Residual Does Rate Analyses for the SNS Accelerator Facility



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OAK RIDGE National Laboratory

Outline

- Introduction
- SNS layout
- Methods for neutronics analyses
- Instruments and uncertainties
- Results from comparison measurements vs. calculations
- Conclusions

Introduction

- **SNS is an accelerator driven neutron scattering facility that recently started operations and in power rump-up process during cycles of operation , maintenance, and tuning**
- **SNS accelerator is loss limited machine In order to limit the activation level**
- **BLM are located along the beam line and measure prompt radiation and inhibit the beam when excessive losses occur**
- **In order to plan maintenance work after each operations period, residual dose measurements are taken at 30 cm and on contact**

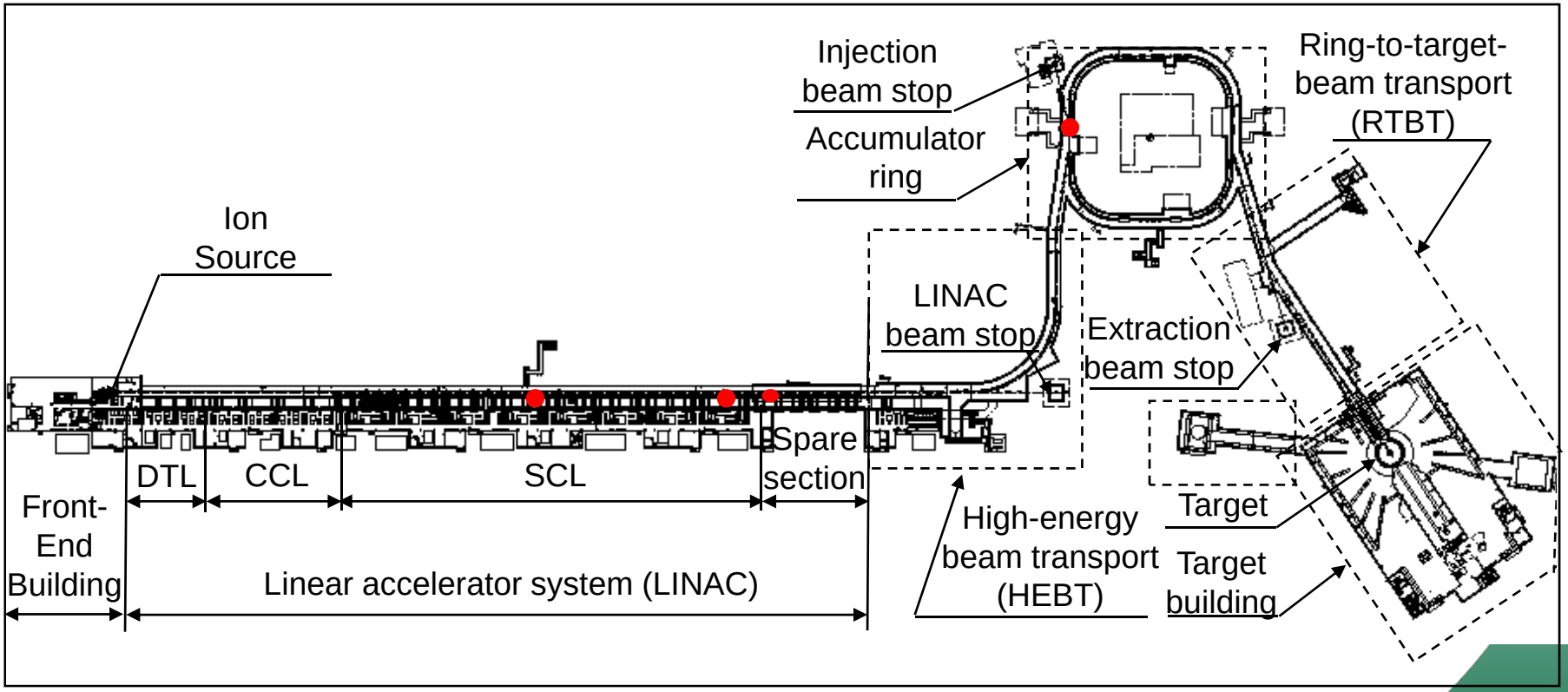
Scope of work

- **Analyses of residual dose rates due to accelerator component activation in order to understand nature of the radiation fields behavior inside the accelerator tunnel**
- **Preliminary results, we started to perform these analyses recently**
- **Analyses performed for two last operation cycles, fall 2007 and spring 2008 and compared with measurements**

SNS Layout and parameters

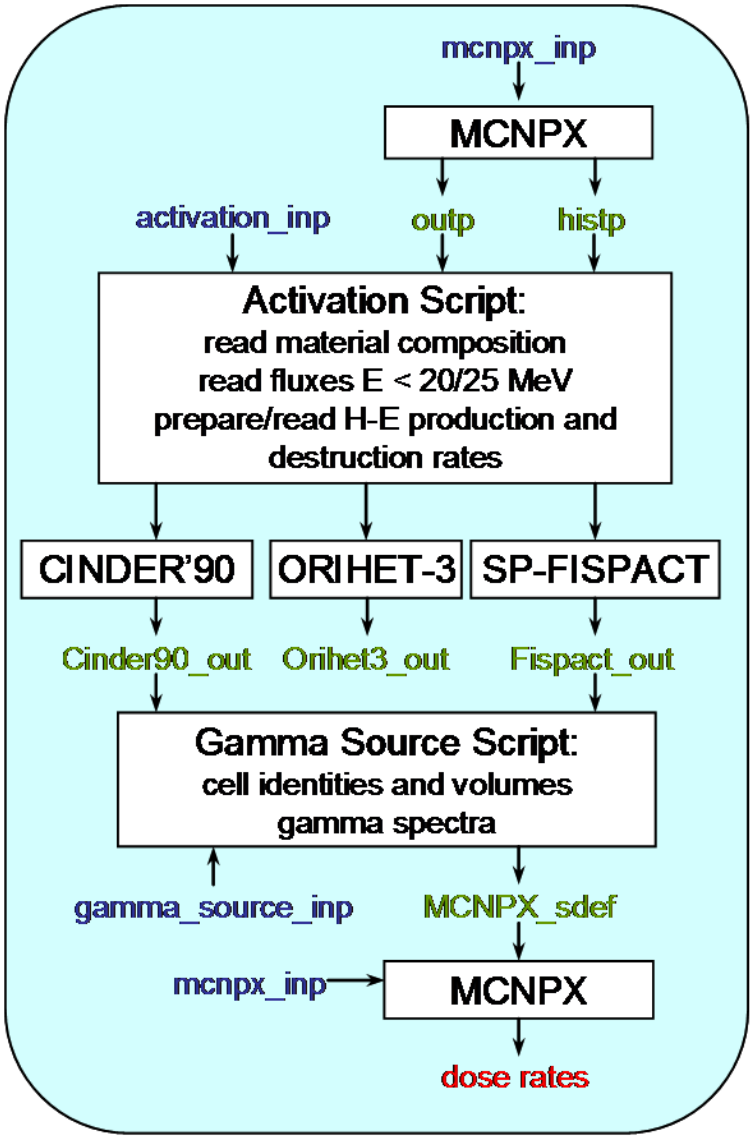
3 measurements location:

- After cryomodule 16
- After cryomodule 24
- After cryomodule 32
- After stripping foil



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Methods



3 steps analyses

- Monte Carlo transport code MCNPX to calculate reaction rates
- Activation script to execute CINDER'90 to obtain the time dependence of the isotope buildup and decay including decay gamma spectra
- Residual dose calculation

Methods

Residual dose calculation

- For simple only beam tube model - by conversion gammas production spectra in the multi-group structure and gamma power for each time step to the dose rate
- For model with beam tube and tunnel walls - by feeding back to MCNPX decay gamma spectra and gamma power for each time step to calculate dose rates

Methods

- **Simplifications in geometry**
  - **Outside the accelerator structures the highest source of residual gammas is the steel beam tube, analyses were performed for a very simple model of beam pipe without adjacent beam structures**
  - **For second round of analyses surrounding concrete accelerator tunnel walls were added**

Methods

- **Sources for calculations**
  - **Proton losses in beam pipe**

Location	After cryomodule 16	After cryomodule 24 and 32	After stripping foil
Beam lost monitor	scl16b	scl32b	ring_A11c
Beam energy	660	845	845

  - **Losses modeled like continuous cylindrical proton source, forward directed inside the beam pipe**
  - **Operational scenario for activation and decay calculation is provided from BLM readings taken during operation cycle for each location**

Instruments and uncertainties

Instrument uncertainties

- **Precision**
- **Location**
- **Timing**

Instruments and uncertainties

Beam loss monitors - ionization chambers

- **Precision is about 20%**
- **Locates about 10 cm from the beam line in SCL and 60 cm from the beam line in Ring Injection, which gives especially for the SCL section about 40%**
- **Data averaged over beam running period**

Instruments and uncertainties

Hand-held ionization chambers

- **Precision is about 15% - 20%**
- **Standard measurements are carried out by hand on 30 cm distance from the beam tube. This introduces at least 20% of geometry uncertainty in radial direction**
- **The location for each measurement is not precise in the axial direction and vary relative to the corresponding BLM location up to 0.5 m. Uncertainty is 10-50%**
- **Loss location relative to the BLM can vary during the run cycle. Measured residual dose rates could not exactly correspond to the loss recorded by BLM**
- **Difference in time of measuring and recording**

Instruments and uncertainties

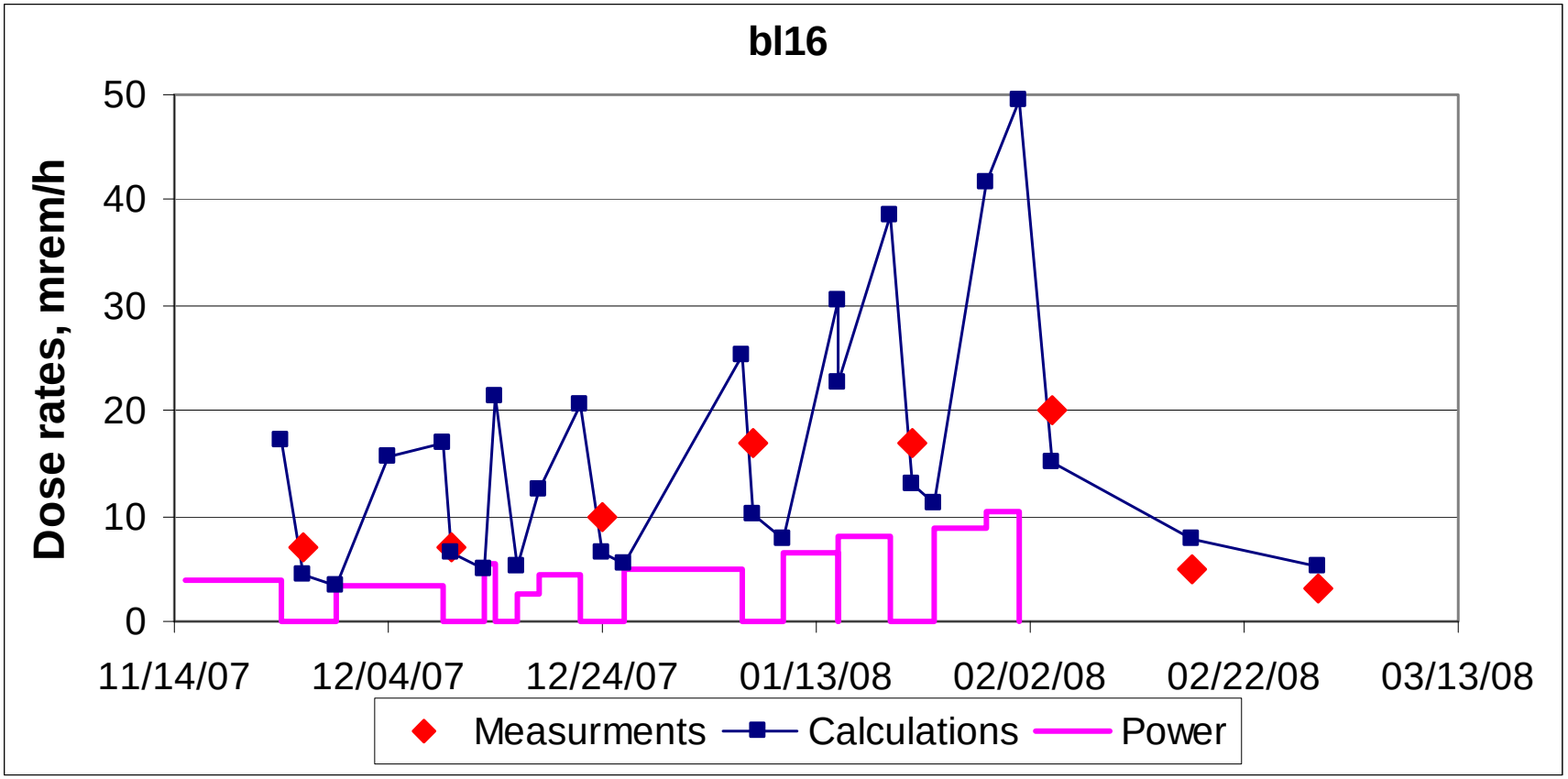
Calculation uncertainties

- **Geometry representation in calculations**
- **Uncertainties in material composition**
- **Assumptions in source representations**
- **Accuracy in physics model and cross sections data**
- **Statistical errors in the code**
- **Calculation accuracy for these analyses could be about 30%.**

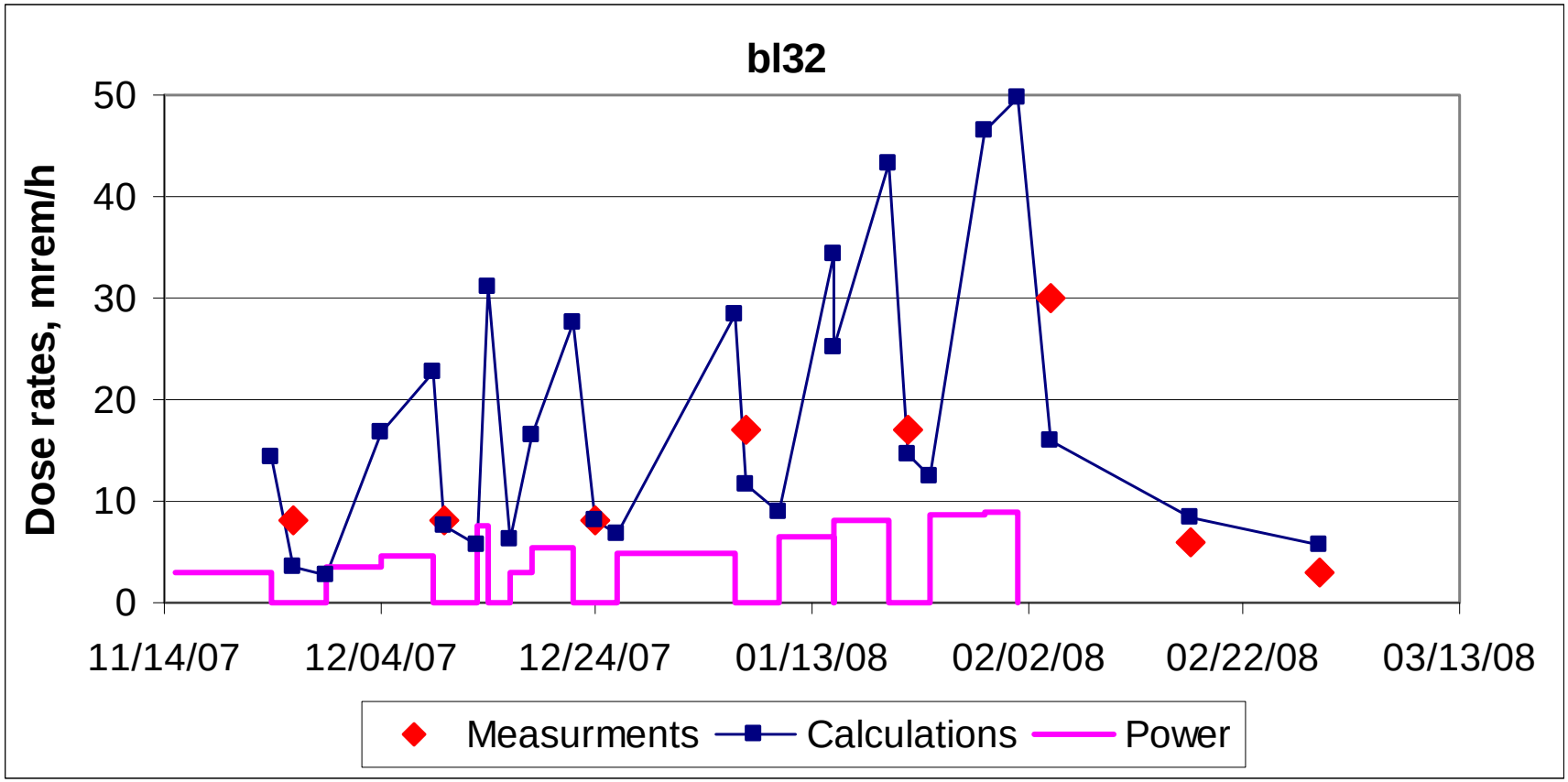
Results, fall 2007

- Calculation performed for one operation cycle with five running periods
- Eight measurement campaigns during operational cycle
- Calculated dose rate are scaled to the measurements

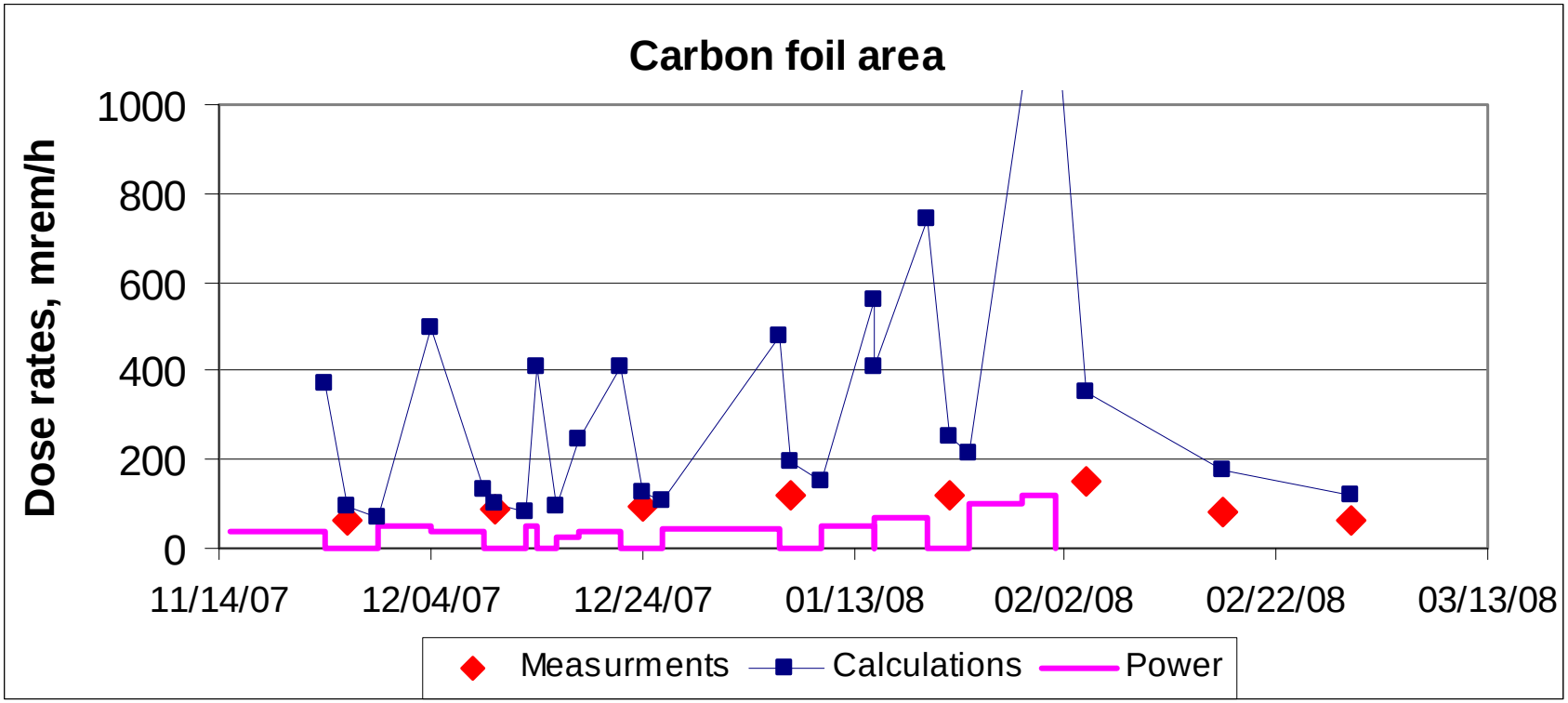
Results, fall 2007



Results, fall 2007



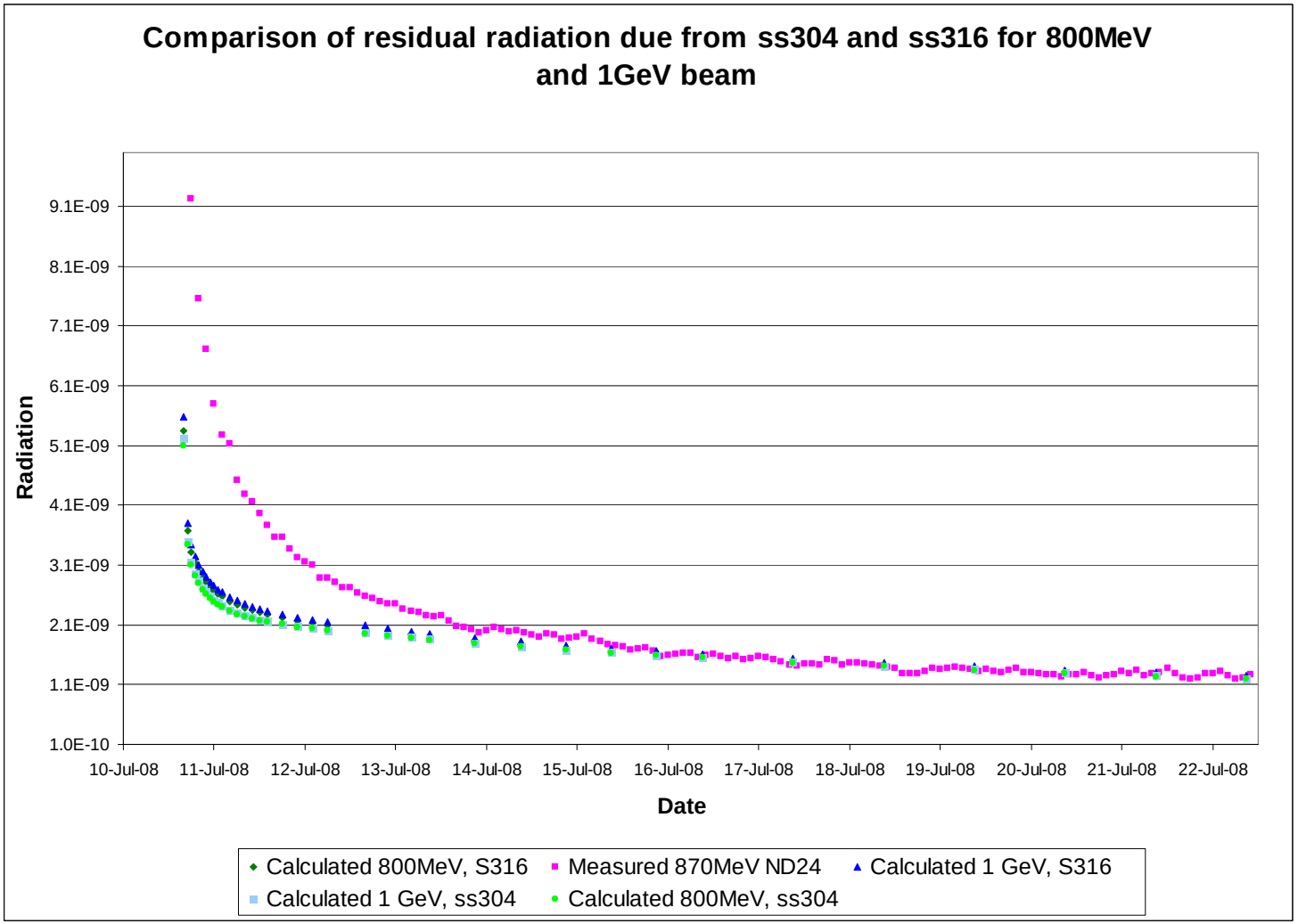
Results, fall 2007



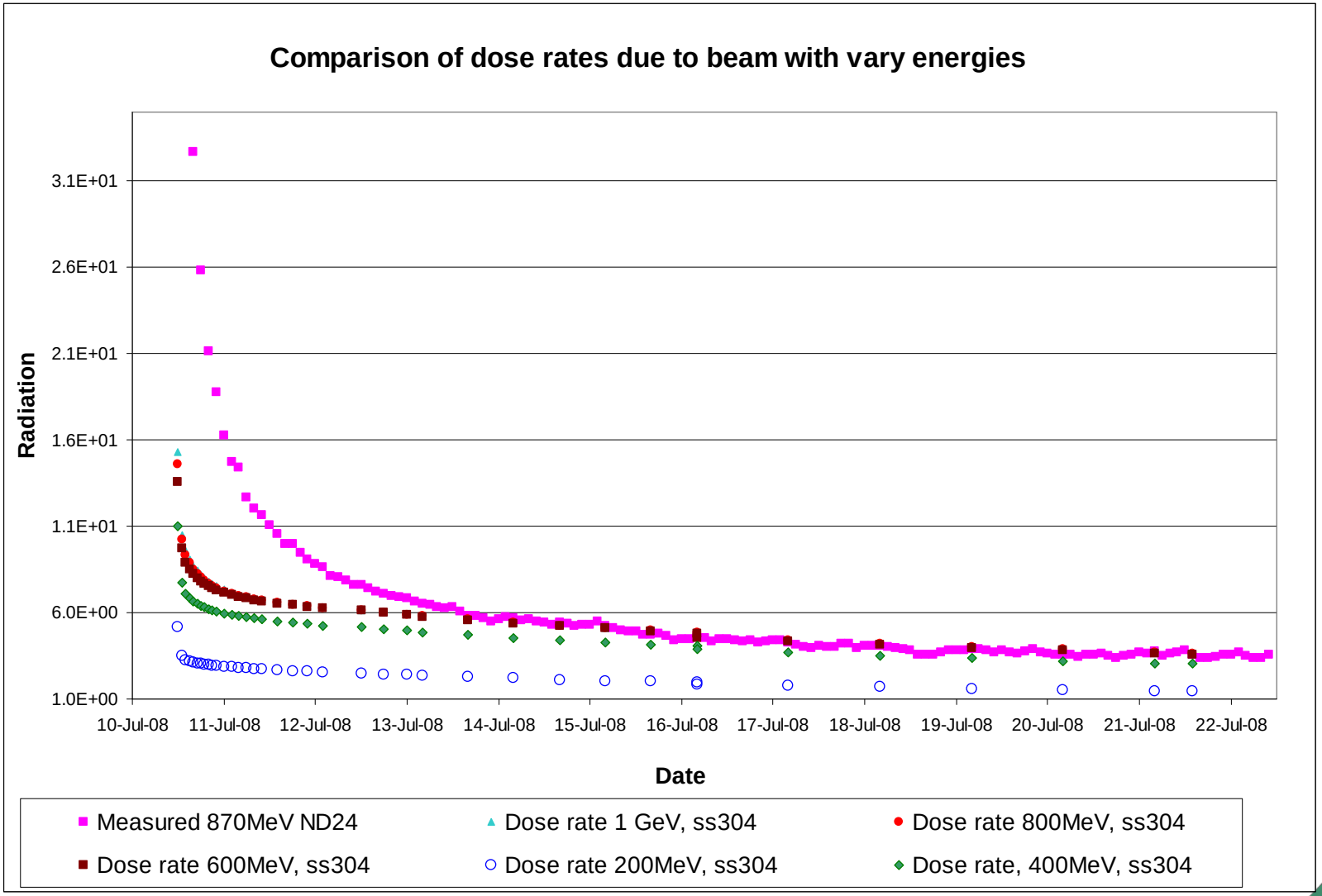
Results, spring 2008

- BLM monitors were set to measure decay gamma radiation in small time increments in the end of the cycle
- Only decay calculations were compared vs. measurements
- Sensitivity analyses were performed to estimate influence of:
  - Different types of steel: S304 vs. S316
  - Energy of beam intercepting the pipe: 200MeV, 400MeV, 600MeV, 800MeV, 1000MeV
  - Influence of surrounding concrete walls

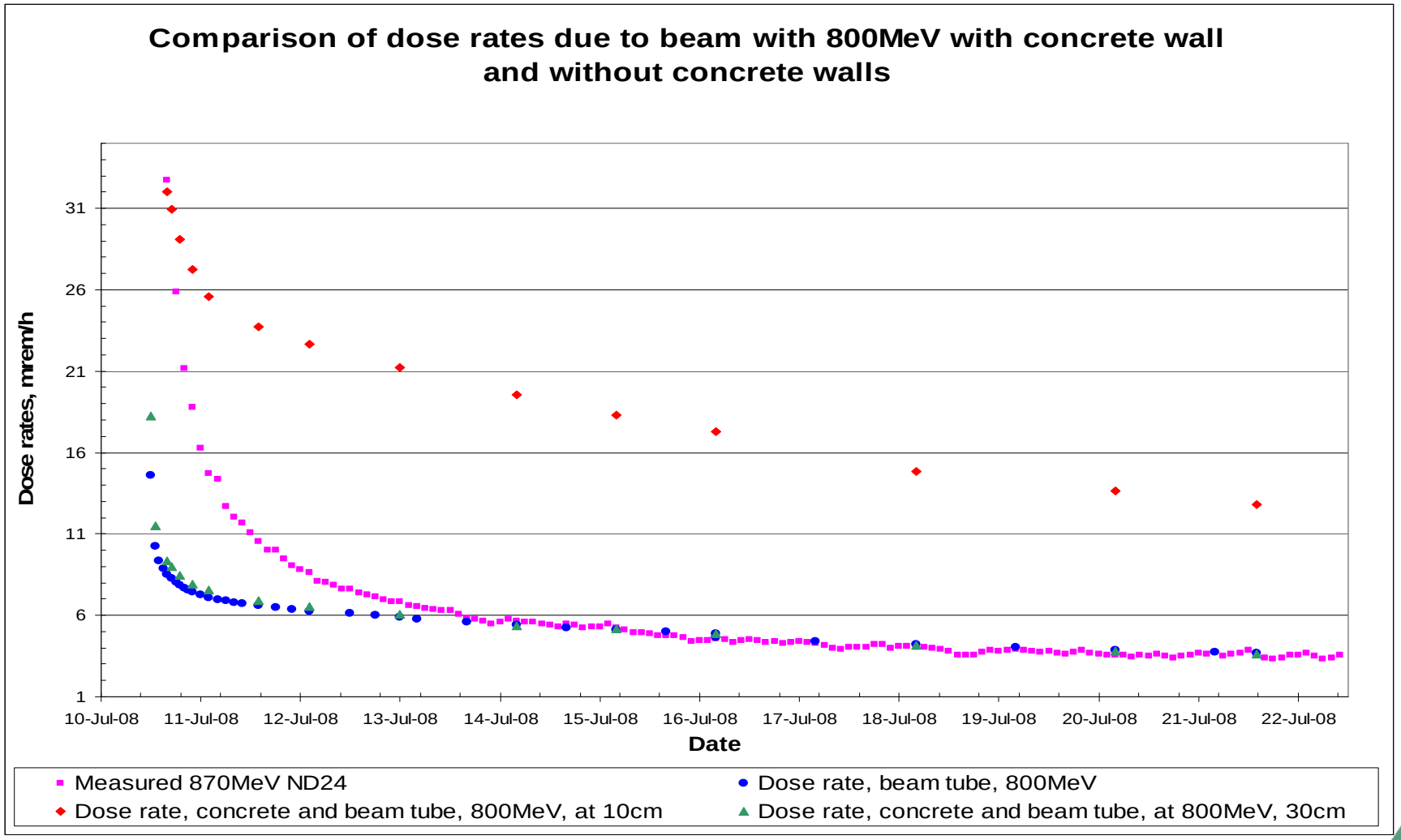
Results, spring 2008



Results, spring 2008



Results, spring 2008



Results, second running cycle

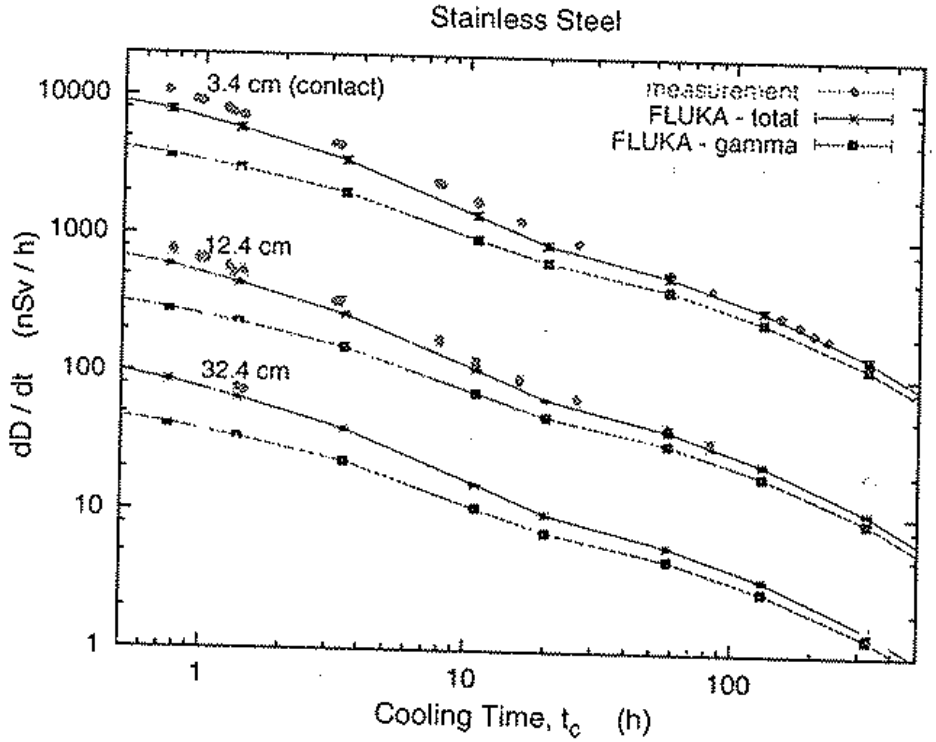


FIG. 7. Dose equivalent rate as a function of cooling time for the stainless steel sample and the three measurement positions.

Additional contribution from gammas ray and positron emitters in the very first hours of decay are about the same like from photon dose

S . Roesler, M. Brugger, Y. Donjoux, A. Mitaroff, “Simulation of Remanent dose Rates and Benchmark Measurements at the CERN-EU High Energy Reference Field Facility”, Sixth International Meeting on Nuclear Application of Accelerator Technology (AccApp/03), pp.655-662

Conclusions

- MCNPX in conjunction with a newly developed activation script with CINDER'90 was used for residual analyses
- Wide range of uncertainties
- Simulations data was compared to the performed measurements and it appears that measured decay is faster than calculated except for injection area
- After 2 days results are in a good agreement
- Steps to improve measurements precisions
- Steps to improve calculations