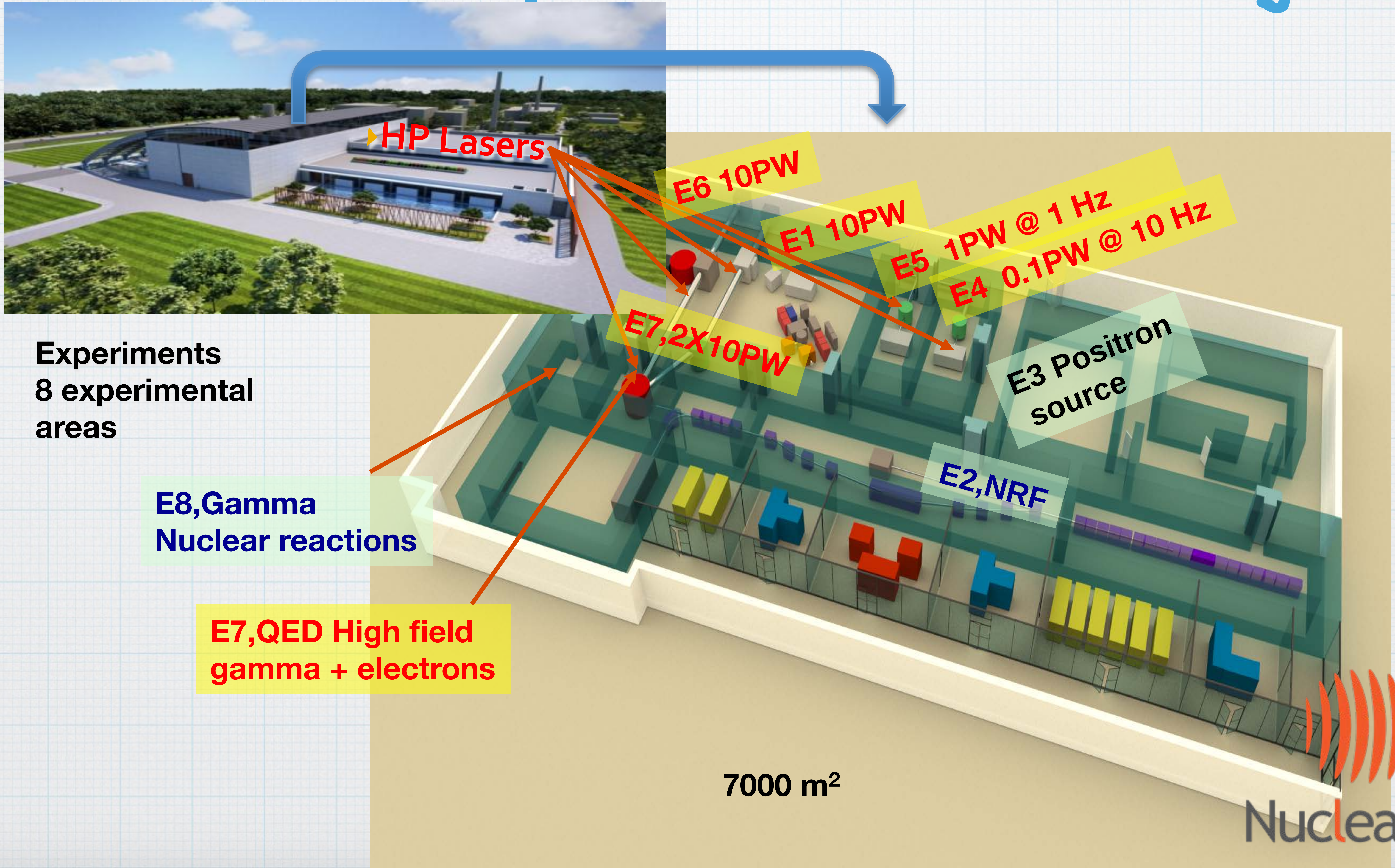
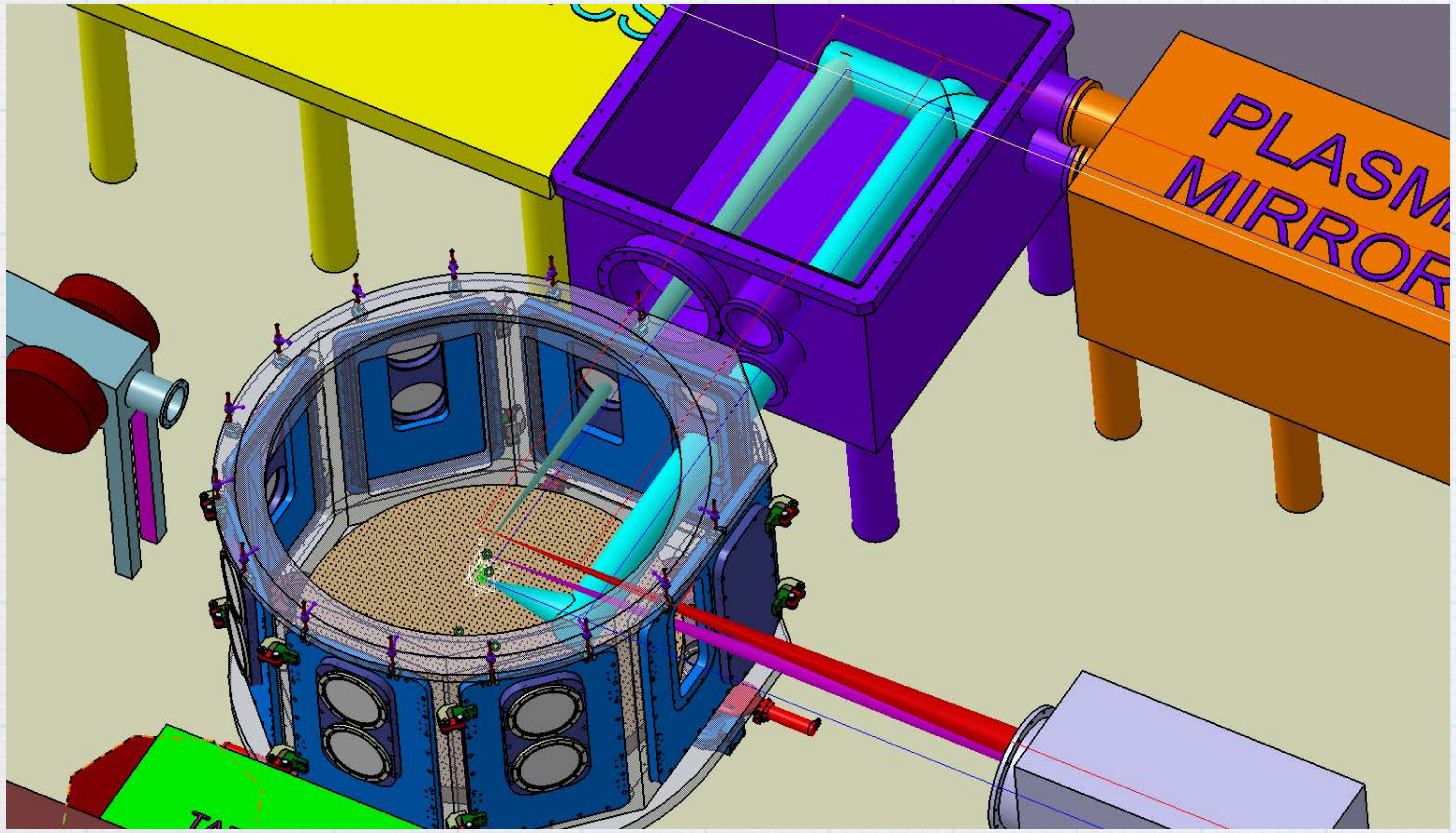
ELI-NP experiment building



Experiments
8 experimental areas

E5



* Material
* Bio-sample
* Extreme condition
* Two 1 PW lasers
* fs order pulse
* Laser target interaction

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Contents

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The aim of simulation (and also experiment)

* Obtaining uniform dose at wide area
  * Standard 96 well plate
* For some studies of bio-samples
  * Cell monolayer
  * And more

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96 well plate

* 96 wells plate with cell mono layer
* Plate: 127.7 x 85.48 x 14.6 mm^3
* Well: ϕ 6.39 mm, 9 mm pitch
* Using mono energetic beam obtained with magnets and collimators
  * Need 96 shot
* To obtaining uniform dose for whole plate
  * Only 1 shot

Simulation condition

* Geant4 10.1
* ROOT
* Scientific Linux 6.8
* gcc 4.4.7

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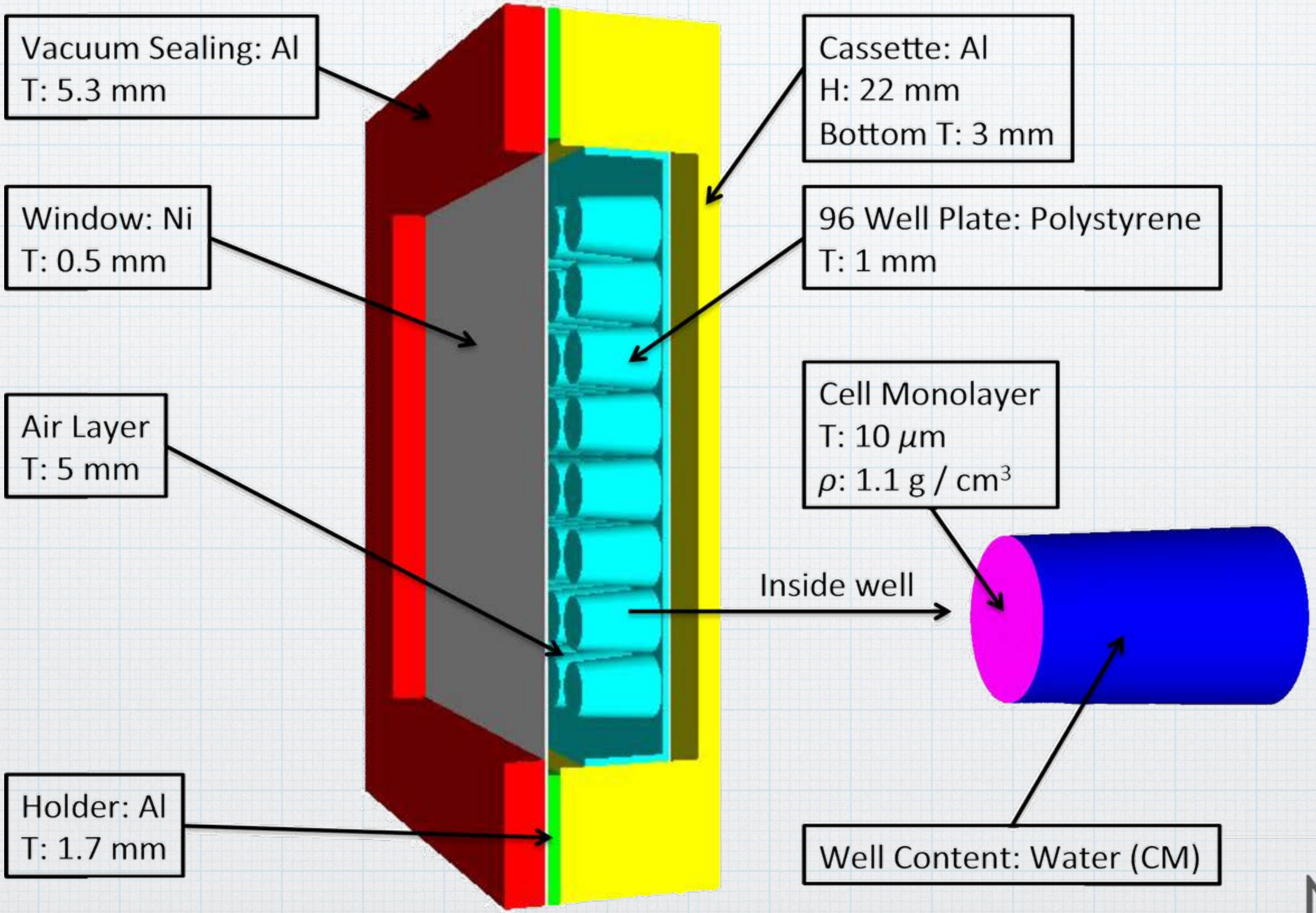
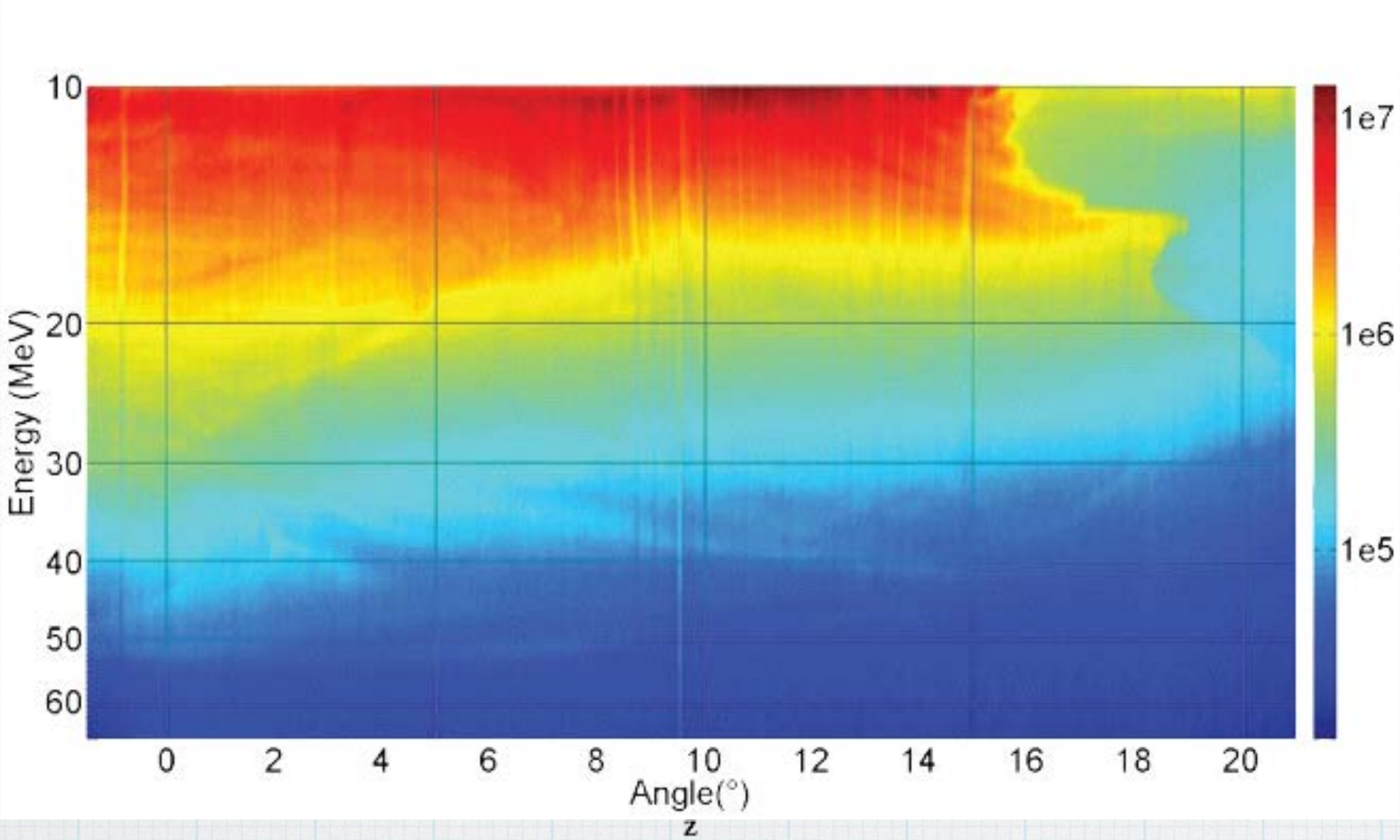
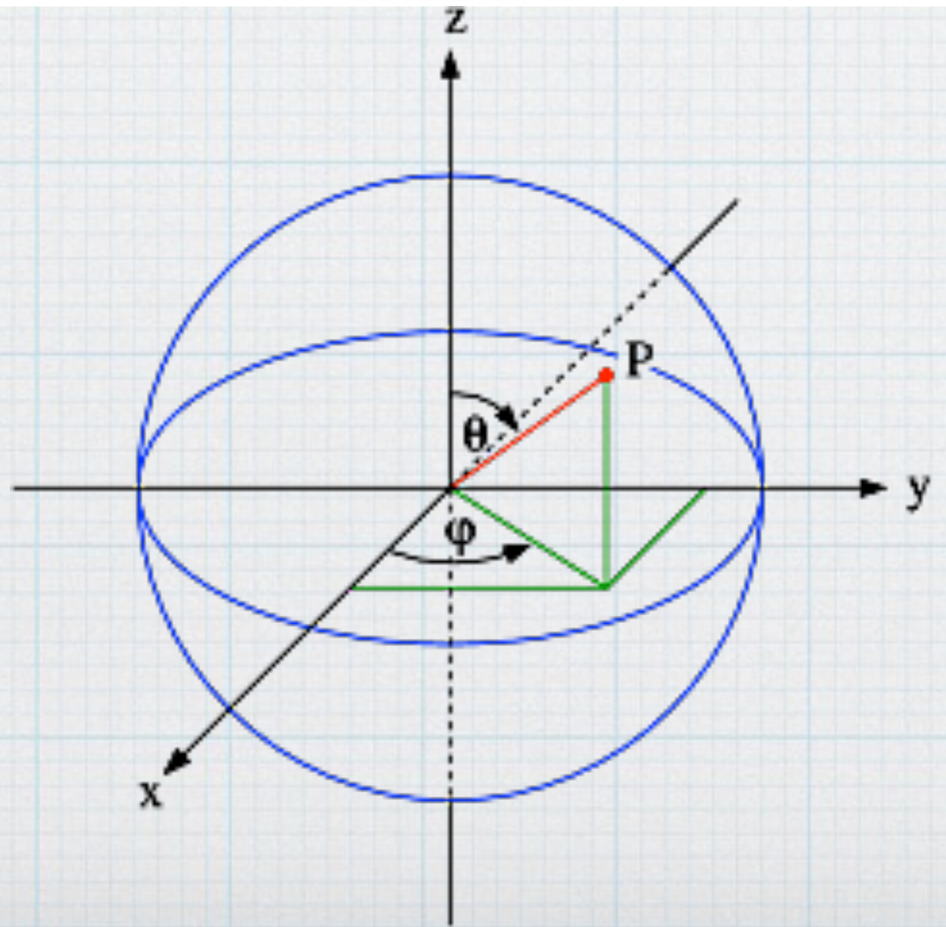
Geometry



Vacuum Sealing: Al
T: 5.3 mm
Window: Ni
T: 0.5 mm
Air Layer
T: 5 mm
Holder: Al
T: 1.7 mm
Cassette: Al
H: 22 mm
Bottom T: 3 mm
96 Well Plate: Polystyrene
T: 1 mm
Cell Monolayer
T: 10 μm
ρ: 1.1 g / cm³
Inside well
Well Content: Water (CM)

Proton beam profile



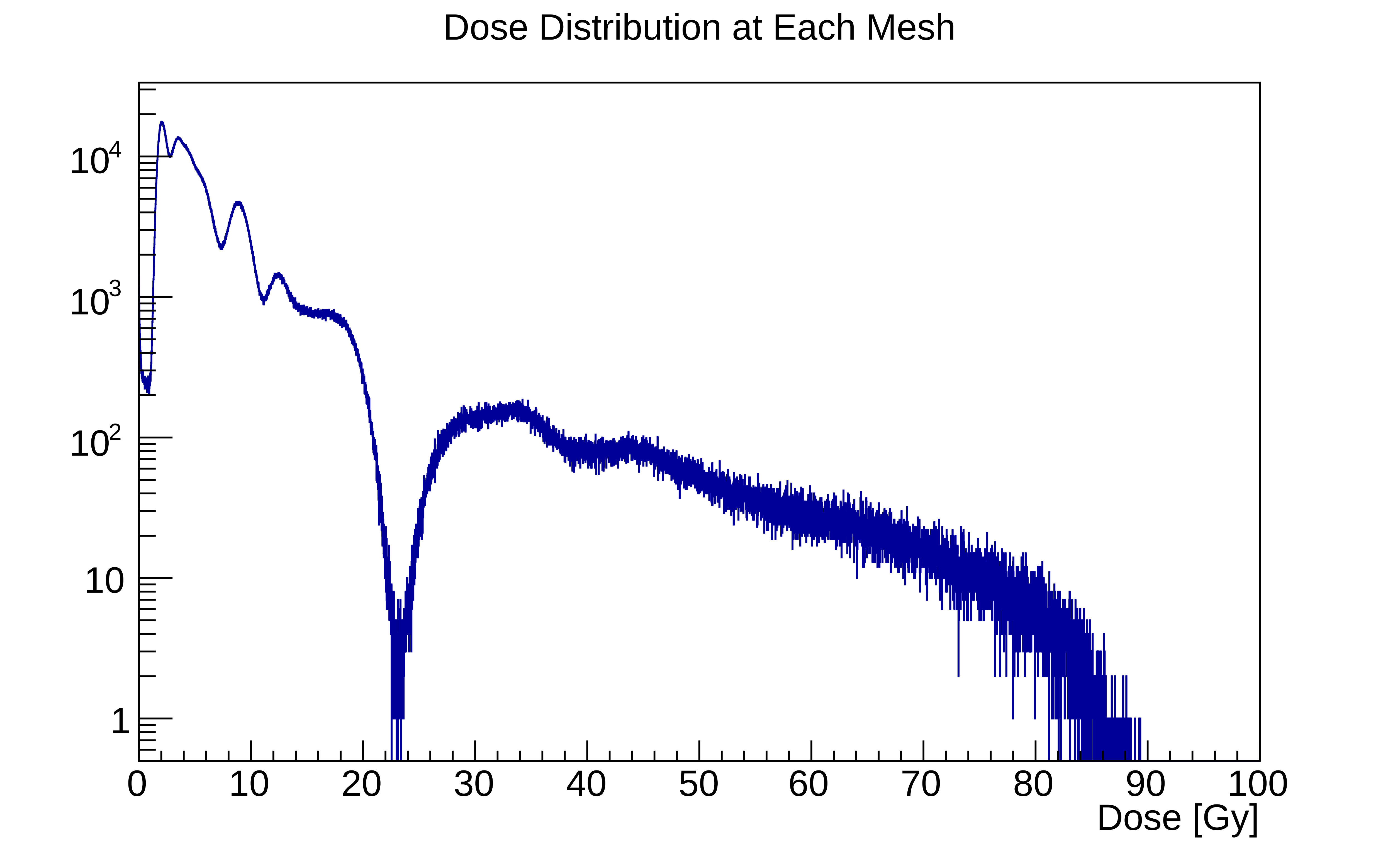


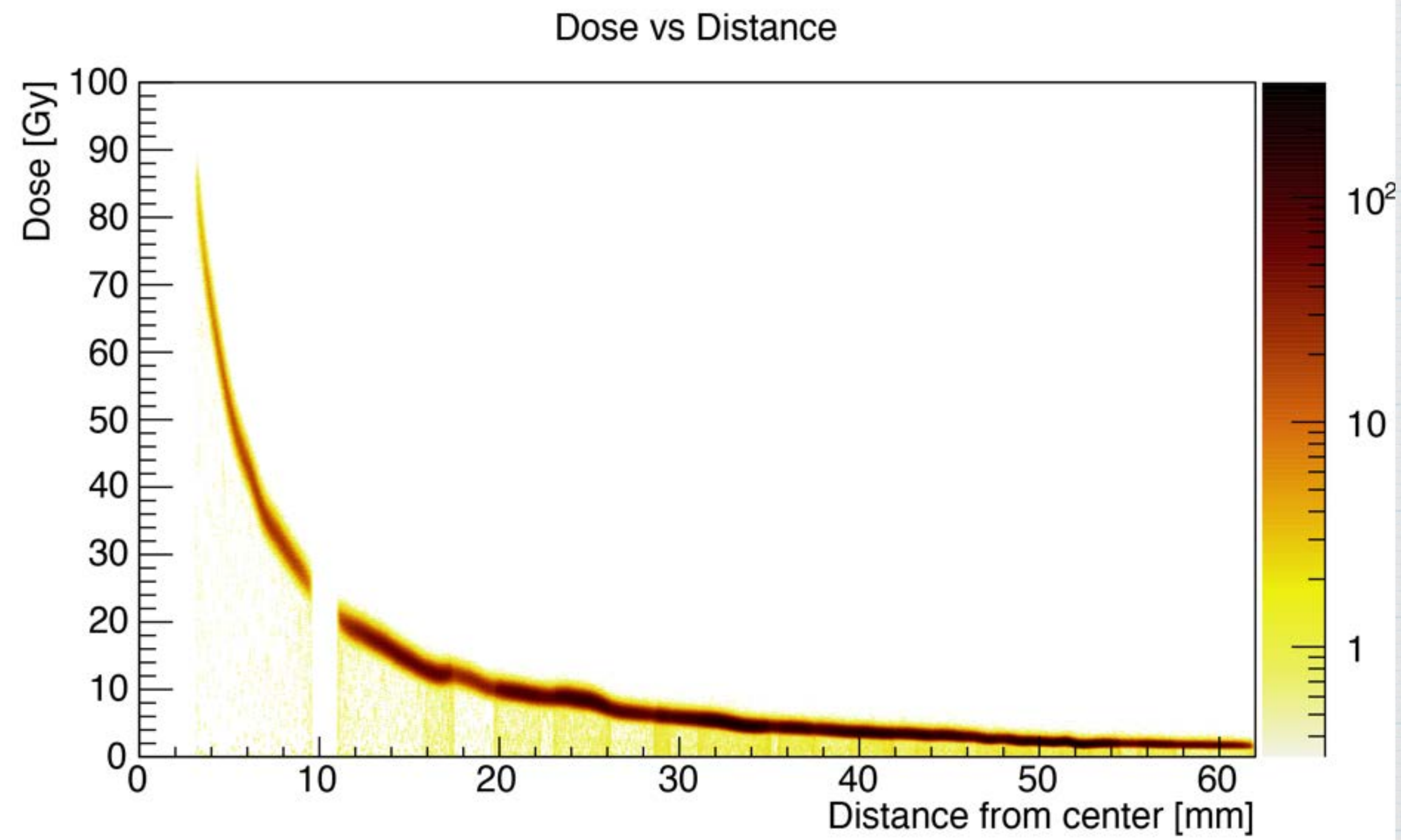
- TNSA (Target Normal Sheath Acceleration)
- Using 0 to 21 degree for θ
- Uniform distribution for φ
- D. Jung et al., New J. of Phys., 2013

96 well plate

- 96 wells plate with cell mono layer
- Plate: 127.7 x 85.48 x 14.6 mm^3
- Well: ϕ 6.39 mm, 9 mm pitch
- Using mono energetic beam obtained with magnets and collimators
  - Need 96 shot
- To obtaining uniform dose for whole plate
  - Only 1 shot

Very wide range of dose





* $20 \times 20 \times 10$ μm mesh
* Position dependence

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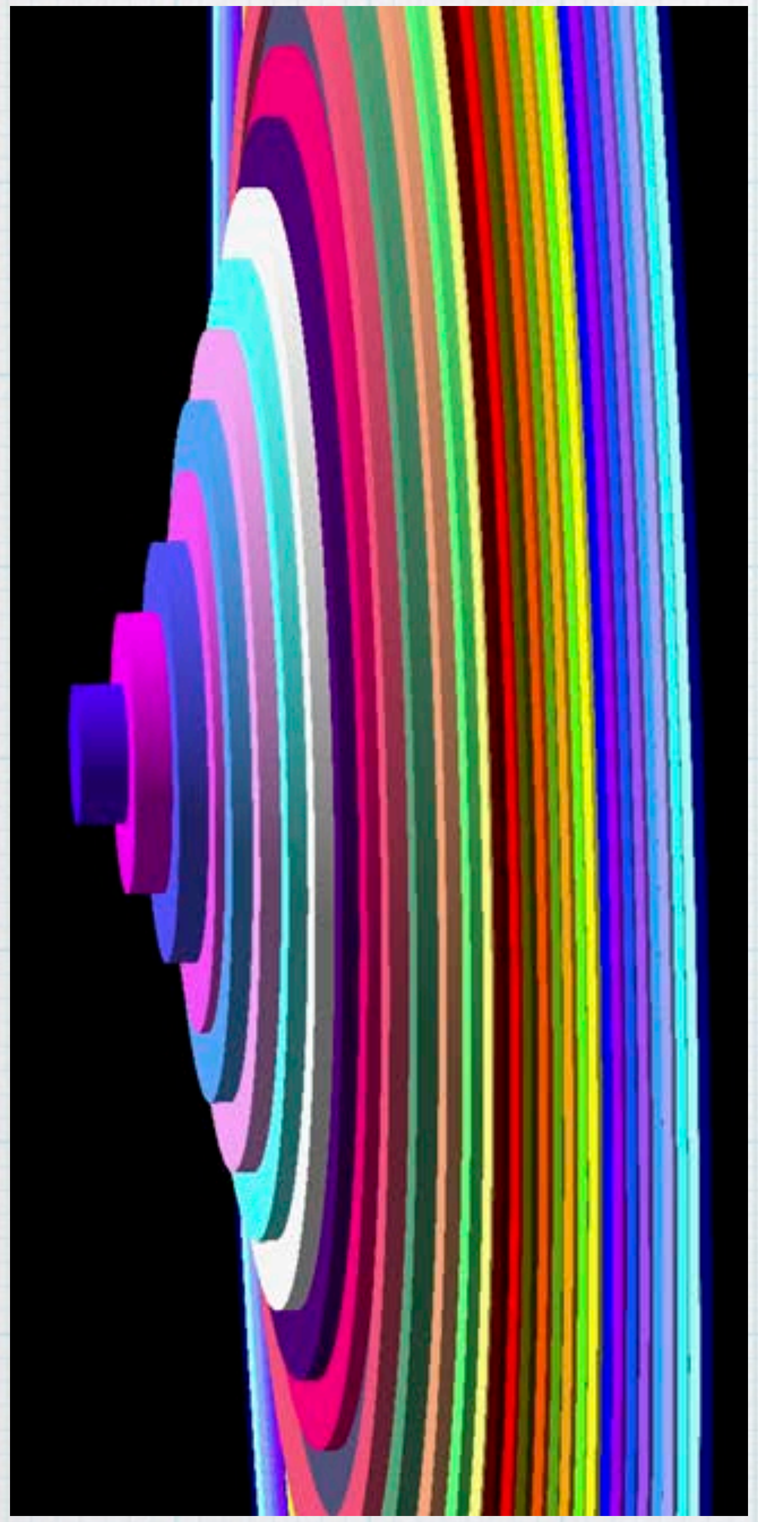
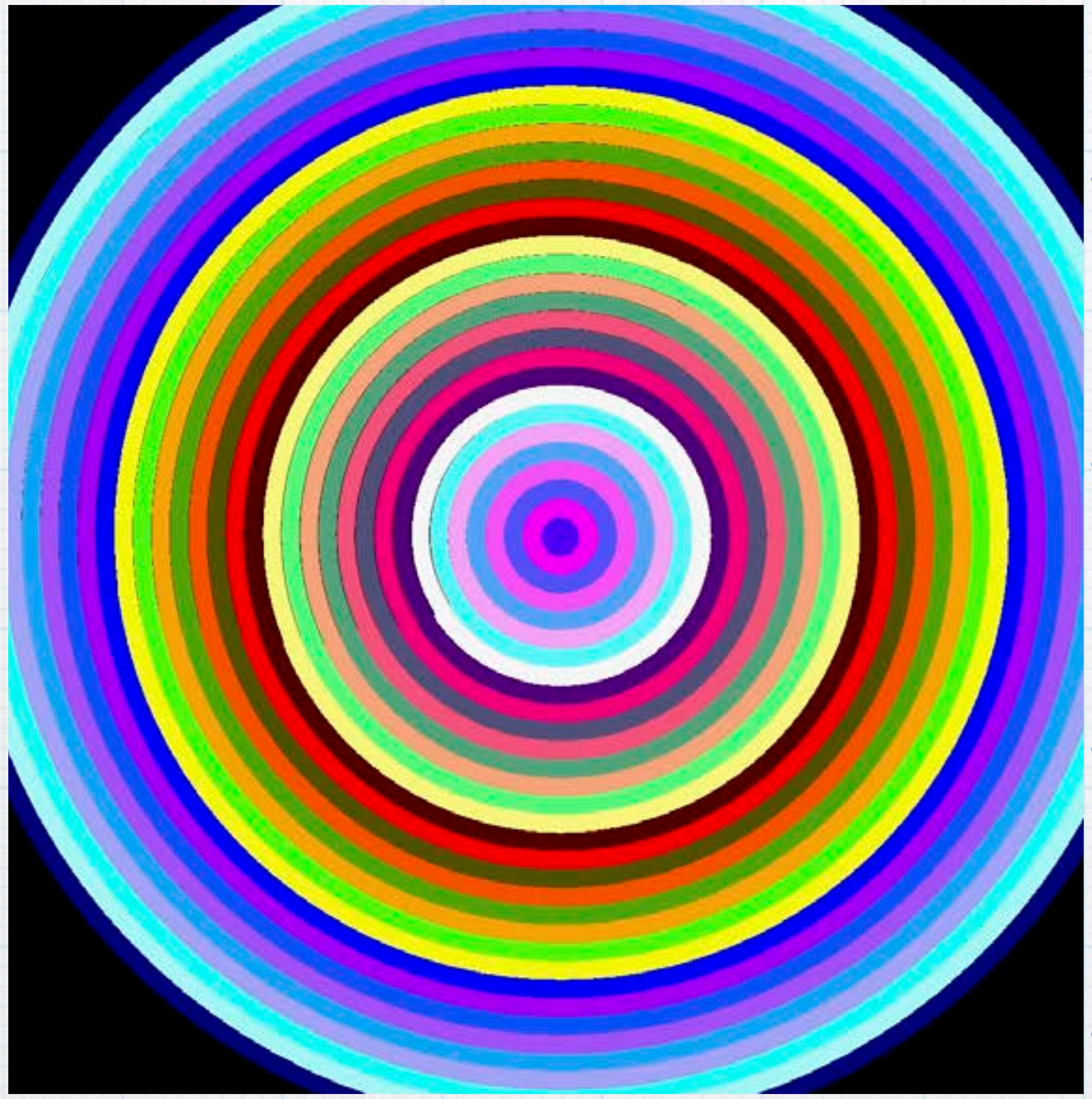
Using attenuator





* Cone shape attenuator
* Ni
* 1mm pitch
* 70 steps
* Determining the thickness

Contents

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* **Why did we need to use Grid**
* Simulation and algorithm
* Conclusion

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Laser and solid target interaction

* 10^{12} protons are generated
* Wide energy range beam
* Difficult to analytical way
* Monte-Carlo simulation

10^{12} ?

* Needs 8000 h by my computer at office (real time)
* Can we scale up 10^9 events to 10^{12}, 8h?
* No!
* At least, 10^{11} events!
* But, Why?

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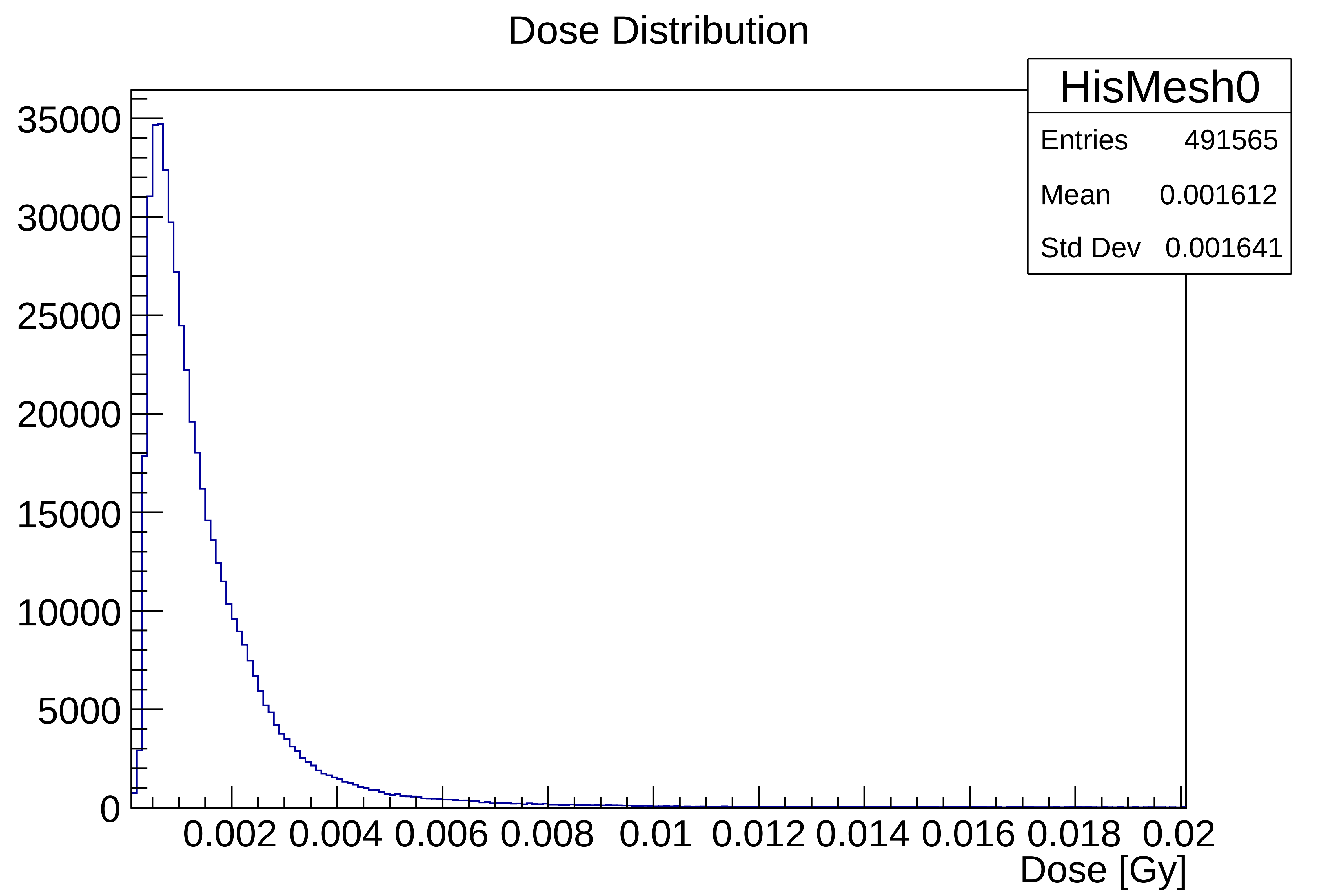
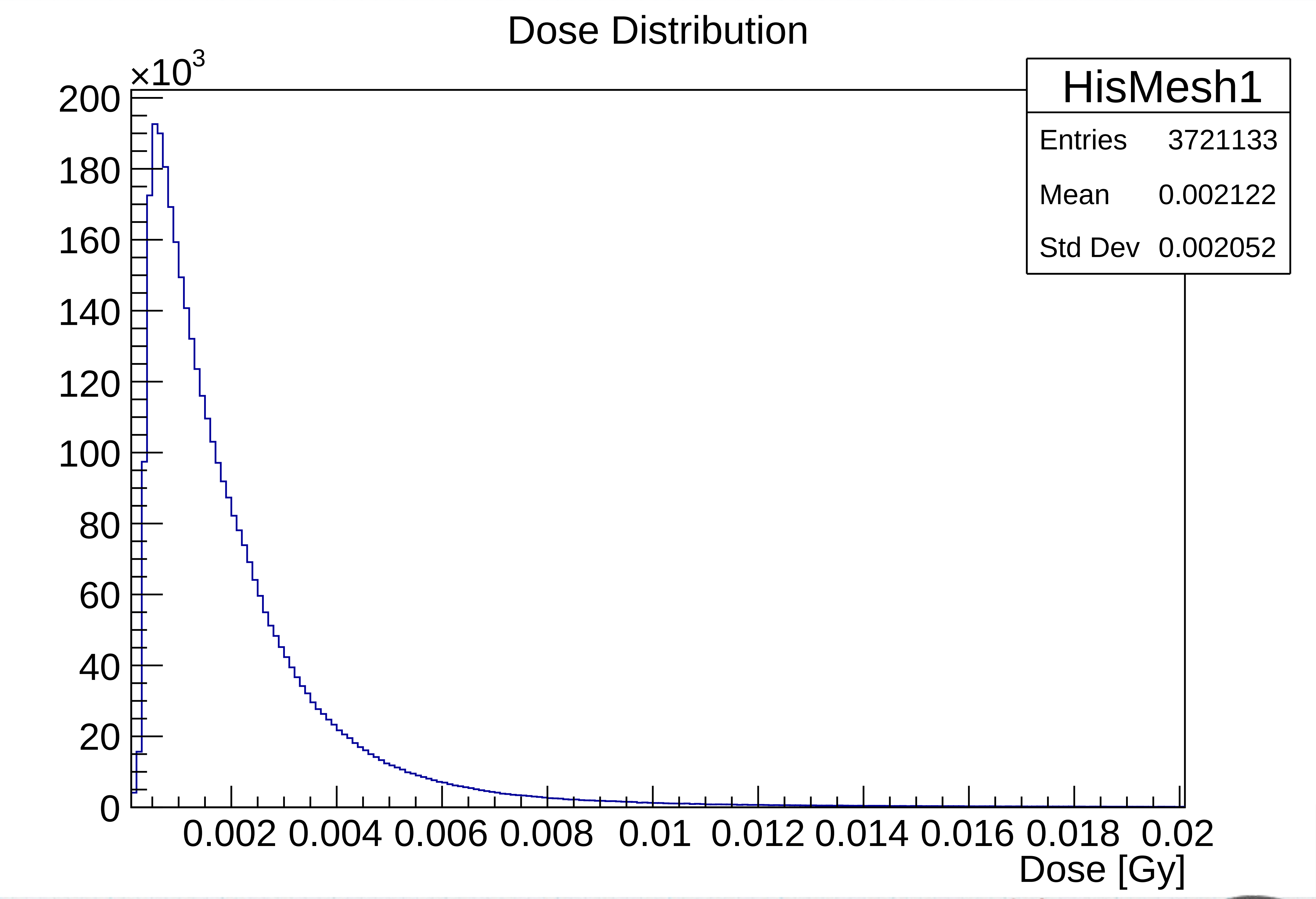
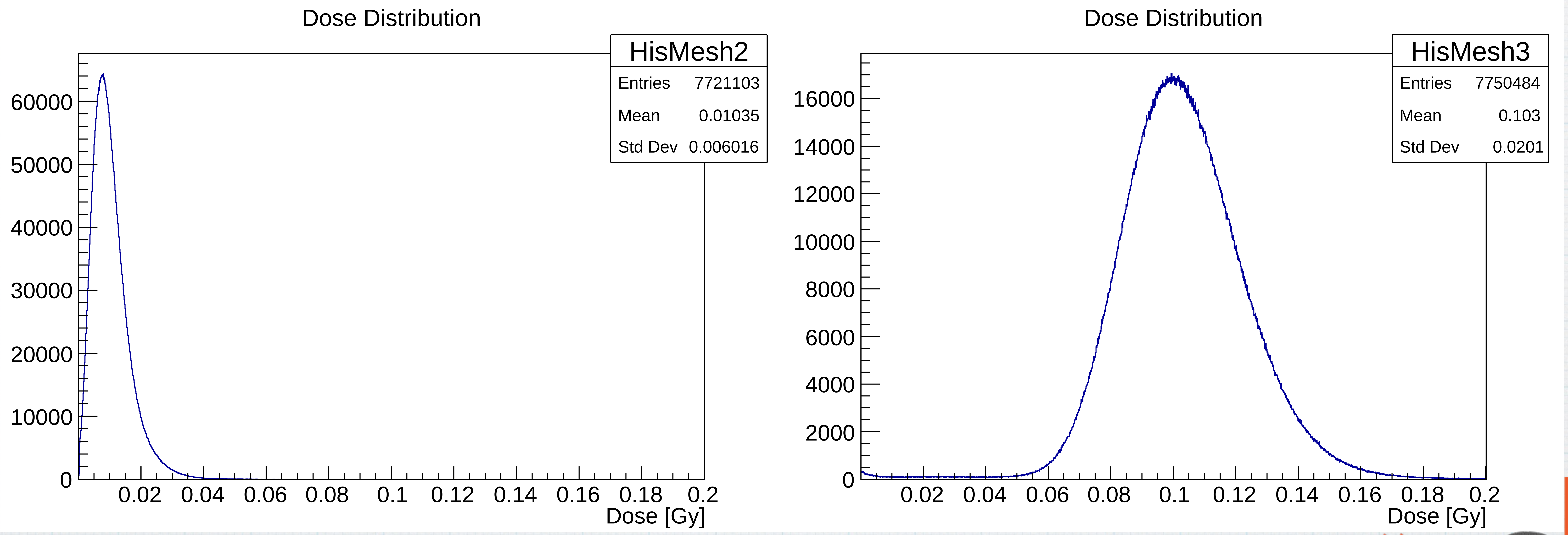
10^8 and 10^9





* Mean is not 10 times large

10^{10} and 10^{11}



- Mean is 10 times large
- We can see the peak separated from 0

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Attention

* In reality, I checked not all wells, only one well
* But, for good statistics, I showed all wells case

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We need at least 10^{11} events

* 800 h?
* Grid!
* Contacting to IT team
* Registering and using Grid

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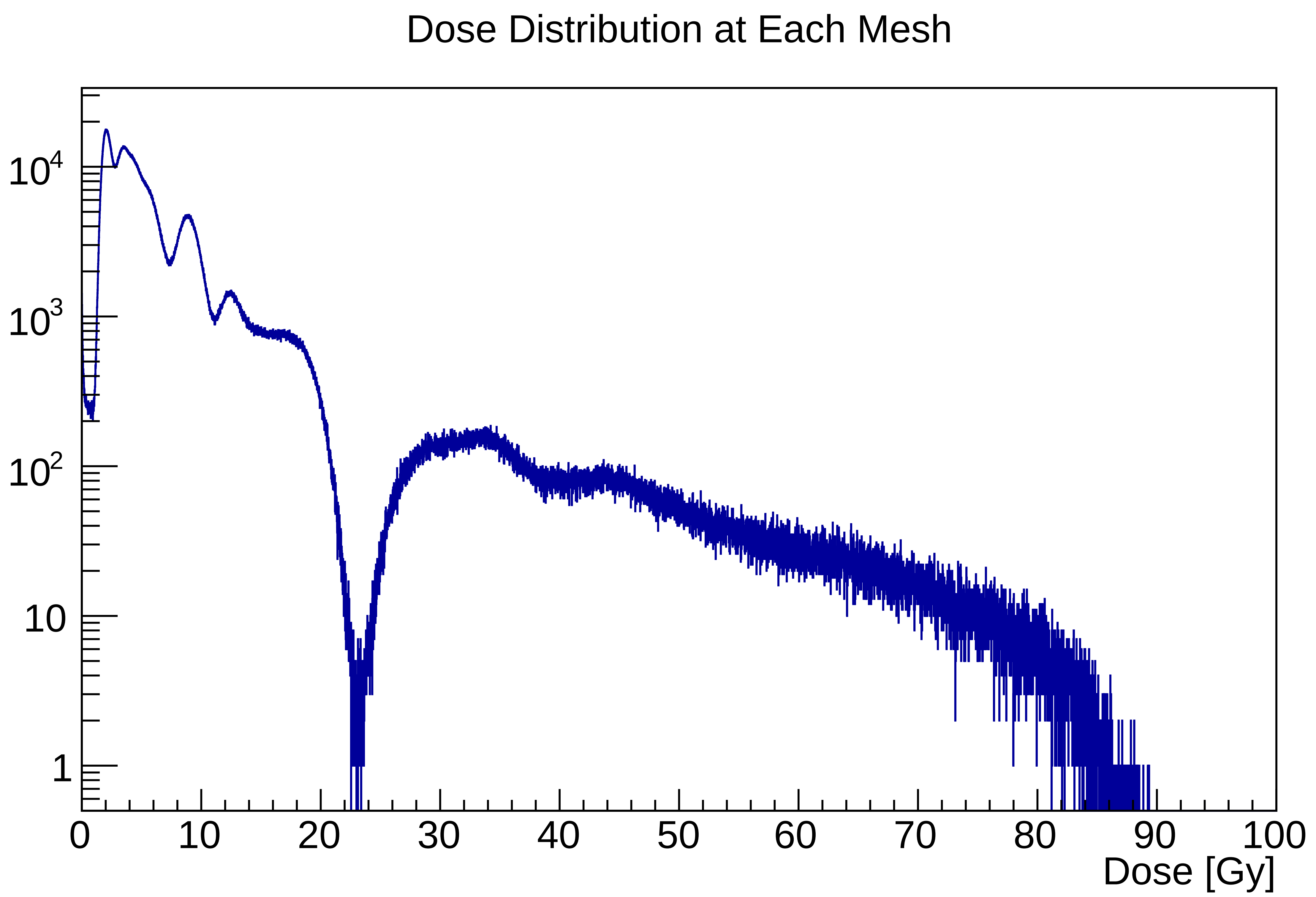
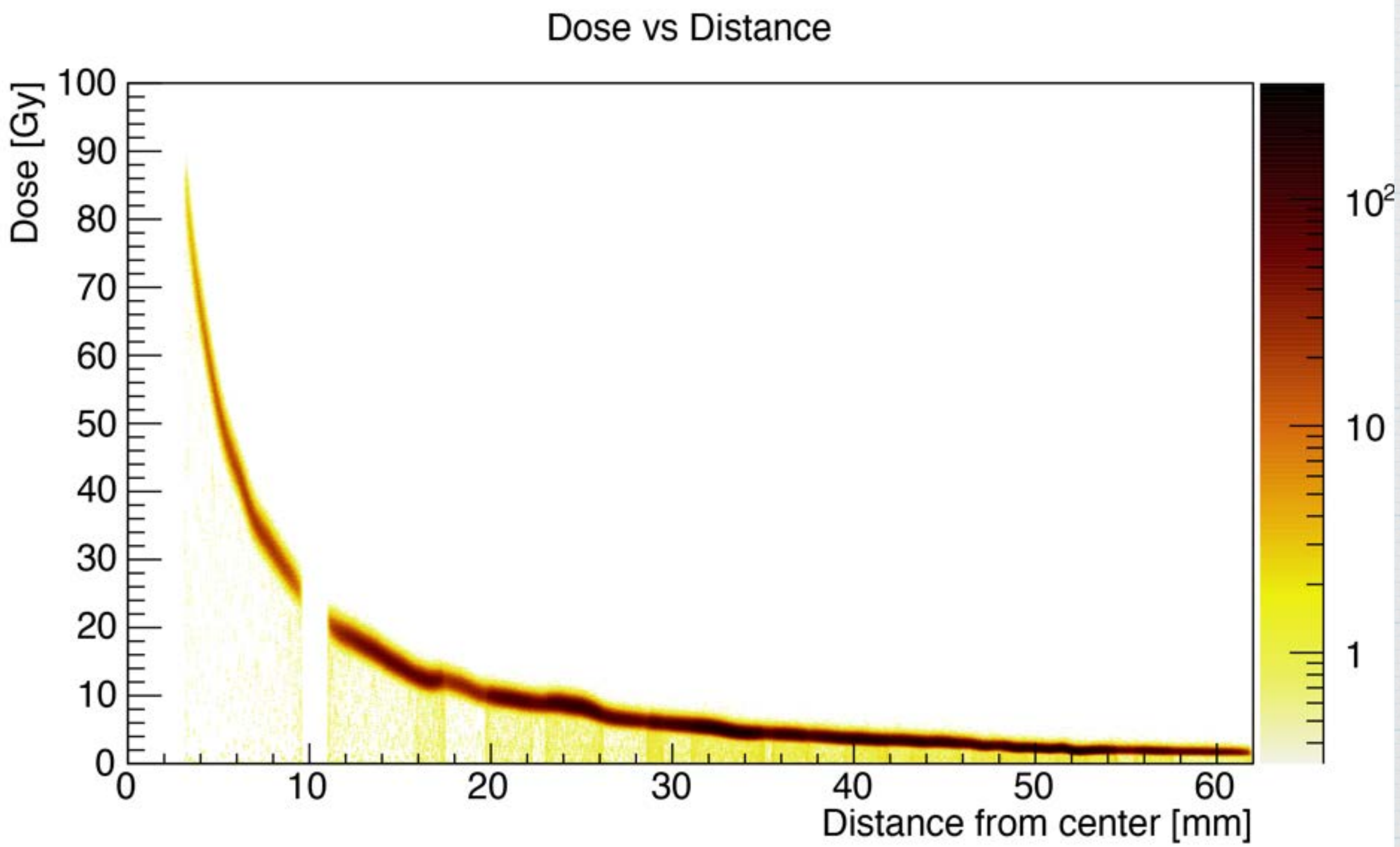
Contents

Nuclear Physics

Strategy





* Make clear peak at left
* Make horizontal flat distribution at right

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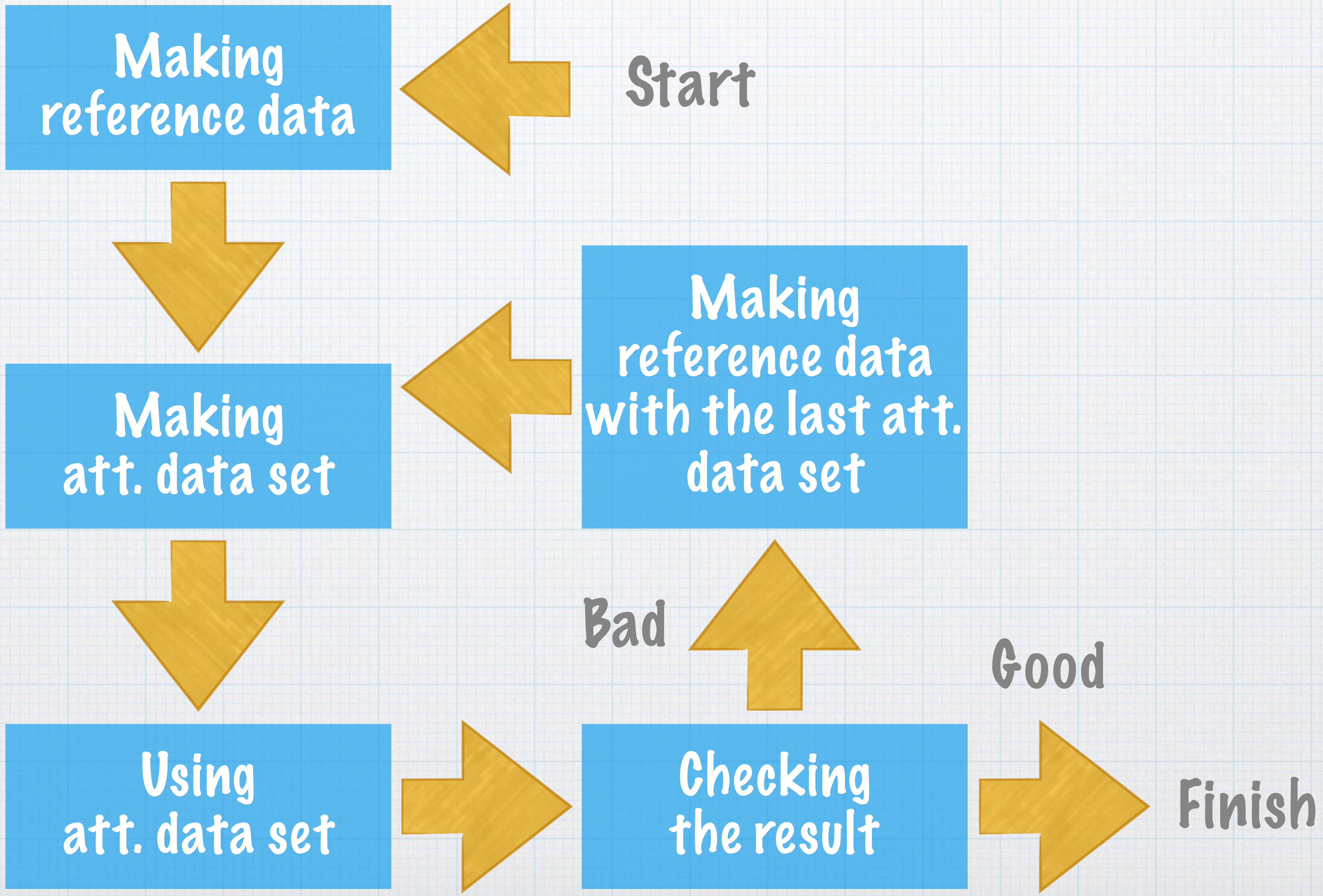
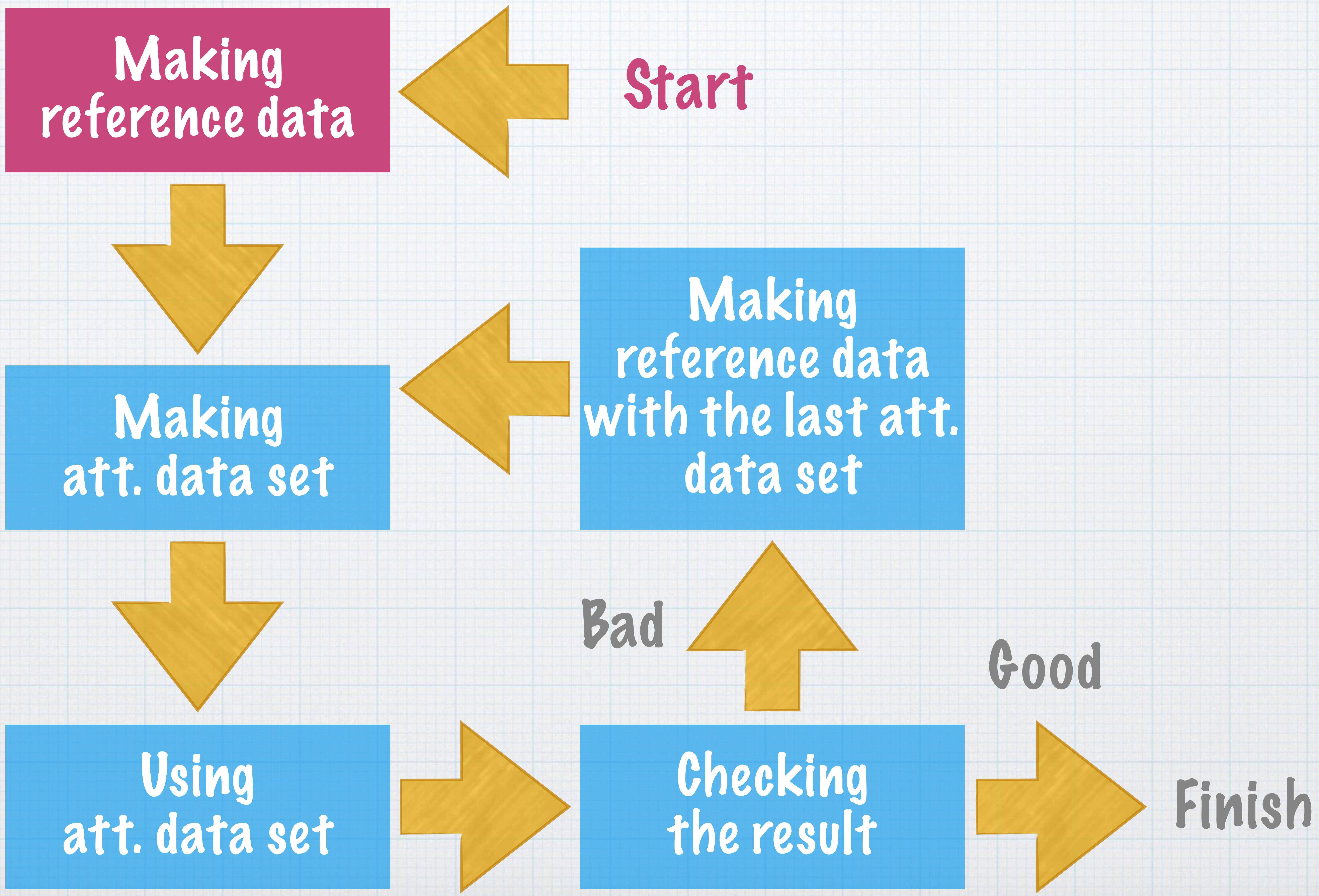
Algorithm


Making reference data
Start
Making reference data with the last att. data set
Making att. data set
Bad
Good
Using att. data set
Checking the result
Finish

Algorithm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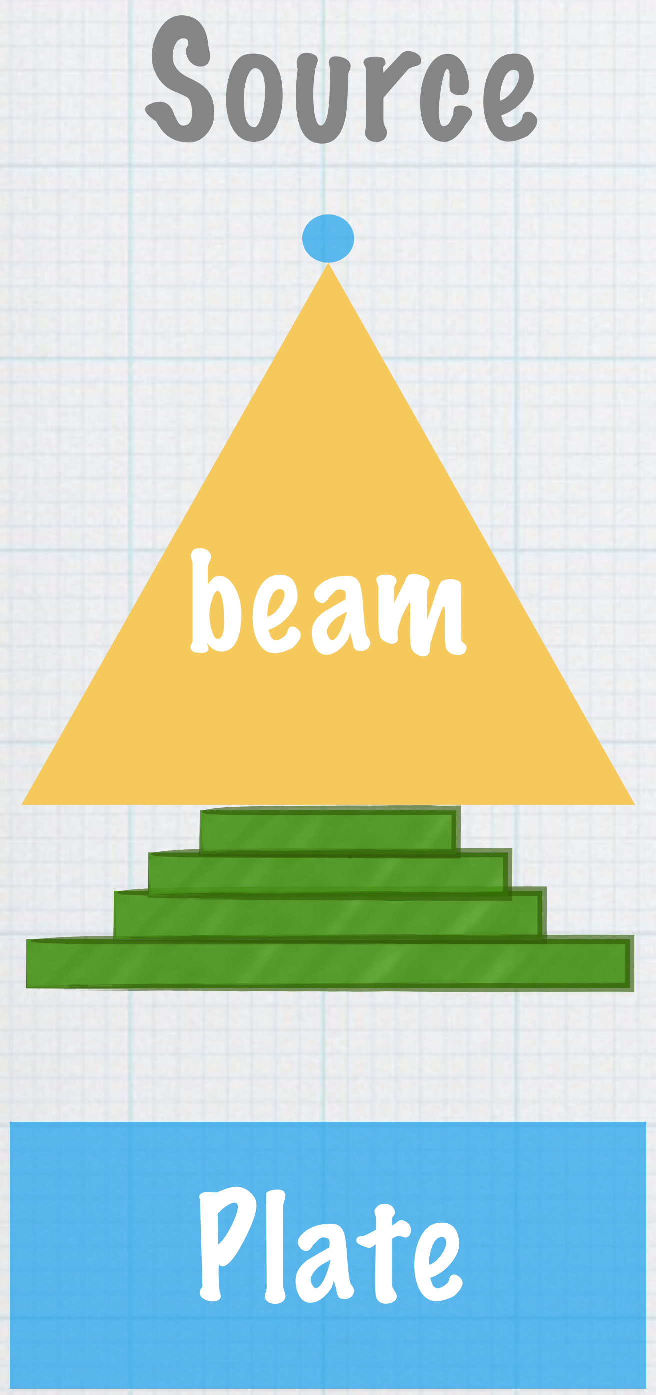
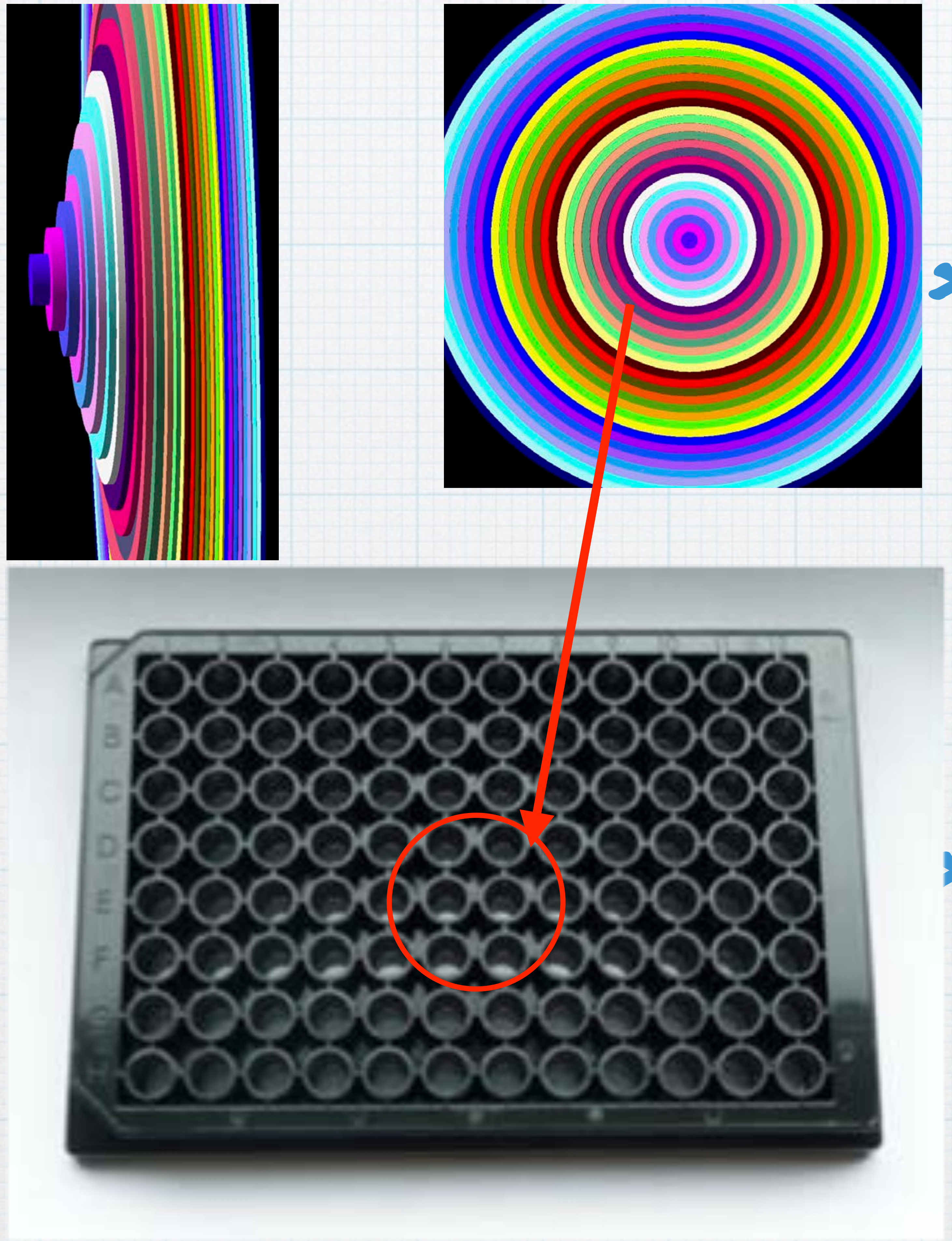
Making reference data





* Each position of attenuator makes projection circle on the plate

* Using this circle

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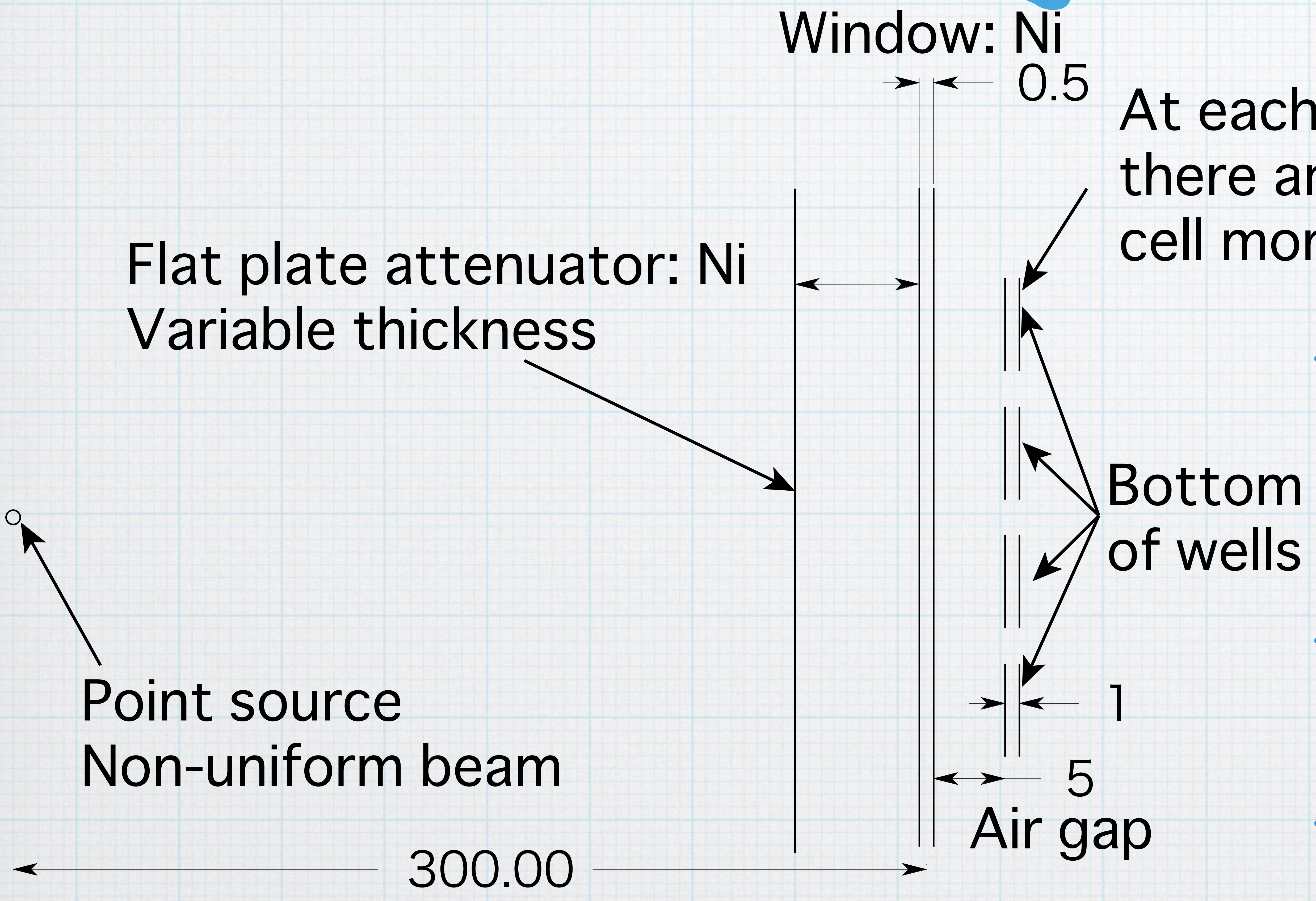
Making reference data



* For simplify, all positions have same thickness
* Not cone attenuator
* Flat plate

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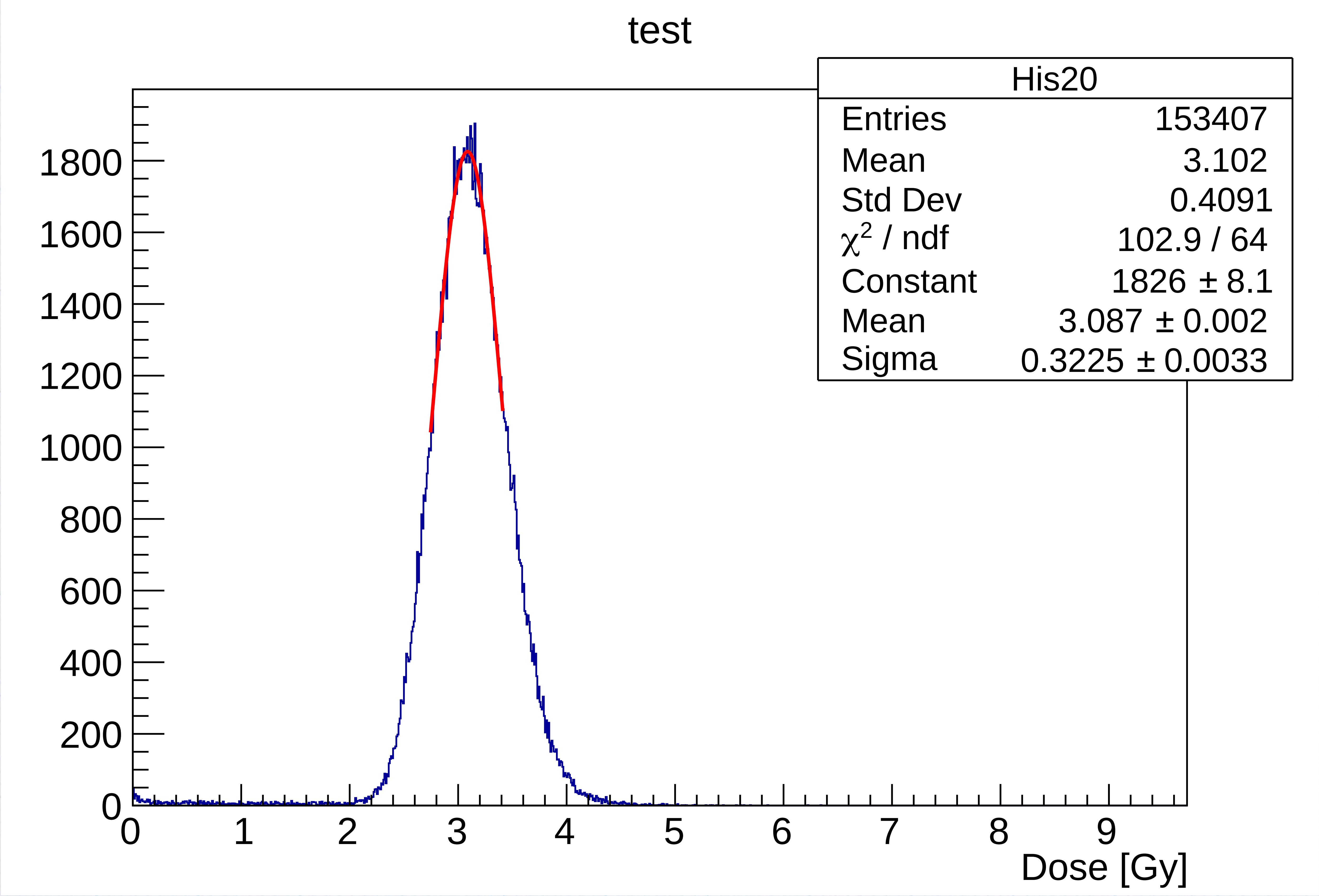
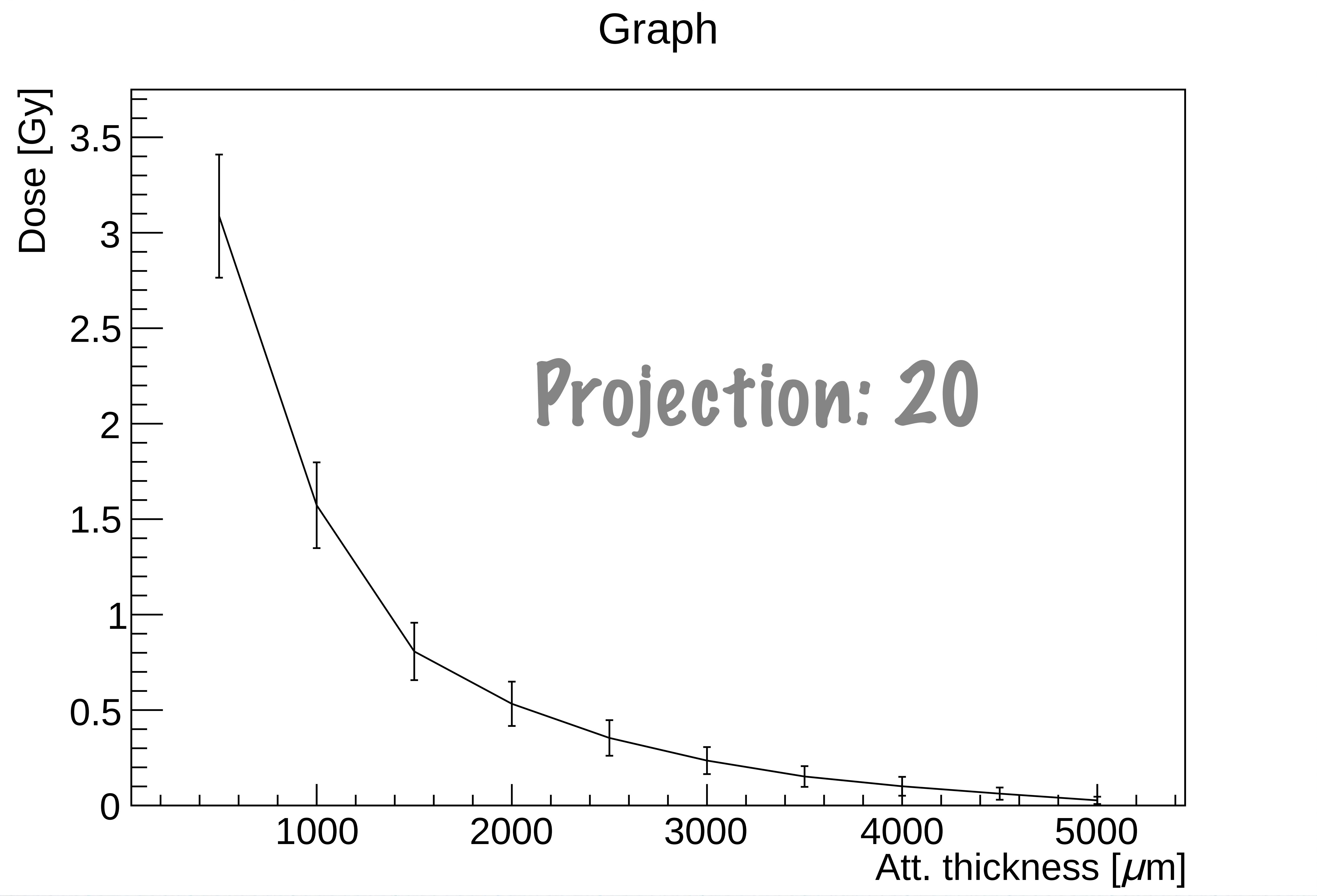
Making reference data



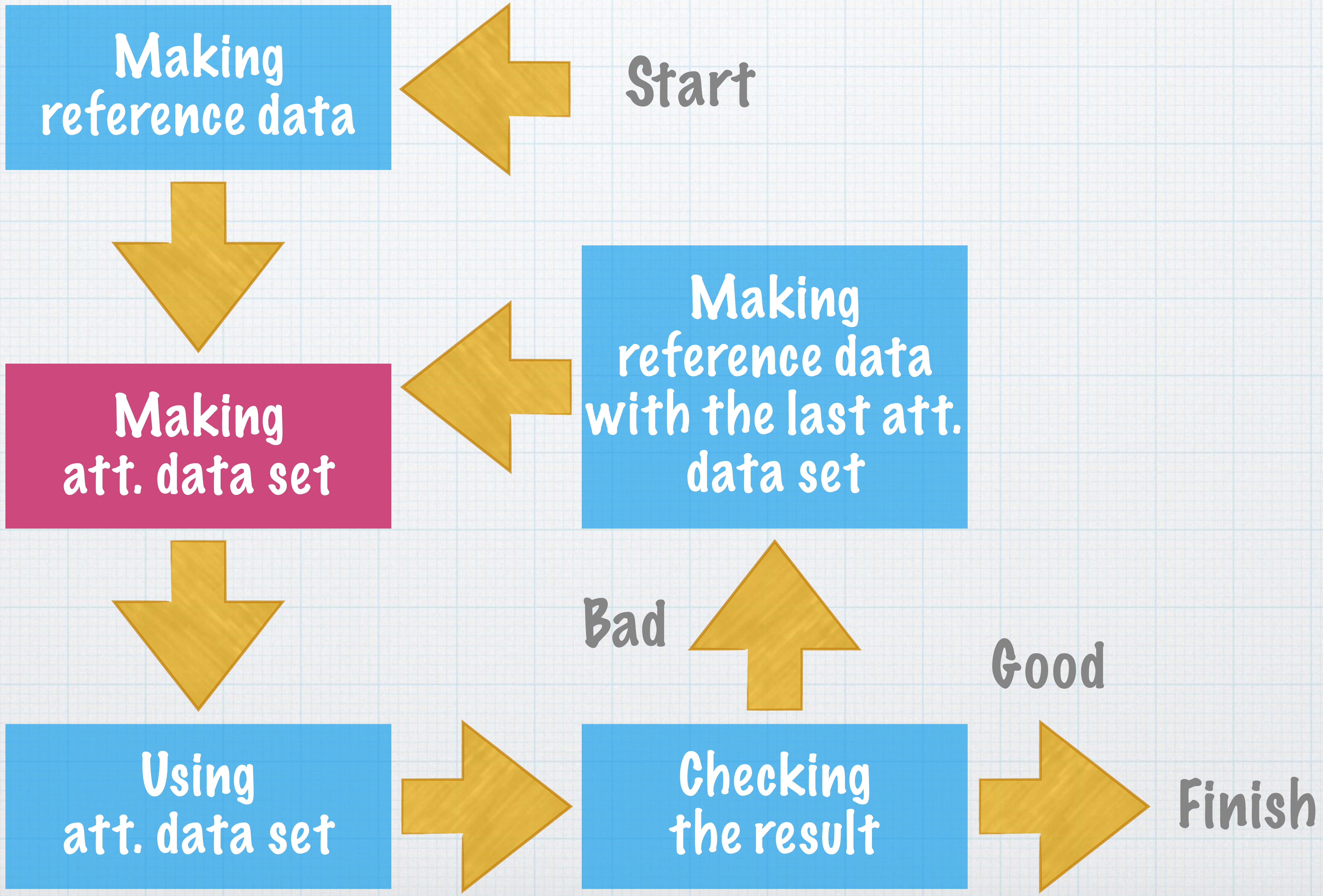
- Projection of 20
- Fitted with Gaussian distribution
- The thickness of att. is 500 μm
- Changing to 5000, with 500 μm step

Making reference data set



* Graph shows Dose vs thickness of att.
* Using this for estimating the thickness of att.
* For obtaining 0.5 Gy, the thickness of att. 20 is about 2200 μm

Algorithm


Making
reference data
Start
Making
att. data set
Making
reference data
with the last att.
data set
Using
att. data set
Bad
Checking
the result
Good
Finish

Making att. data set

Position	Thickness (μm)
11	3047.24
12	2973.98
13	2857.45
14	2733.15
15	2615.66
16	2489.58
17	2428.46
18	2364.78
19	2278.69
20	2184.9

* Determining the thickness of attenuator at each position
* The target dose of this is 0.5 Gy
* Making some att. data sets with various target doses

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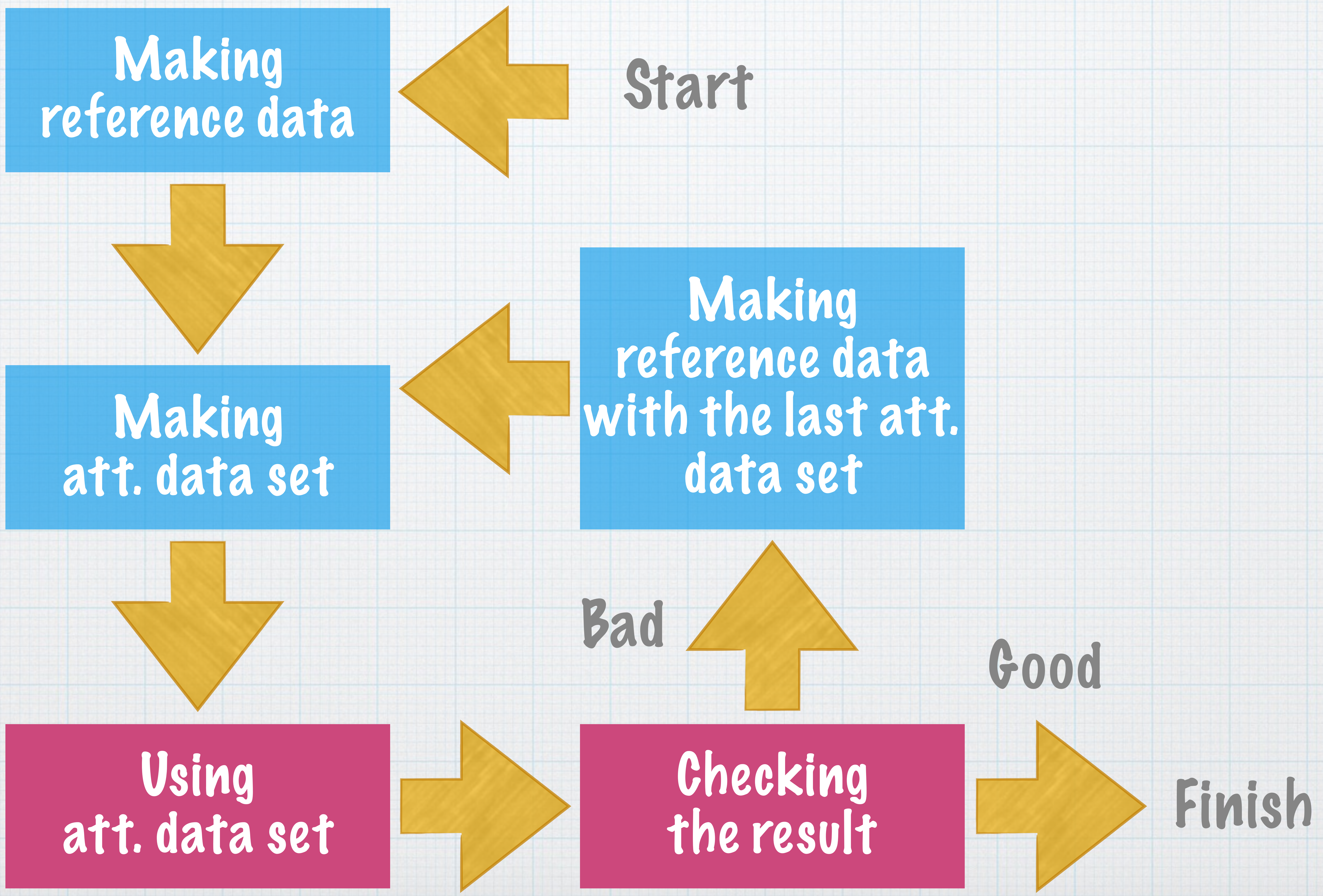
Algorithm


Making
reference data
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att. data set
Making
reference data
with the last att.
data set
Bad
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att. data set
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the result
Finish

Checking the result

* Due to the difference of flat panel and cone shape
* The result has not good uniformity
* Now, we have results of various target doses
* Using those are next reference data

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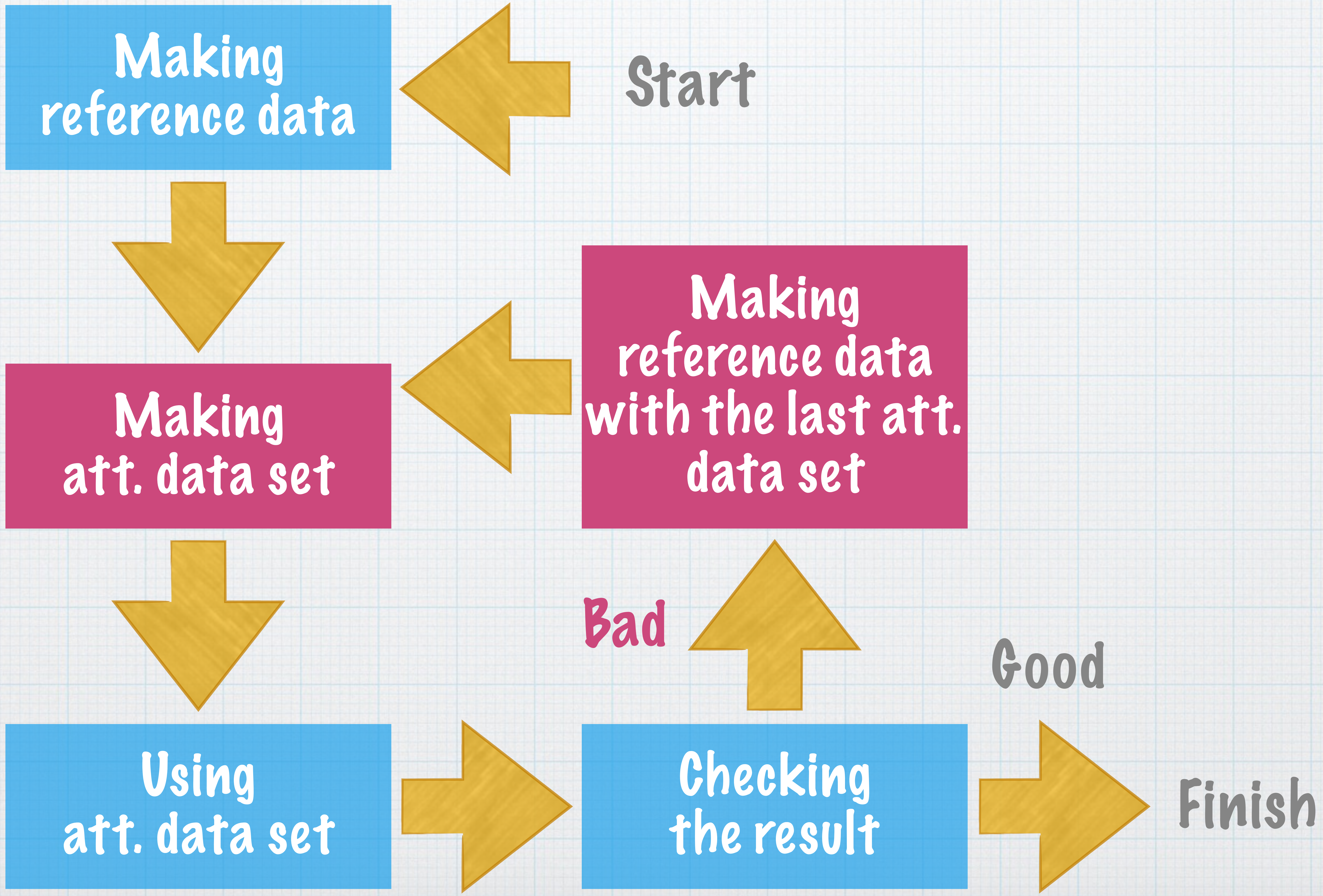
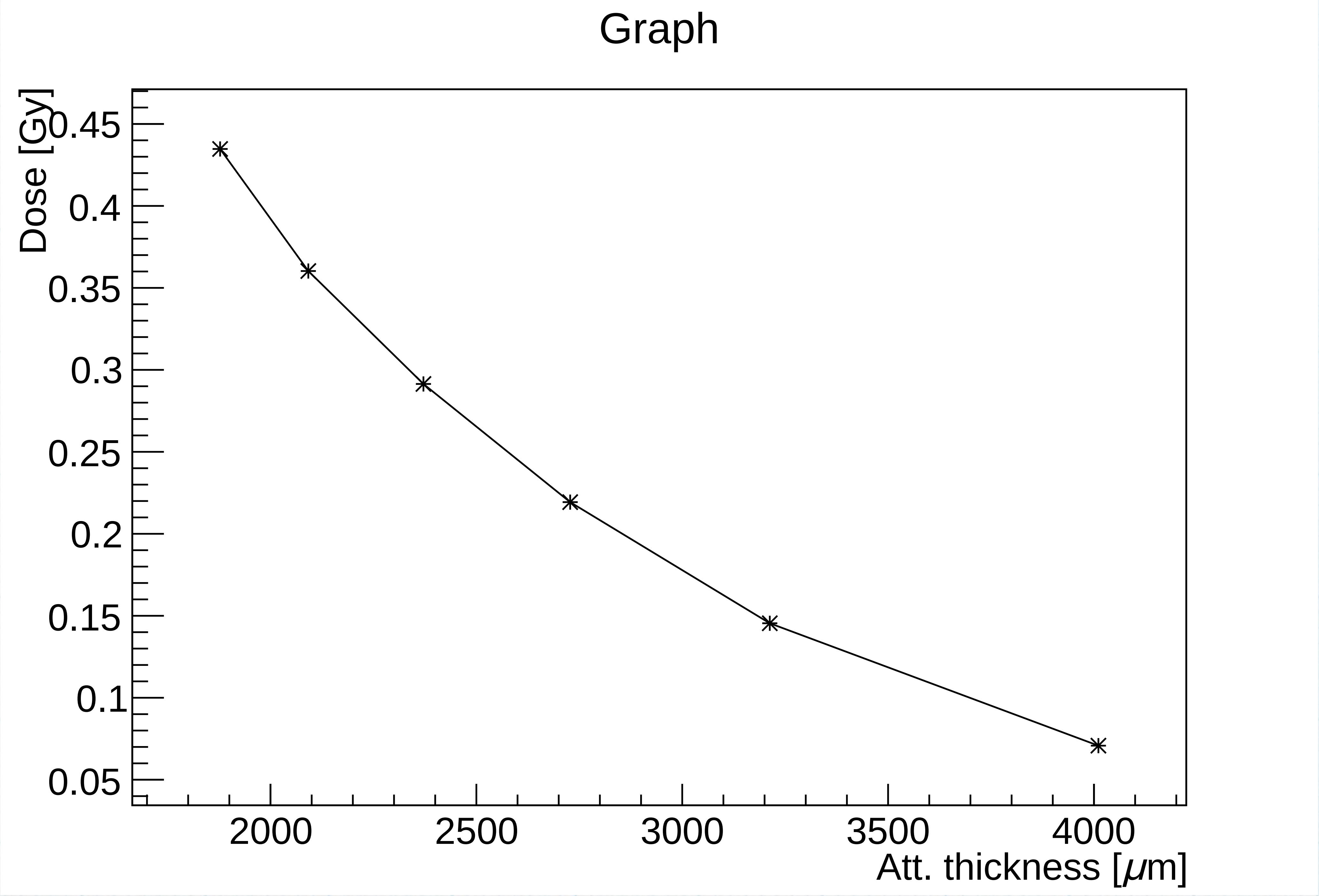
Algorithm


Making reference data
Start
Making reference data with the last att. data set
Making att. data set
Bad
Good
Using att. data set
Checking the result
Finish

Projection: 20



* Using this and make again
* Now, target dose is 0.2 Gy
* Reason
    * I lost the data...

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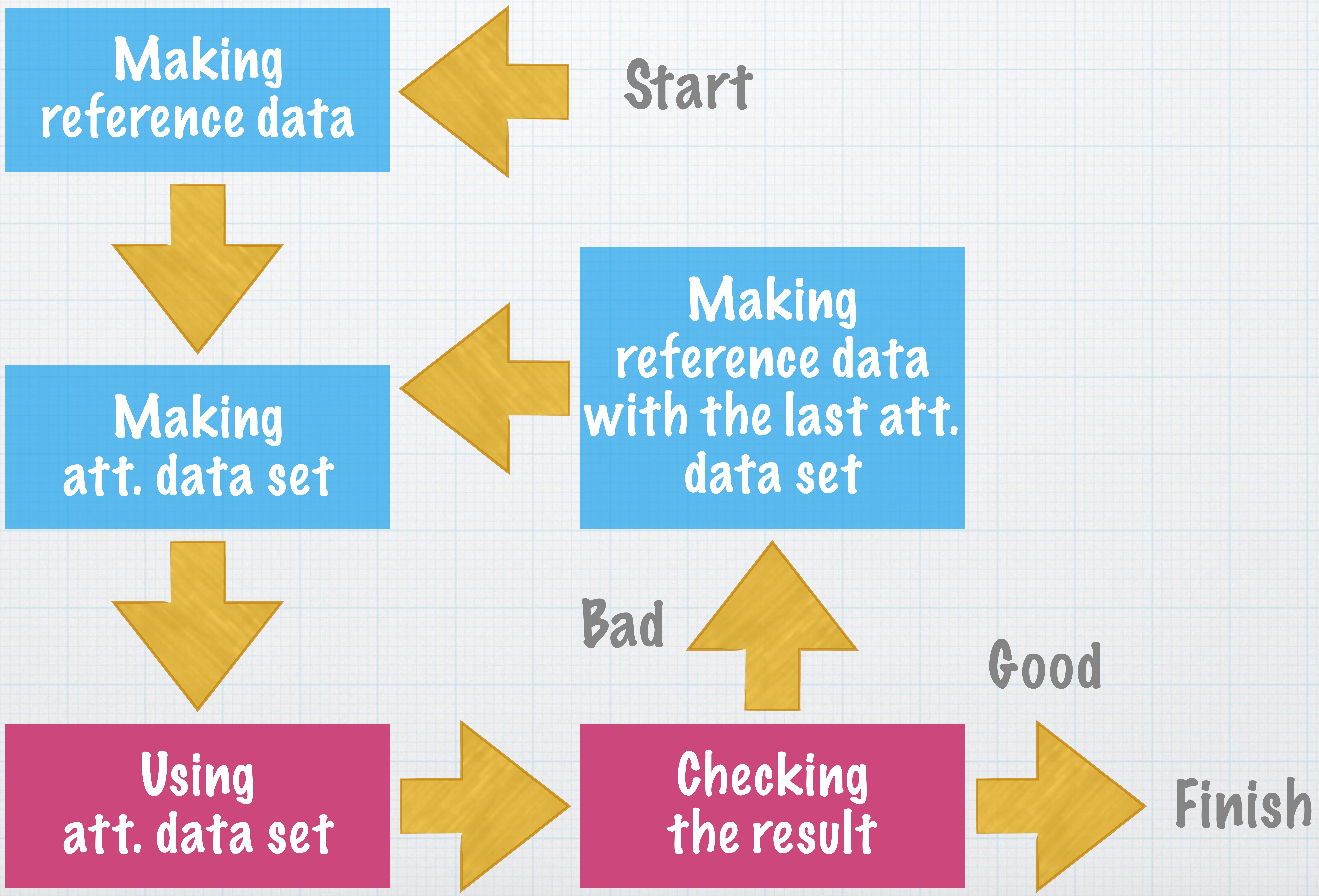
Algorithm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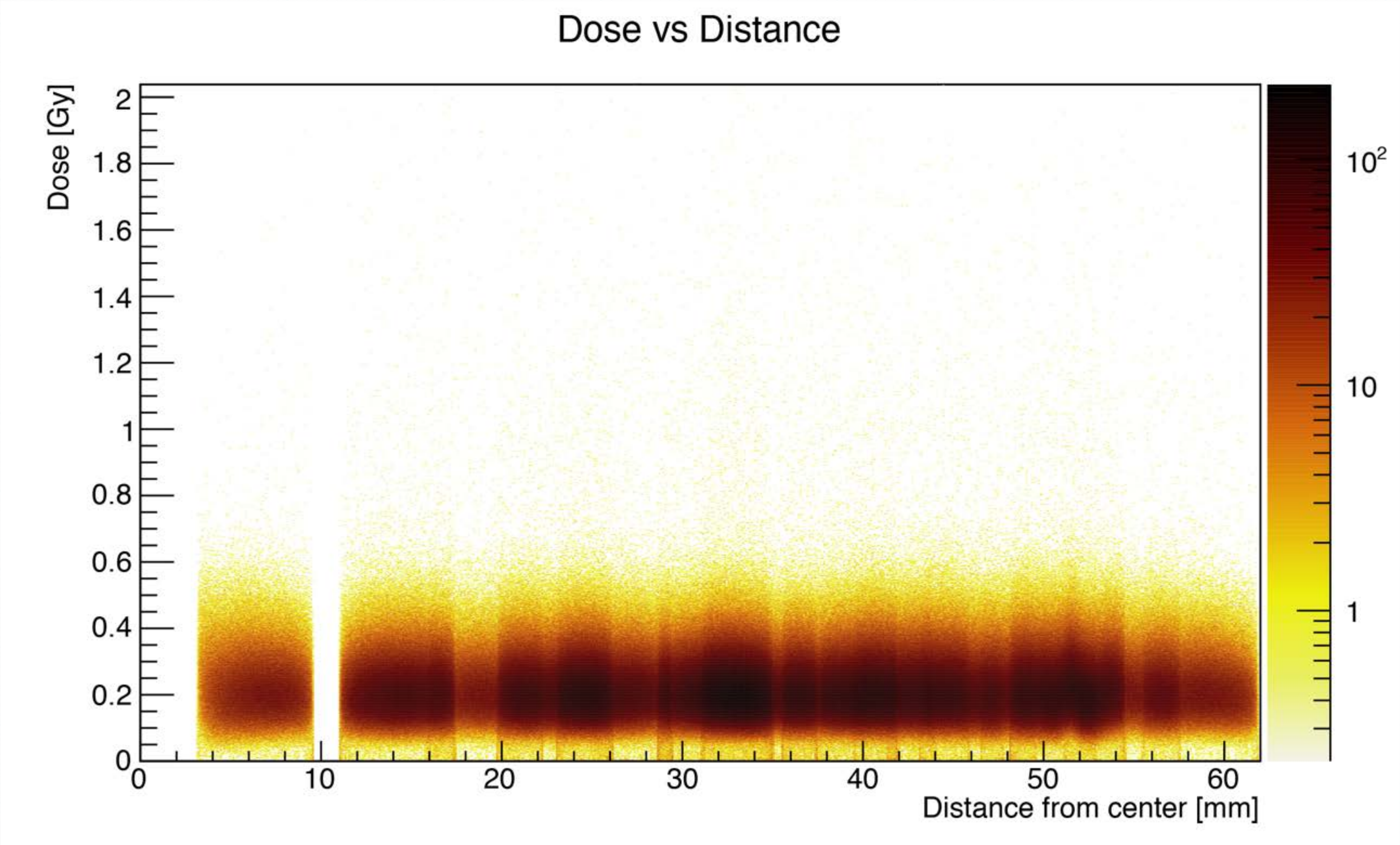
Checking the result
Finish

Good!



- Dose VS DIS 0.2 Gy

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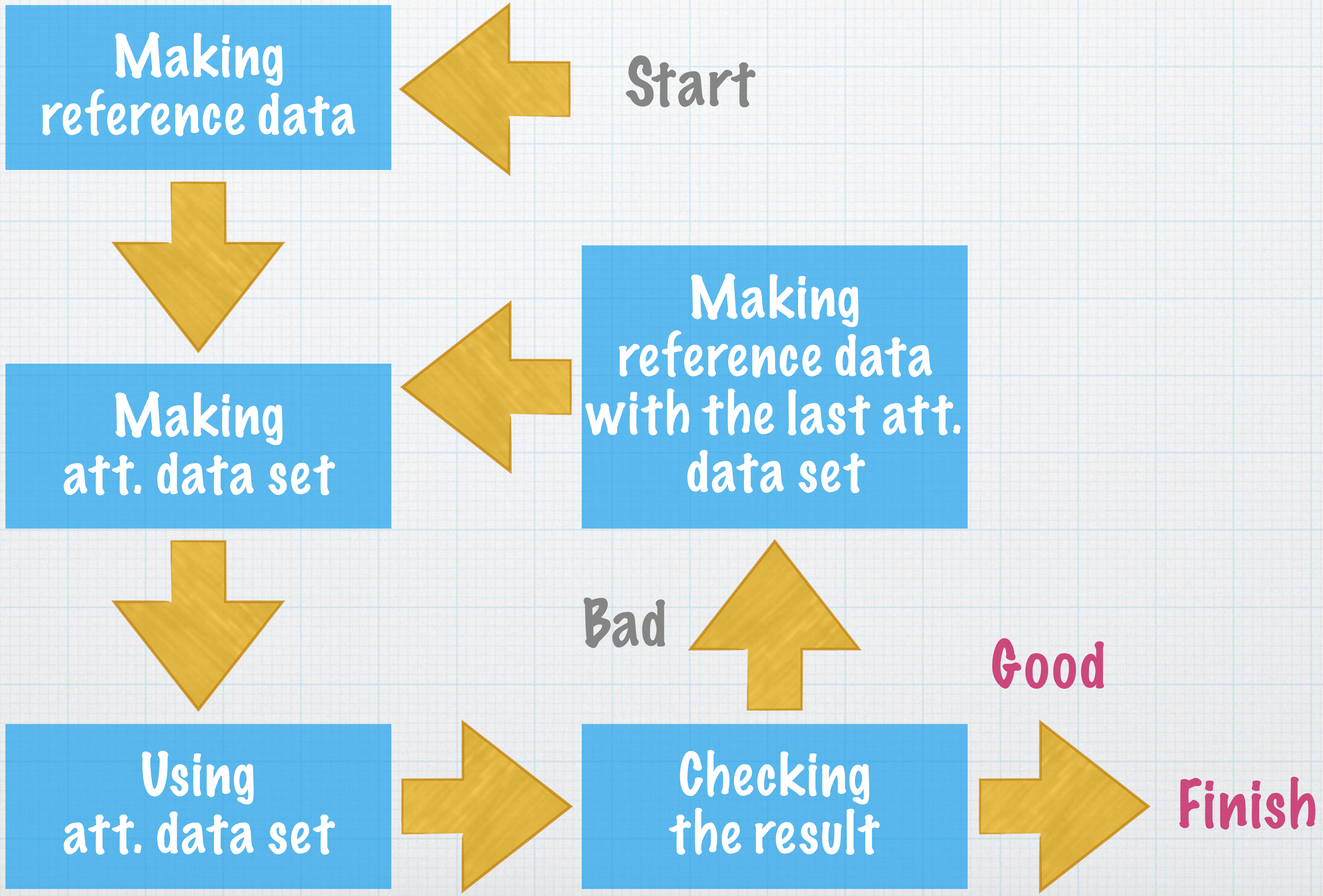
Algorithm


Making reference data
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Bad
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Finish

Contents

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Conclusion

* Not only proton
  * TNSA generates electron, gamma-ray, ions
* Particle In Cell (PIC) simulation
* We, ELI-NP, will use more and more computer resources

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Thank you for your attention

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