Performance Requirements for Monitoring Pulsed, Mixed Radiation Fields Around High-Energy Accelerators

D. Forkel-Wirth, S. Mayer, H.G. Menzel, A. Muller, T. Otto, M. Pangallo, D. Perrin, M. Rettig, S. Roesler, L. Scibile*, H. Vincke,

*CERN SC-RP, CERN TS-CSE**

C. Theis

TU Graz, Graz, Austria

M. Latu

Saphymo-Genitron-Novelec, Grenoble, France

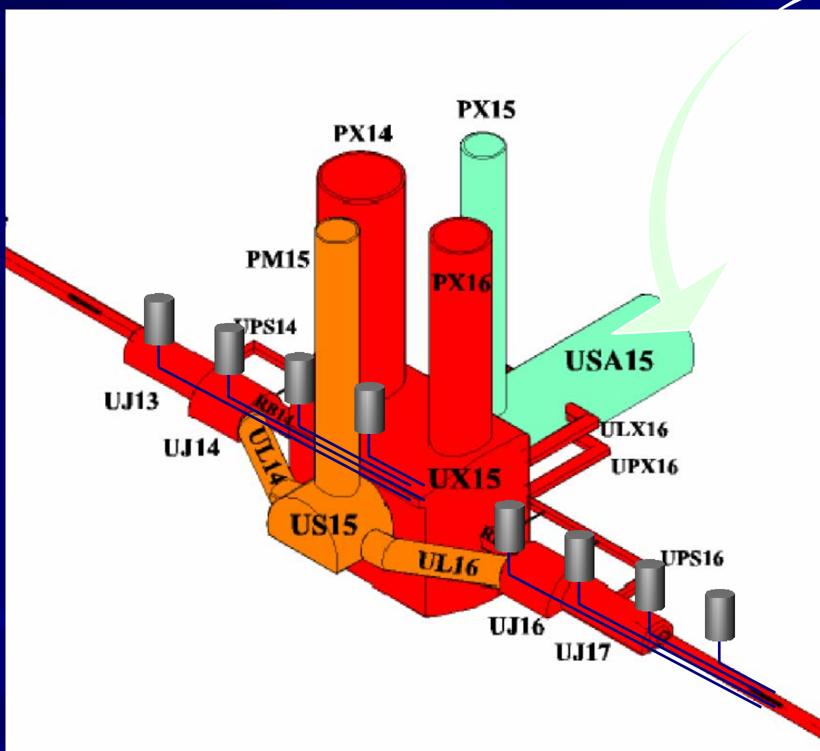
Contents

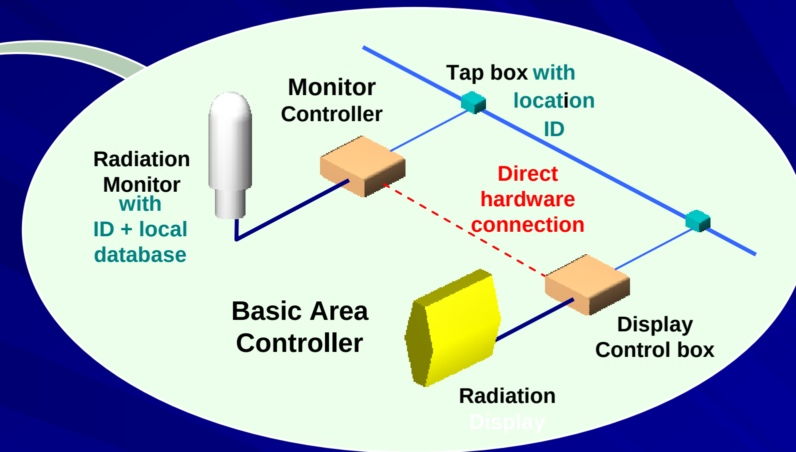
- Metrology in High-Energy Mixed Radiation Fields
- Metrology
  - Comparison between experiment and Monte Carlo simulation for
    - High-pressure ionisation chambers (H, Ar filled)
    - Air filled plastic ionisation chambers
  - Recombination effects
- Technique
  - Read-out electronics: charge digitizer
- Conclusion

Radiation Protection Task

- Radiological survey of work places:
  - Measurement of ambient dose equivalent H*(10) [Sv] in pulsed, high energy, mixed radiation fields
- Challenge:
  - Correct
  - Reliable
  - State-of-the-art
  - Compliant with international standards and legal requirements
- Radiation Monitoring System for the Environment and Safety for LHC (RAMSES)

Monitoring of Ionising Radiation

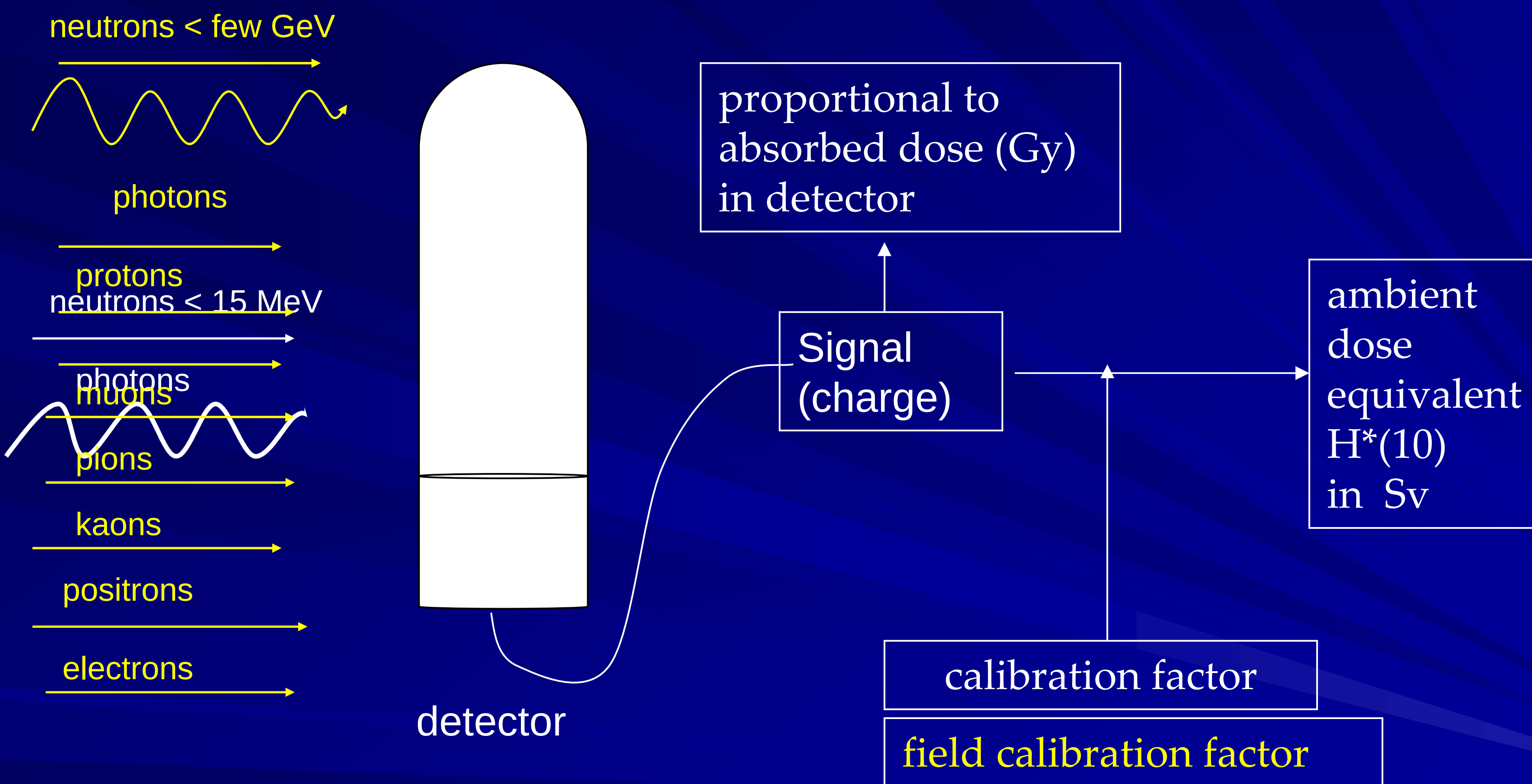




Monitoring of dose rates caused by
by

- Prompt radiation (beam on)
- Induced radioactivity (beam off)
off)

Mixed High-Energy Radiation Fields



Detector response to mixed fields?

=> Experiment ⇔ Monte Carlo simulation

Comparison of Experiment and Simulations

PMI

wall: C-H2

volume: 3 l

gas: air, 1 atm

voltage: 400 V

IG5

High-pressure ionisation chamber

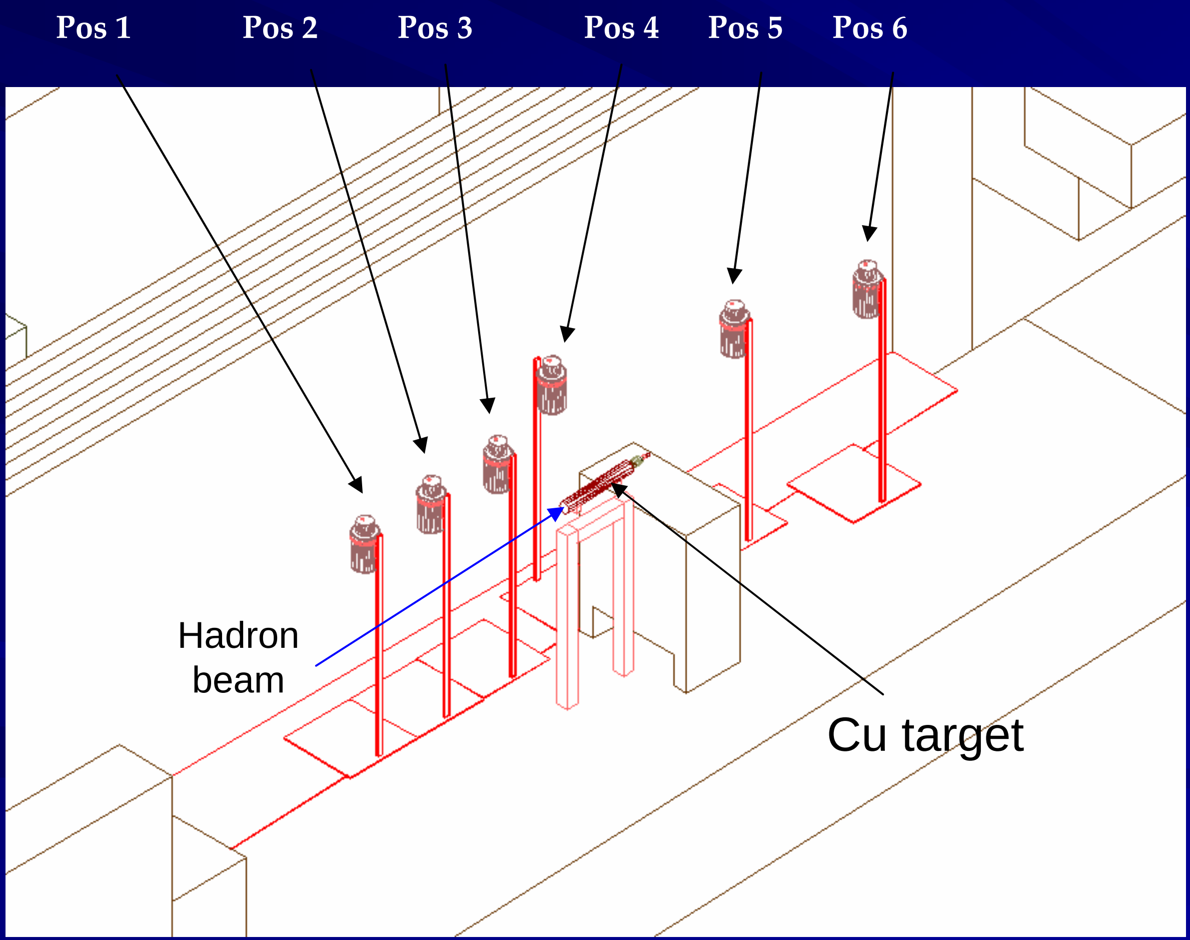
volume: 5,2 l active

gas: Ar or H (20 bar)

high-voltage: 1200 V

Set-up in the CERF Target Area (PMIs)

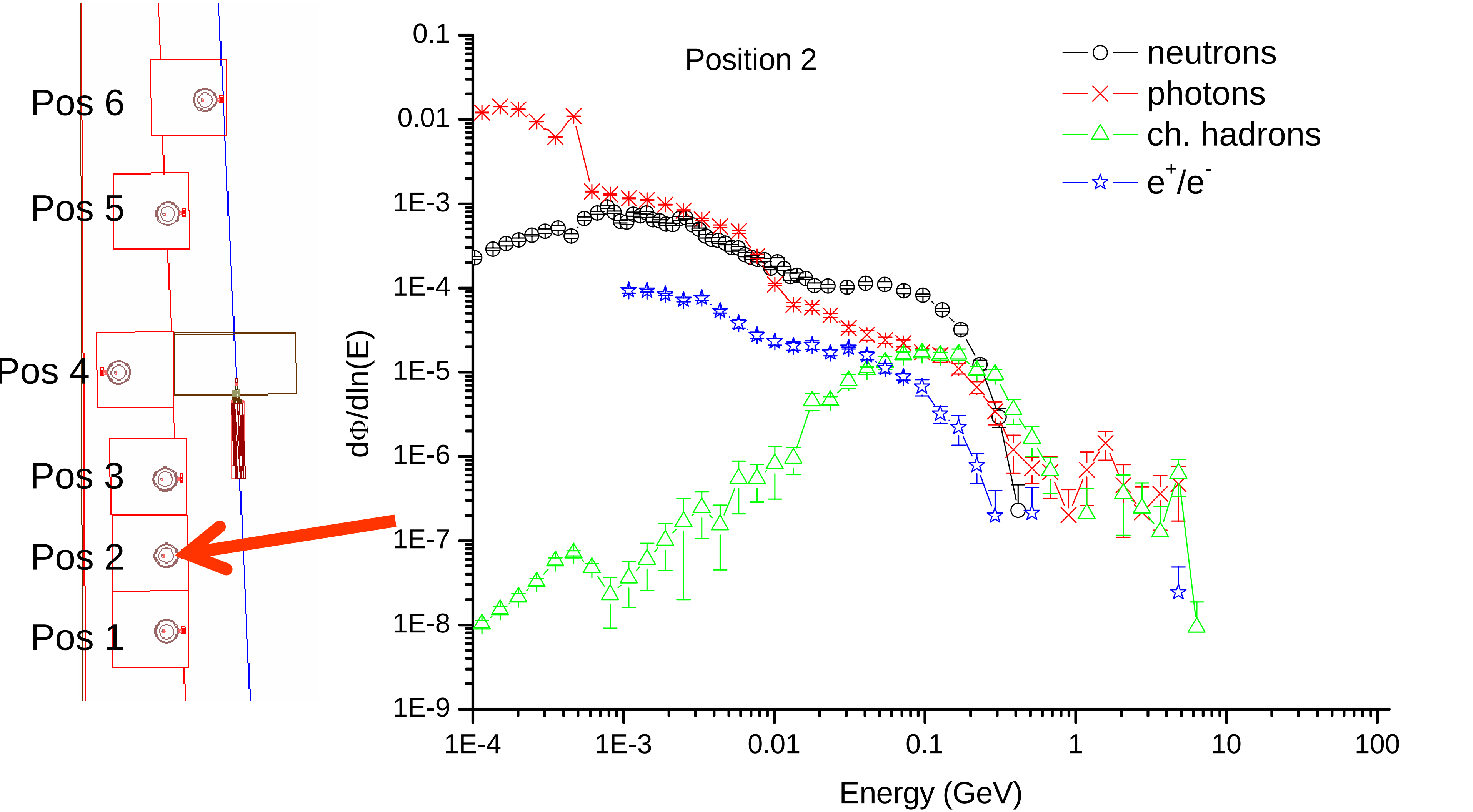
SPS secondary hadron beam is hitting a copper target ➔ irradiation of the PMI chambers with different radiation fields at various positions.



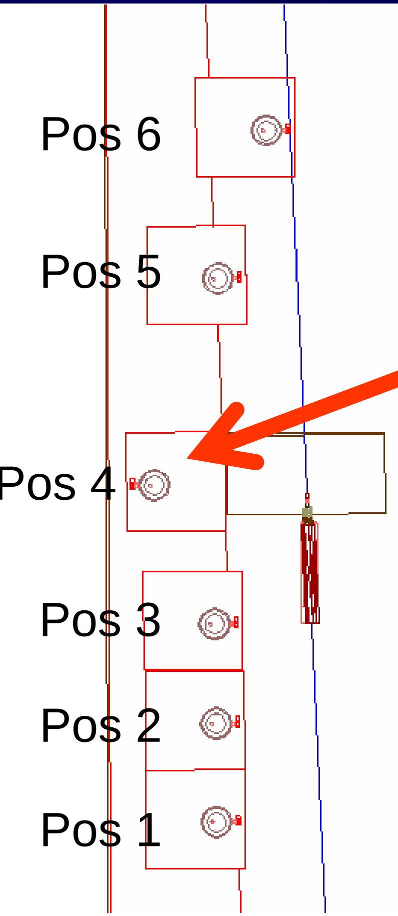
Beam parameters:

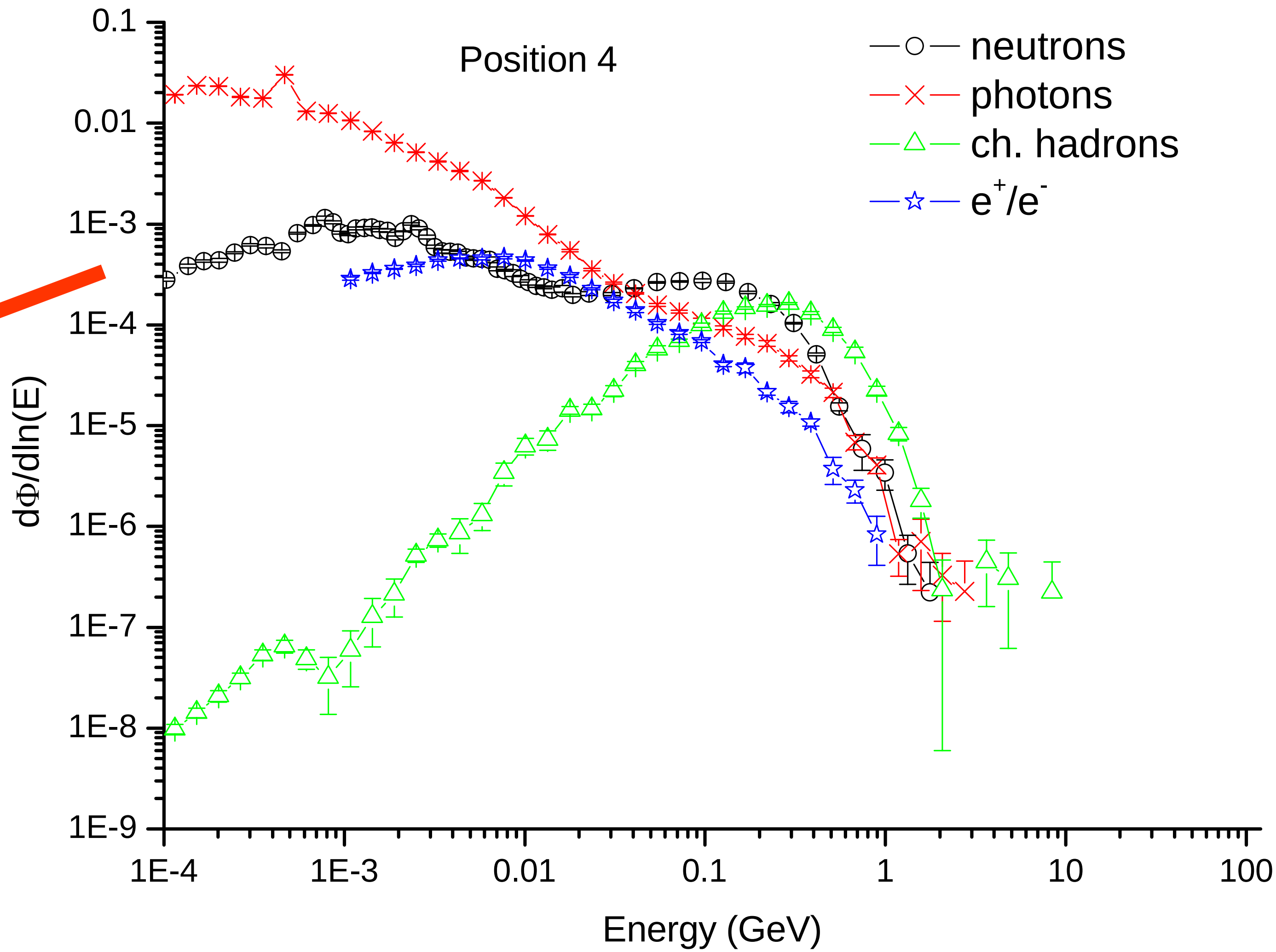
- Momentum:
  120 GeV/c
- Intensity:
  9*107 hadrons/ SPS cycle (16.8 s with 4.8 s continuous beam)
- Composition:
  60.7% π^+
  34.8% p
  4.5% K^+

Simulation of Particle Fluences

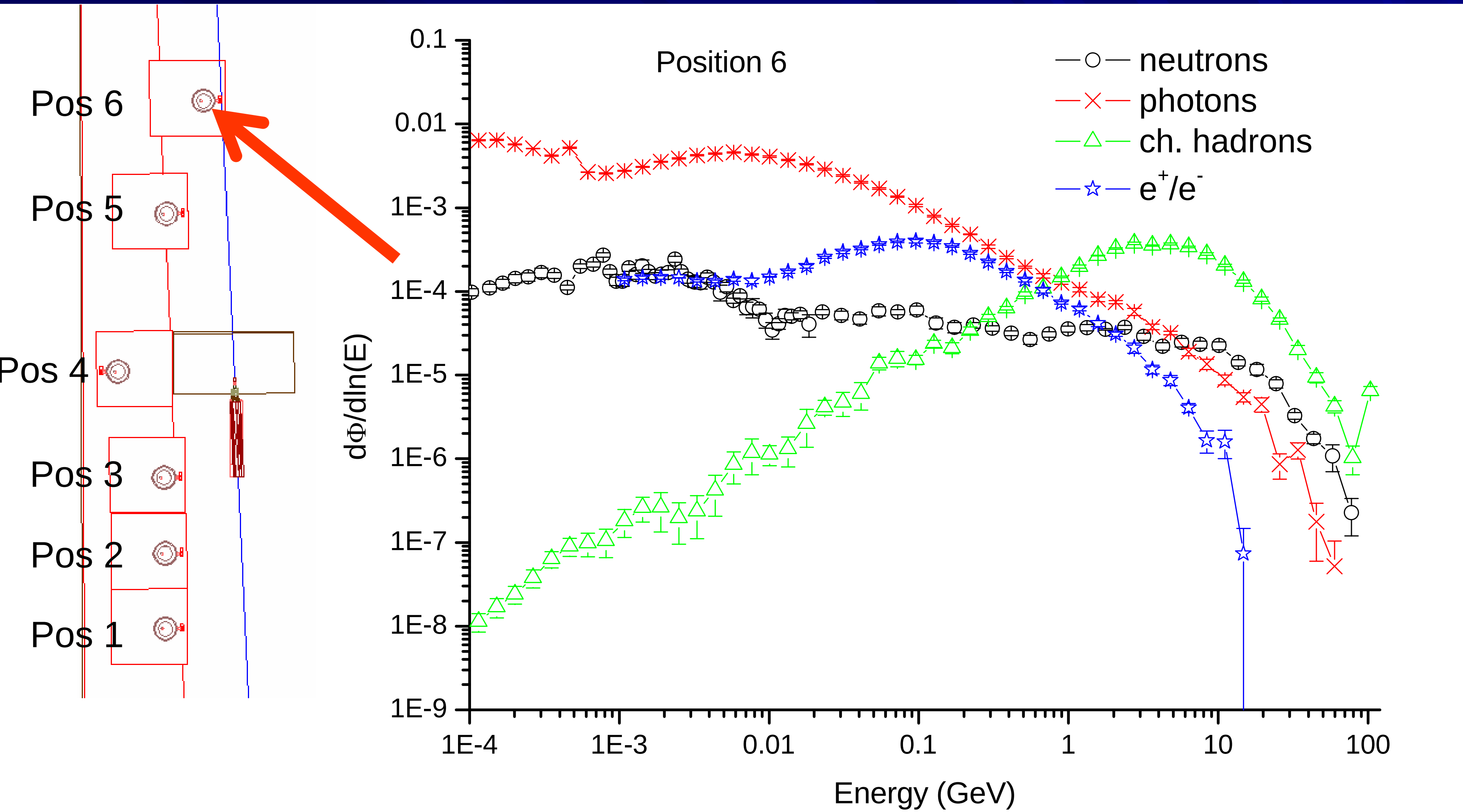


Simulation of Particle Fluences

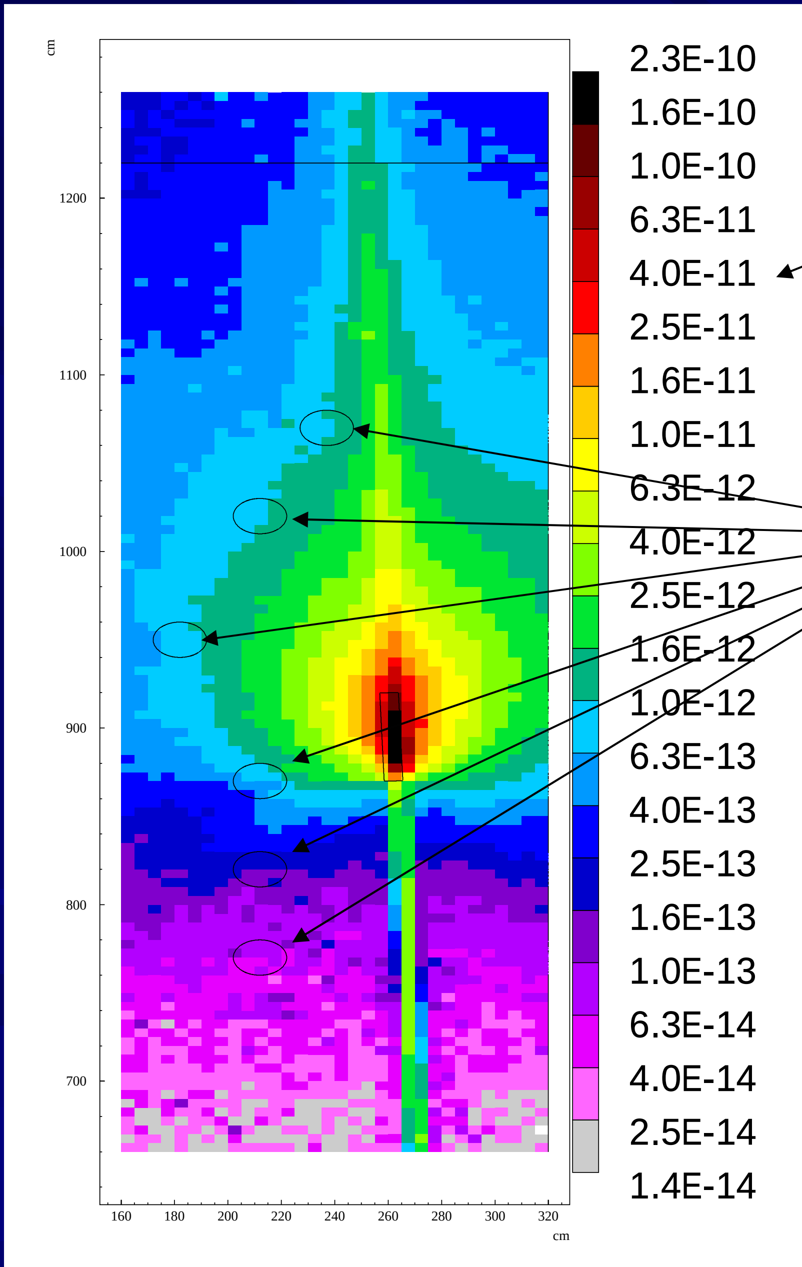




Simulation of Particle Fluences



Simulated Dose Distribution

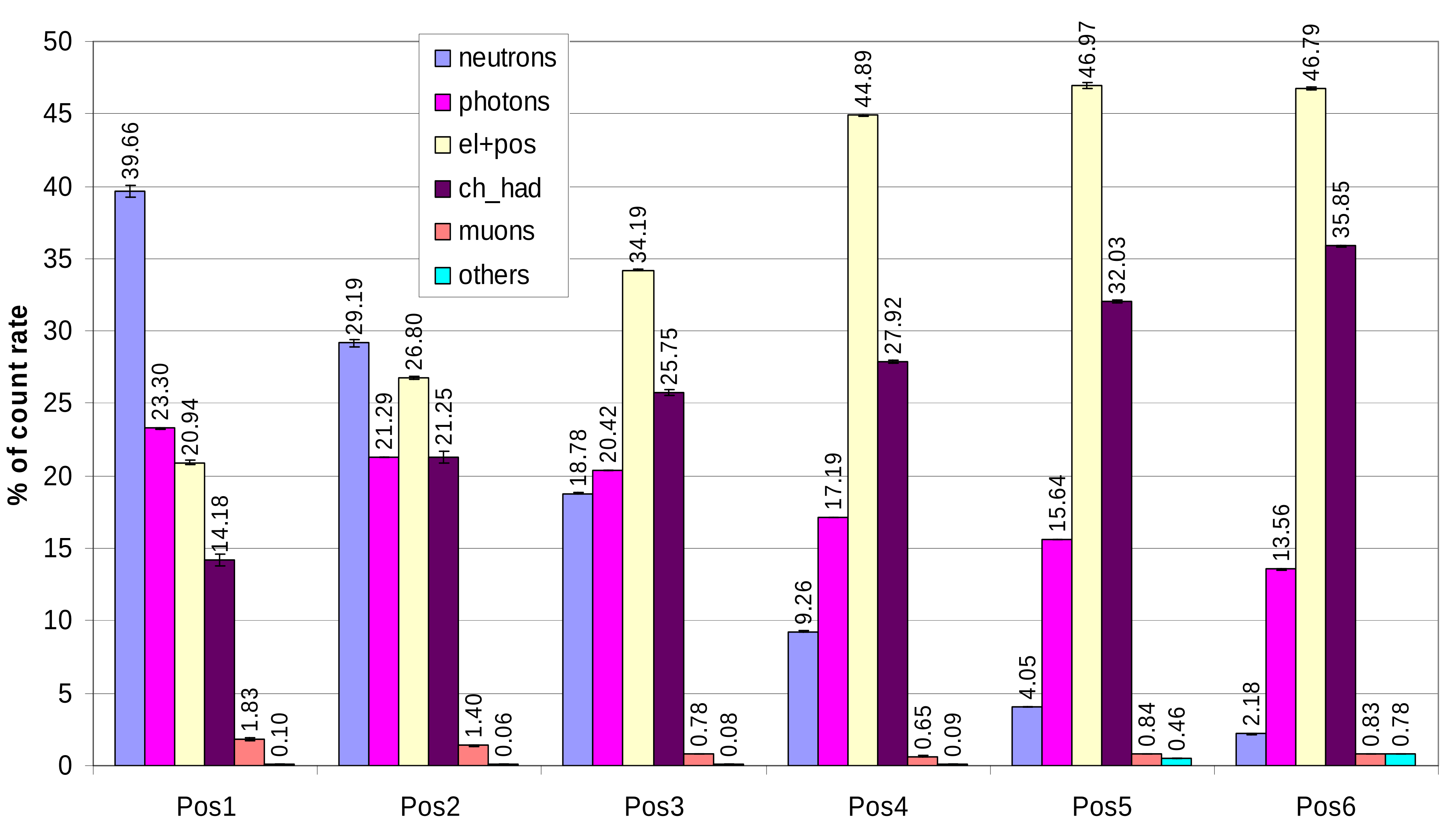


Dose (average within ±10 cm) given in Gy per primary particle hitting the target.

The circles indicate the positions of the chambers.

1 pC = 10 nGy deposited in active volume

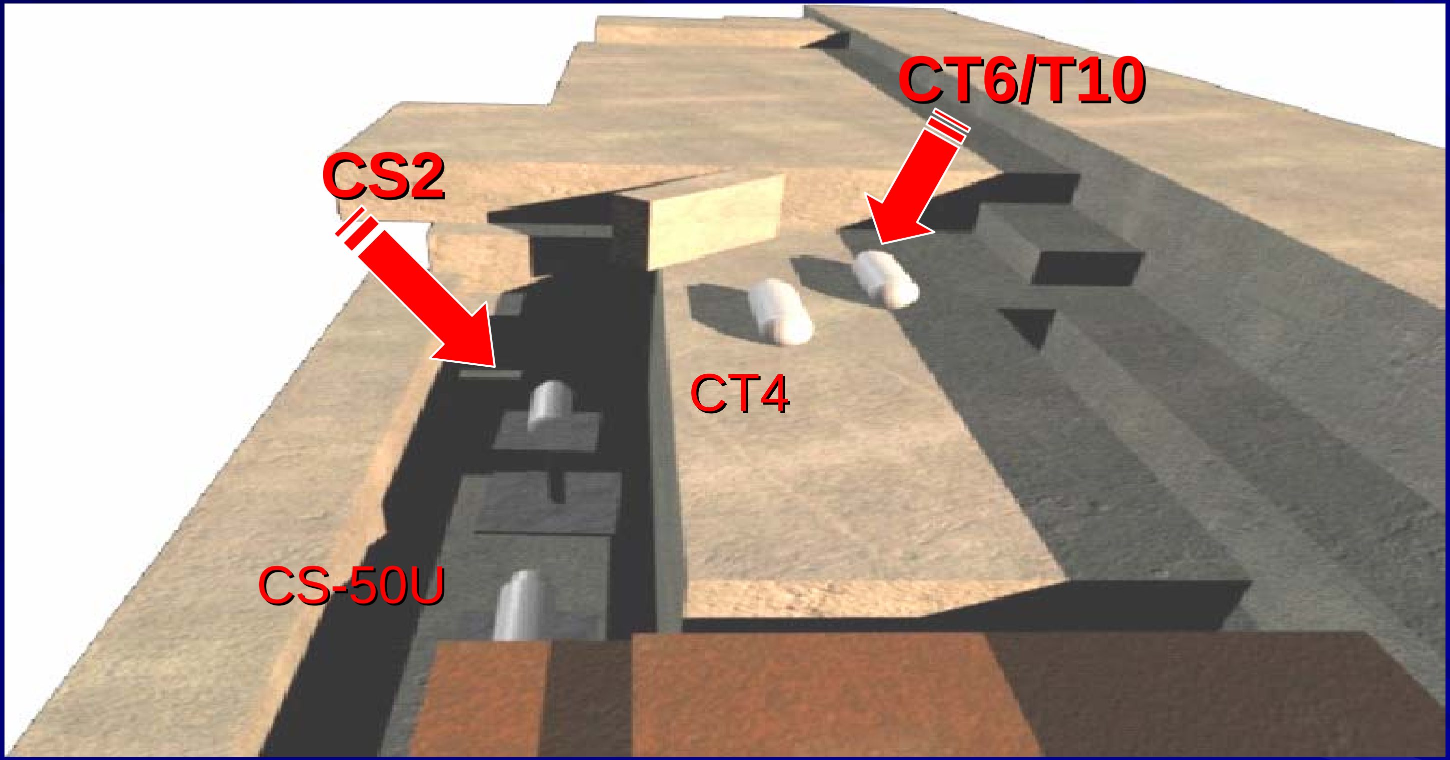
Contribution of the Different Particle Types to the Energy Deposition



Comparison simulation and experiment

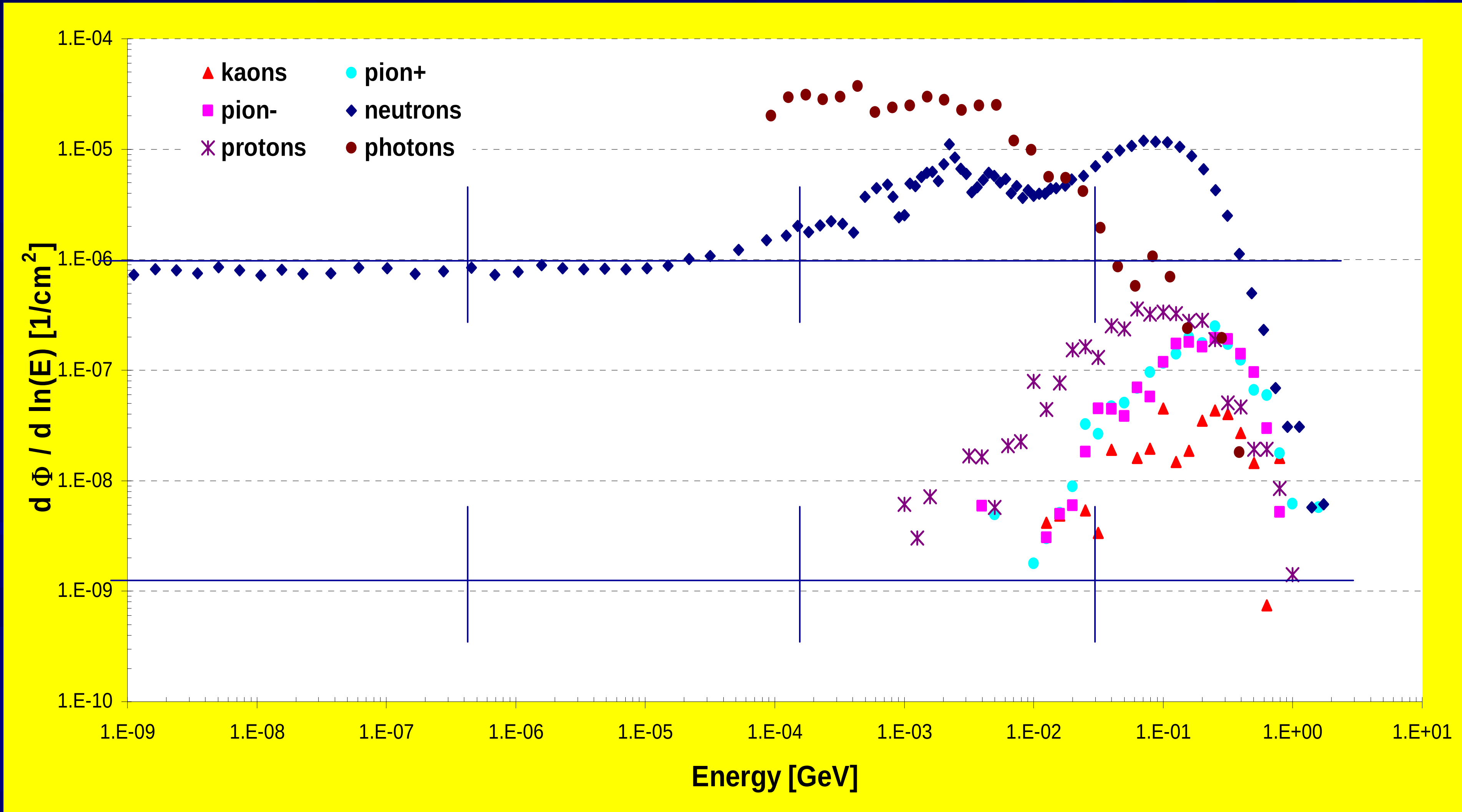
	Simulation Counts/ prim. part. $*10^{-6}$	Simulation error $*10^{-6}$	Measurement Counts/ prim. part. $*10^{-6}$	Measurement error $*10^{-6}$	Simulation/ Measurement	Error
Pos 1	**5,63**	**± 0,12**	**5,64**	**± 0,56**	**0.998**	**± 0.102**
Pos 2	**16,06**	**± 0,44**	**15,58**	**± 1,56**	**1.031**	**± 0.107**
Pos 3	**67,46**	**± 0,73**	**67,25**	**± 6,93**	**1.003**	**± 0.104**
Pos 4	**85,33**	**± 0,64**	**79,00**	**± 8,67**	**1.080**	**± 0.119**
Pos 5	**96,20**	**± 1,26**	**89,39**	**± 9,47**	**1.076**	**± 0.115**
Pos 6	**108,31**	**± 0,82**	**115,74**	**± 17,99**	**0.936**	**± 0.146**

The IG5 at CERF

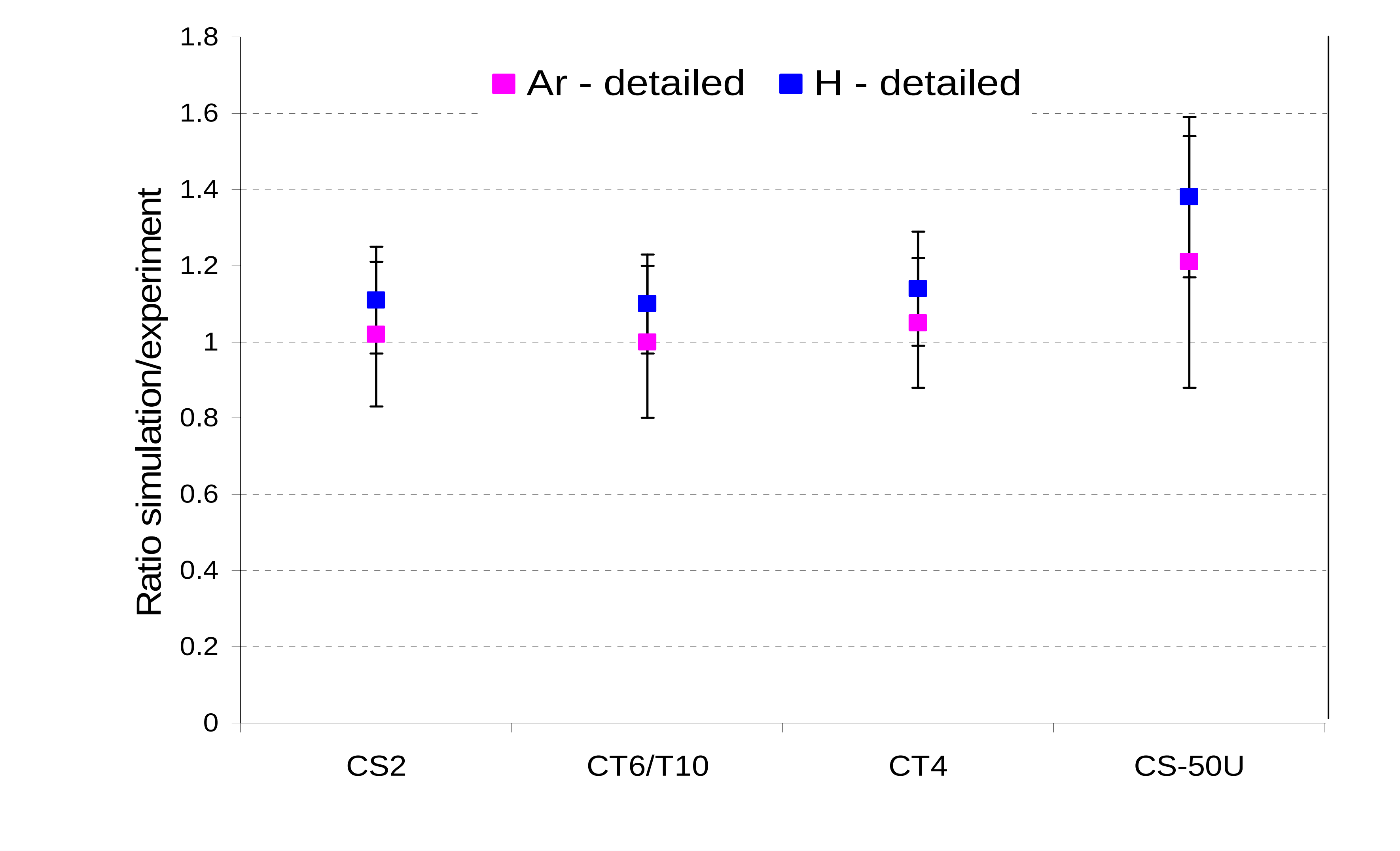


80 cm of concrete between detector and target

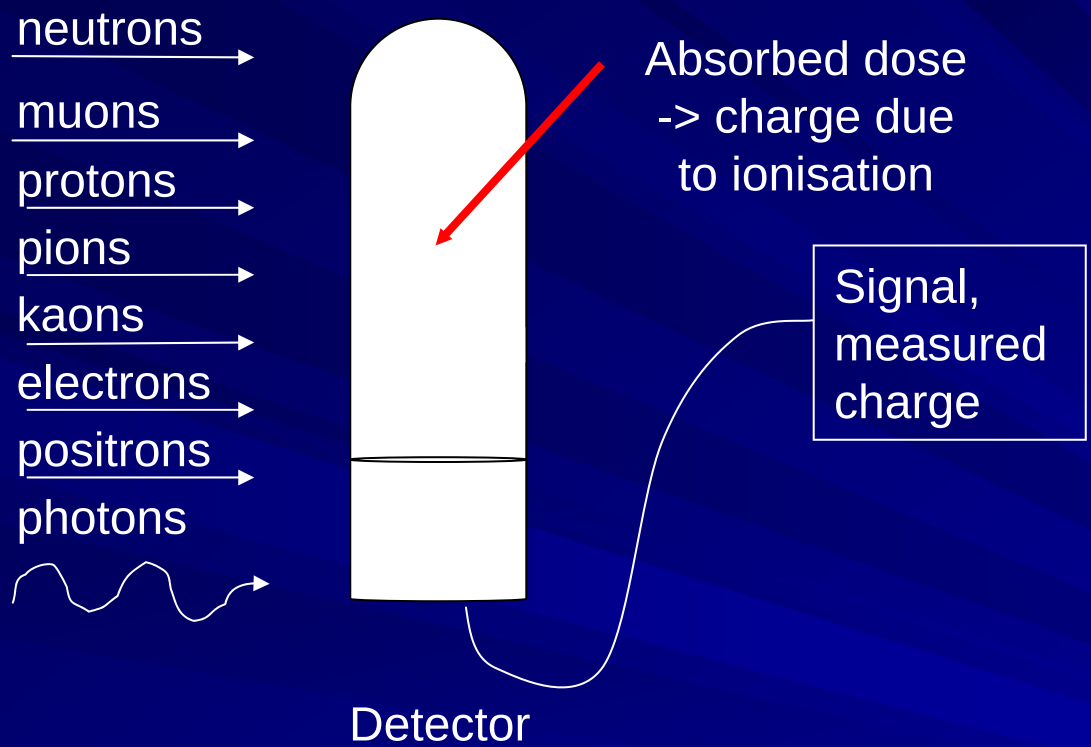
Particle fluence at CT6/T10



Comparison simulation & experiment for IG5



Dose Measurements in Pulsed Fields



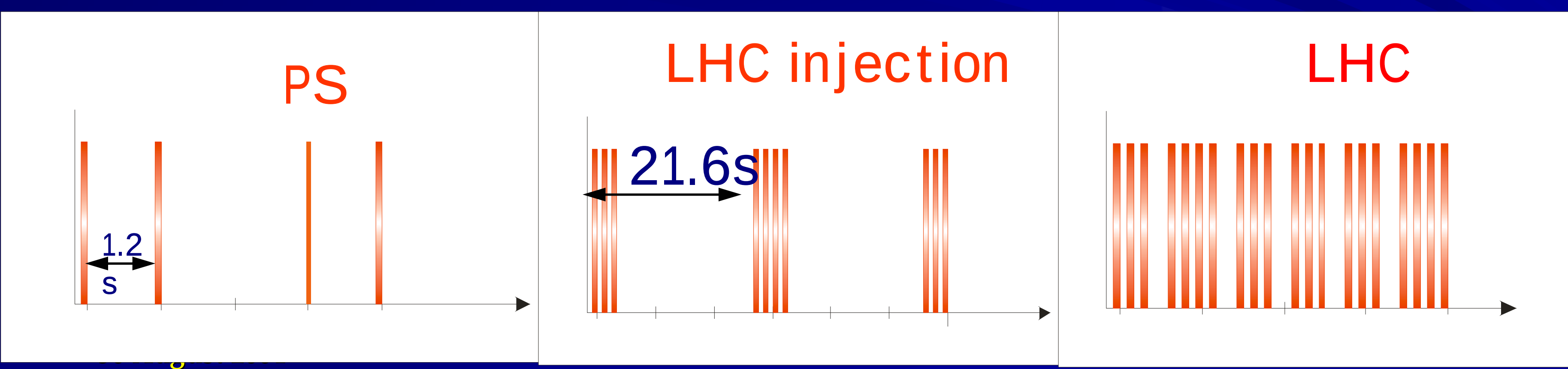
Problem in case of short pulses:

↓

Recombination effects (charge loss)

↓

Underestimation of absorbed dose

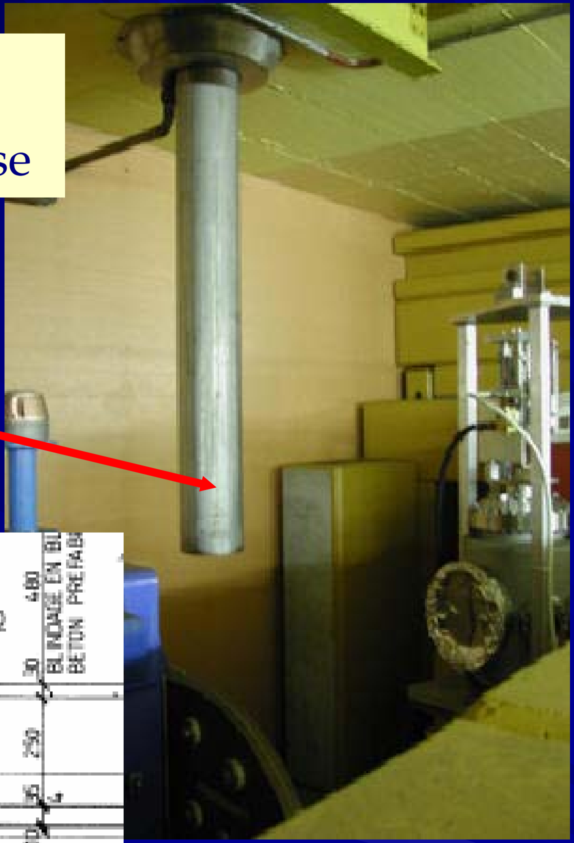


Recombination effects

Ionisation chambers exposed to pulsed, high energy mixed radiation fields:

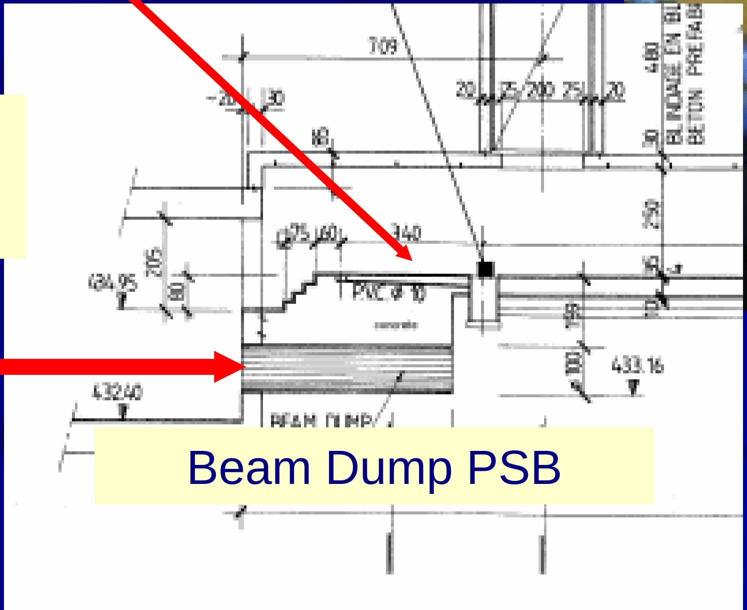
AD:

up to 50 mGy/pulse



PSB:

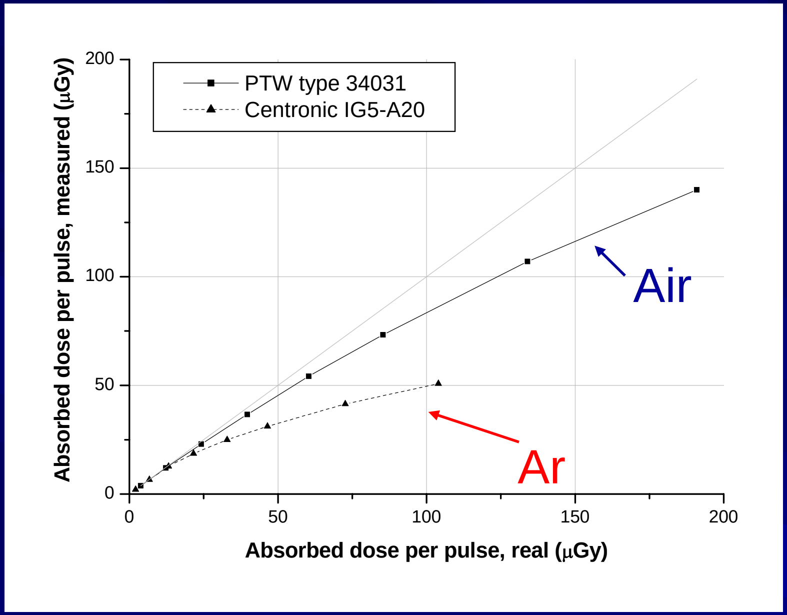
up to 160 µGy/pulse

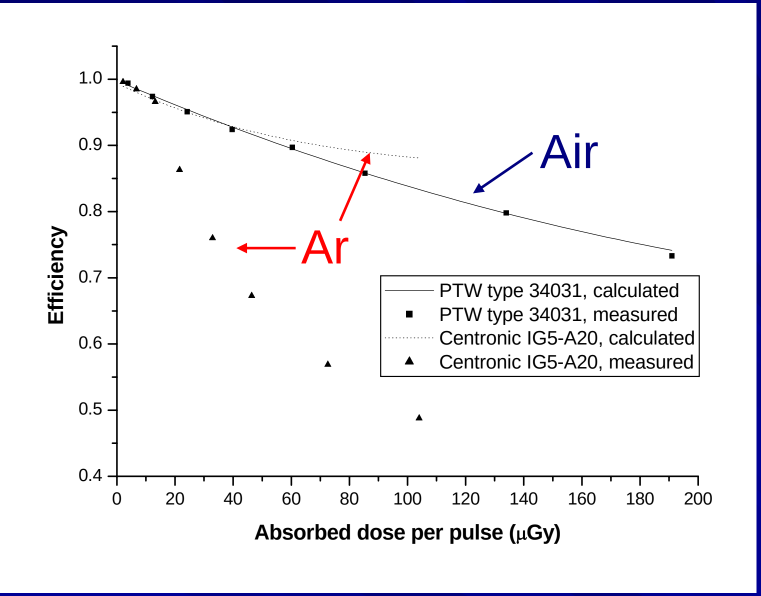


Proton beam

Beam Dump PSB

Recombination effects





90 % ion collection efficiency level

Ar	~ 15 µGy/pulse
H	~ 250 µGy/pulse
Air	~ 50 µGy/pulse

Experiment agrees well with recombination model of W. Boag (ICRU 34) for air and H

(the model is not applicable for Ar)

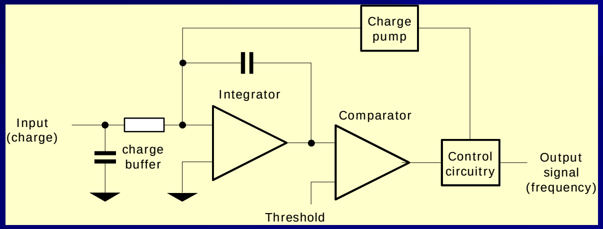
Read-Out Electronics

For pulsed fields the read-out electronics has to be based on charge digitizers

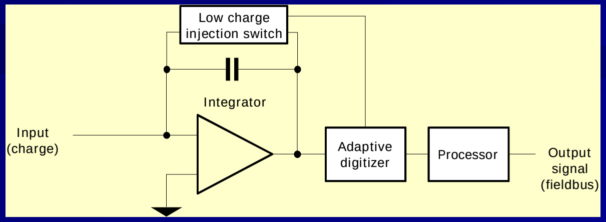
Range to be covered:

10^{-14} A (background level) - 10^{-5} A

Switching not permitted!



Present CERN electronics covers 5 – 6 decades



Newly developed: 9 – 10 decades

First tests: electronics measures reliably up to

300 nC/pulse ~ 50 mGy/hour (LHC injection)

Conclusion

- Response of ionisation chambers to pulsed, mixed high energy radiation fields is very well understood
- Detector response to LHC radiation fields can be extrapolated by Monte Carlo simulations
- Studies will be used to define RP standards in the field of radiation monitoring around particle accelerators
- Adequate read-out electronics is developed to cover a wide measuring range
- *"Pulse per pulse" data locking possible*
- Air filled plastic ionisation chambers can be used for on-line monitoring of high doses inside the tunnel or the experiments

- Further studies: optimisation of the detector design by Monte Carlo simulations (variation of fill gases, walls…)

- All radiation protection competencies, experience and tools exist to survey properly the LHC