Background studies at ATHENA

Yuri Fisyak

Outline

- My neutron's story
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- ATHENA
  - Why ?
  - How ?
  - What ?
- Questions ?

My neutron's story

- The story has started during preparation of "GEM Technical Design Report" (https://lss.fnal.gov/archive/other/ssc/ssc-gem-tn-93-262.pdf) early 1992:
  - In "GEM Letter of Intent" (https://lss.fnal.gov/archive/other/ssc/sscl-sr-1184.pdf) it has been proposed a forward calorimeter with high η coverage (John Rutherford, University of Arizona, et al.). The GEM tracker group was worried that this design would keep background particles, and especially neutrons, within the Central Tracker volume and would cause additional radiation damage of Silicon detectors.
  - Los Alamos group using software for calorimeters (calor89) and reactors (nucleon-meson transport code, NMTC, low energy neutron MICAP) made calculations. There were two answers from these calculations:
    - The forward calorimeter would increase radiation damage of the tracker by 30-50%, but
    - the main background would be in the Muon system due to neutrons which would fill up whole GEM cavern and create background hits in large muon chamber detector elements via to knock out proton from hydrogen containing materials and due to (n,γ) reaction.
- Thus the main task became: How to design shielding for the muon system ?
- The reactor codes did no allow us to do this because:
  - The codes did not allow to describe high energy part of interactions, and
  - The codes did not have particle transport with magnetic field.
- John Rutherford has proposed to merge calor89, MICAP with GEANT3 which used FLUKA for high energy interaction. John found Christian Zeitnitz to do this task.
- **Christian Zeitnitz** made this merge and created **gcalor** in 1992 (http://www.atlas.uni-wuppertal.de/zeitnitz/gcalor). This version first of all has been used for GEM and SDC detectors. I believe that the latest update he has made in 2005.
- Since that I have used **gcalor** codes for GEM, CMS, ATLAS, D0, HERA-B, and STAR.

STAR

Oleg Tsai (2013) expressed a worry about behavior of SiPM for Forward PreSower (FPS) which was planned to install in STAR in Run 2015 due to radiation and especially neutron background:

neutrons with kinetic energy in range 0.1 – 1.0 MeV could destroy the silicon crystal structure,

the thermal neutrons could destroy silicon nuclei, and

Both effects would increase dark current.

The question was what is background conditions at location of FPS SiPM ?

We can calculate the background using gcalor. But again, the question is : Can we trust them ?

We found out that Graham Smith (Instrumentation Division) has the He_3 calibrated thermal neutron detector.

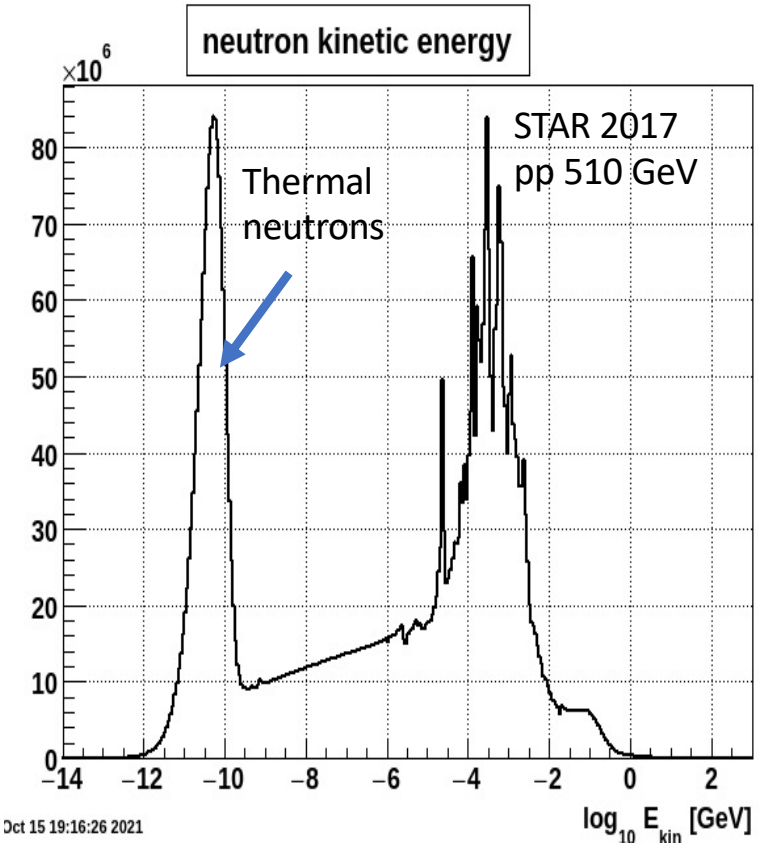
Then proposal was

- To measure the thermal neutron flux at different STAR WAH positions,
- To compare gcalor calculation for the thermal neutron flux with the measurements, and
- To this "calibration" to estimate flux for most damaging energy range 0.1 – 1.0 MeV.

The measurements and calculations have been done in Run 2013 (https://www.star.bnl.gov/~fisyak/star/Flux/2013_2014.html).

It was found that the agreement is pretty good (within 30%, except two locations where difference is a factor of 2) and published as *Nucl. Instrum. Meth.A* 756 (2014) 68-72 (https://inspirehep.net/files/0a41f10df2027dd4962531d6117990c7).

After FPS has installed Oleg Tsai made a dark current measurements which confirmed the results of the calculations (https://www.star.bnl.gov/~fisyak/star/Flux/2015/)



ATHENA.

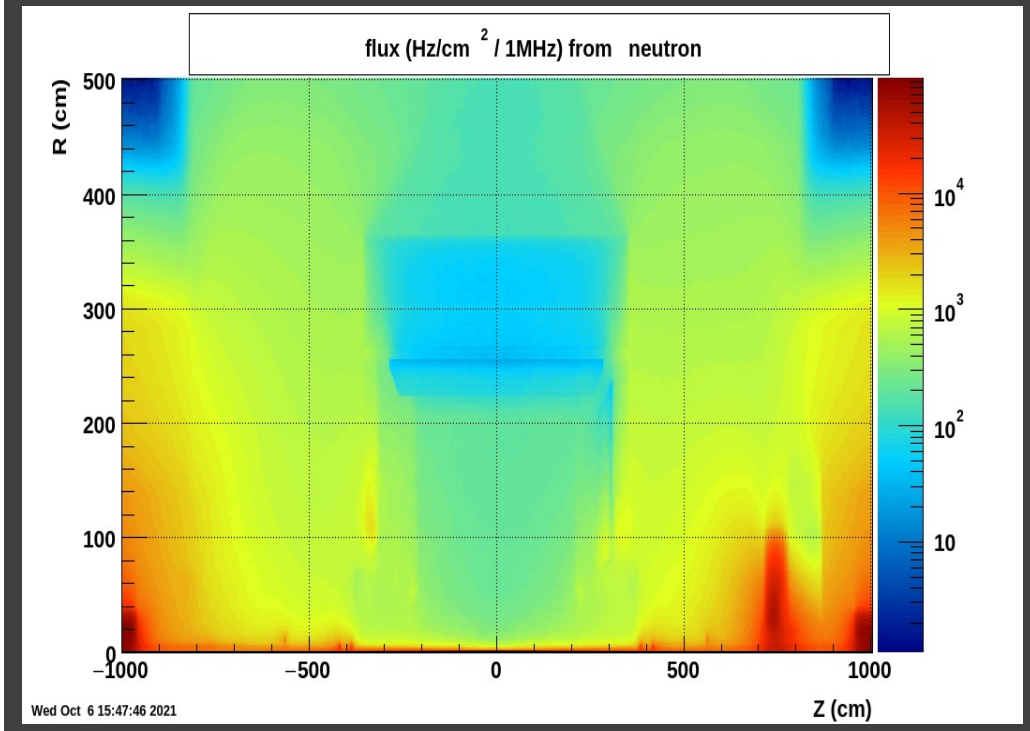
- Why ?
  - Elke-Caroline Aschenauer (09/24/2021) has asked me to repeat the above STAR exercise with neutron flux for ATHENA.
- How ?
  - Obstacles:
    - We have to keep in mind that there is an assumption that the main source of radiation is primary beam-beam interaction. It is assumed that the beam halo, beam-pipe and beam-gas interactions are on the level below 10% from beam-beam one. This assumption is strongly depended on accelerator and interaction region design.
    - For electron machine the importance sources of background are photo absorption processes. I don't know how well these processes are described by simulation.
    - For STAR 2013 exercise we used geant3+gcalor. I have ATHENA geometry only in VMC (TGeo) format. We have to switch from geant3 to VMC simulation.
    - For neutron background calculation is important to have geometry description of whole experimental cavern, including walls. The effect of walls could be up to factor of 2 for low energy neutrons. We have used this description for STAR simulation. ATHENA does have it.
    - …
  - Proposed way to solve them in 4 steps:
    - Repeat the same background simulation with geant3+gcalor (the same software as used for the NIM paper) for STAR Run 2017 geometry (**pp2017_510GeVB**),
    - For the same 2017 geometry converted to VMC use VMC+gcalor simulation (**pp2017_510GeV_gcalorC**),
    - For ATHENA geometry with STAR magnetic field and VMC+gcalor simulation for pp 510 GeV (**pp510GeV_AthenagcalorB)**, and
    - For ATHENA geometry with ATHANA magnetic field and ep18x255 kinematics and primary vertex σ_Z = 11 cm (**epAthena**).
    - Compare results (https://www.star.bnl.gov/~fisyak/star/Flux_2017_ATHENA/) of these steps and reiterate.

A few comments

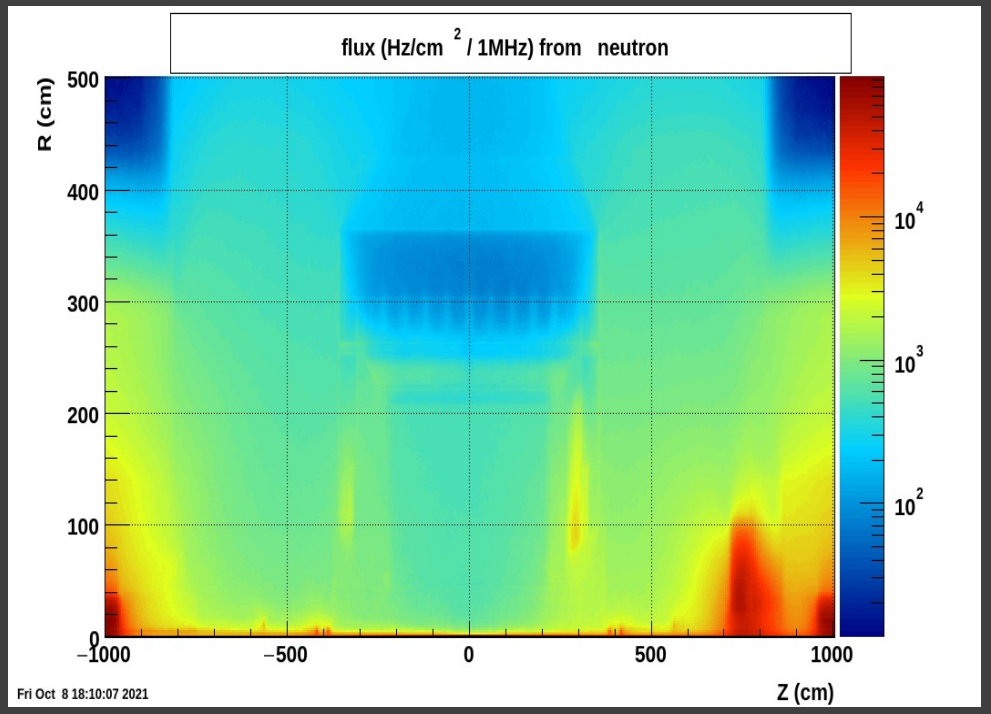
- One definition: flux = Sum of particle lengths in a given Volume divide by the Volume.
- Below all fluxes are normalized on inelastic event rate 1 MHz. At ATHENA expected rate is 0.5 MHz. (The STAR 2013 pp 510 GeV rate is ~ 10 MHz). Thus, all fluxes presented below for ATHENA should be scaled down by a factor of 2 (and for STAR scaled up by a factor of 10).
- The integrated dose estimations is based on EIC run time 30 weeks per year ($1.8e^7$ seconds), RHIC – 16 weeks per year ($1e^7$ seconds).
- I assume rather old number for critical neutron (0.1 – 1.0 MeV) integrated fluence 10^9-10^{10} (cm^{-2}).

ATHENA, What ? Neuron flux: STAR geant3 and VMC

STAR 2017 pp 510 GeV, geant3+gcalor



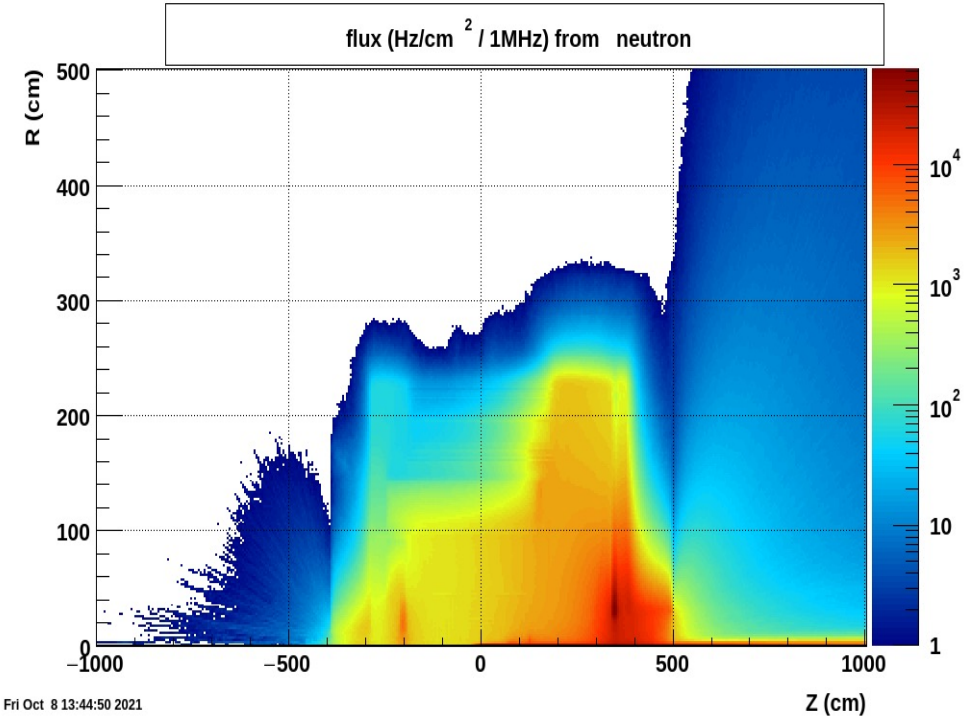
STAR 2017 pp 510 GeV, VMC+gcalor



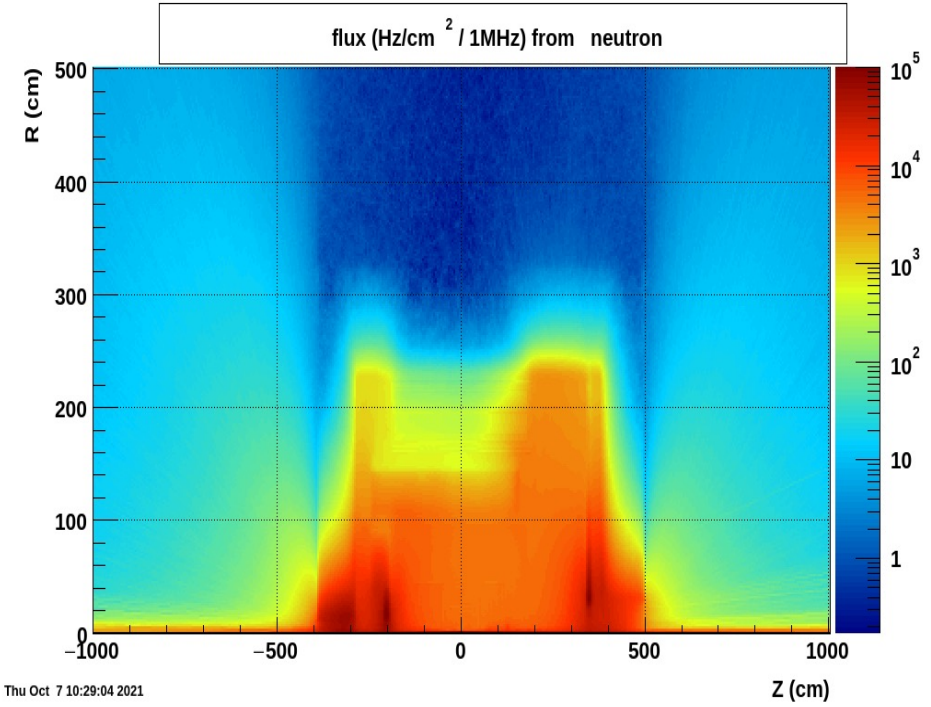
Trends are same. There are some differences which could be due to differences in kinematics and material descriptions. It should be checked.

ATHENA. Neuron flux: ATHENA ep and pp

ATHENA, ep 18x275, ATHENA mag. field

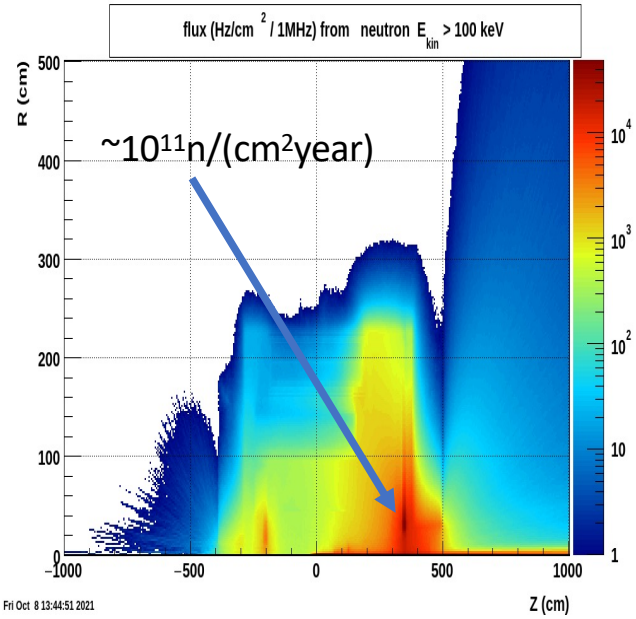


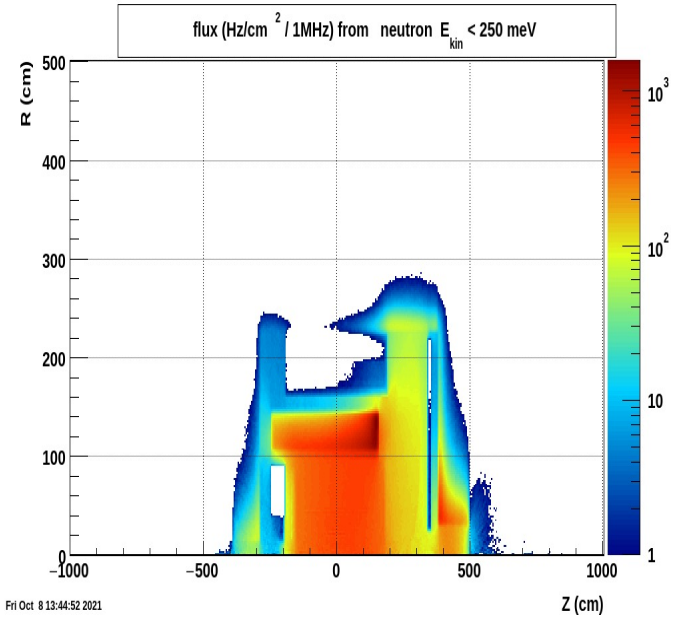
ATHENA, pp 510, STAR magnetic field

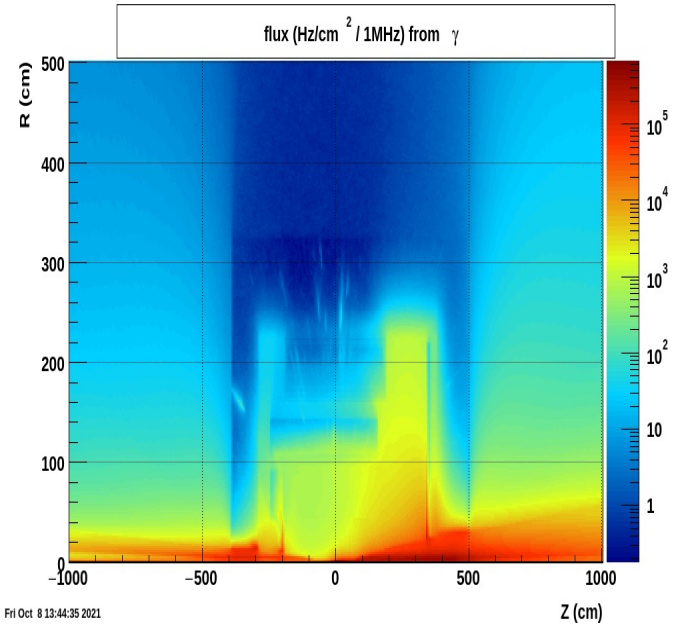


Asymmetries in Z due to the detector design and interactions.

ATHENA, ep 18x275, neutron and thermal neutrons, γ

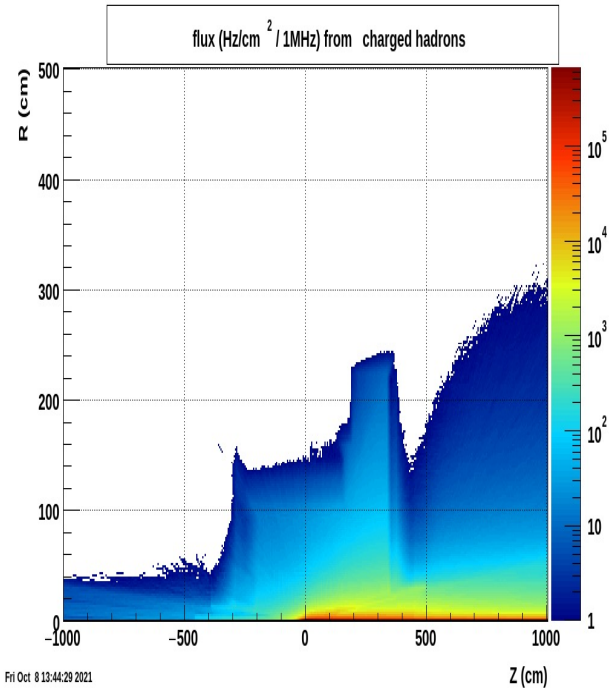




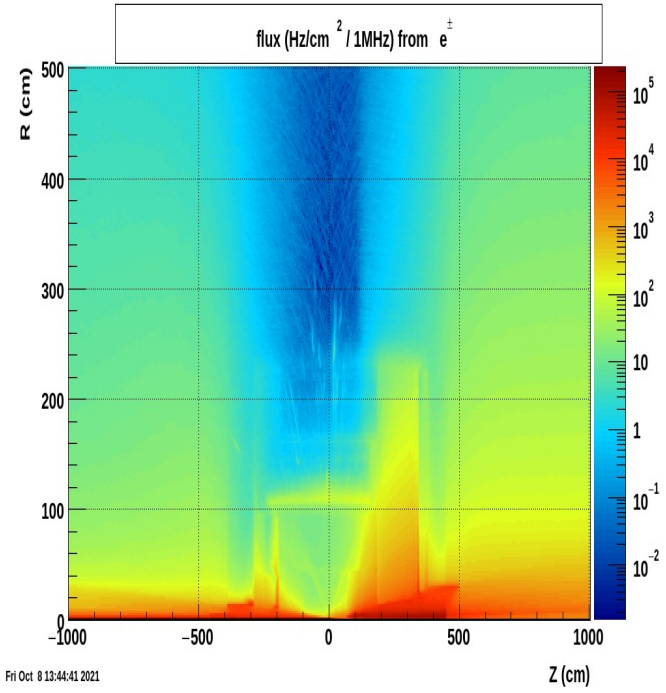


ATHENA

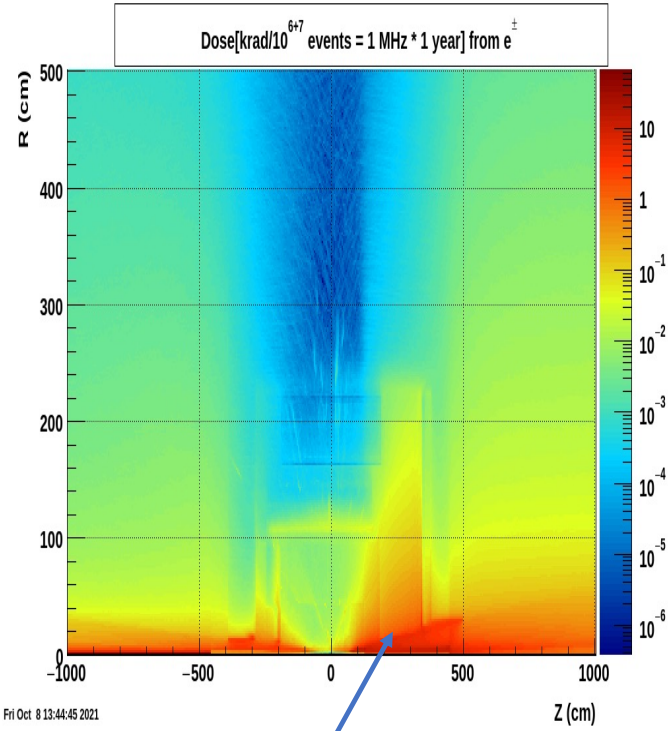
Charged hadrons



Electrons



Radiation dose



10 krad/year

Questions ?