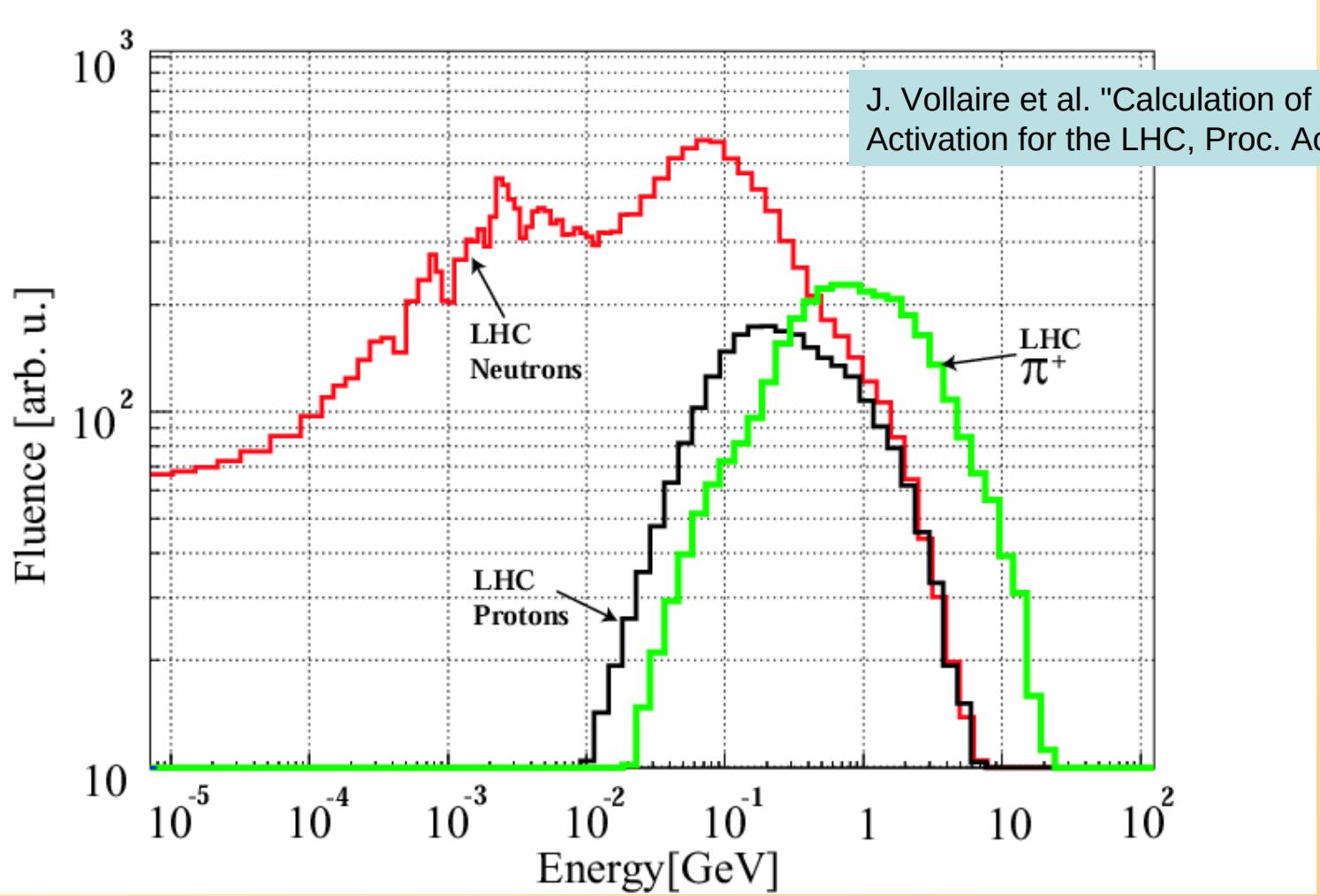
Passive dosimetry at the LHC

D. Forkel-Wirth, M. Fuerstner, F. Jaquenod,
M. Silari and H. Vincke

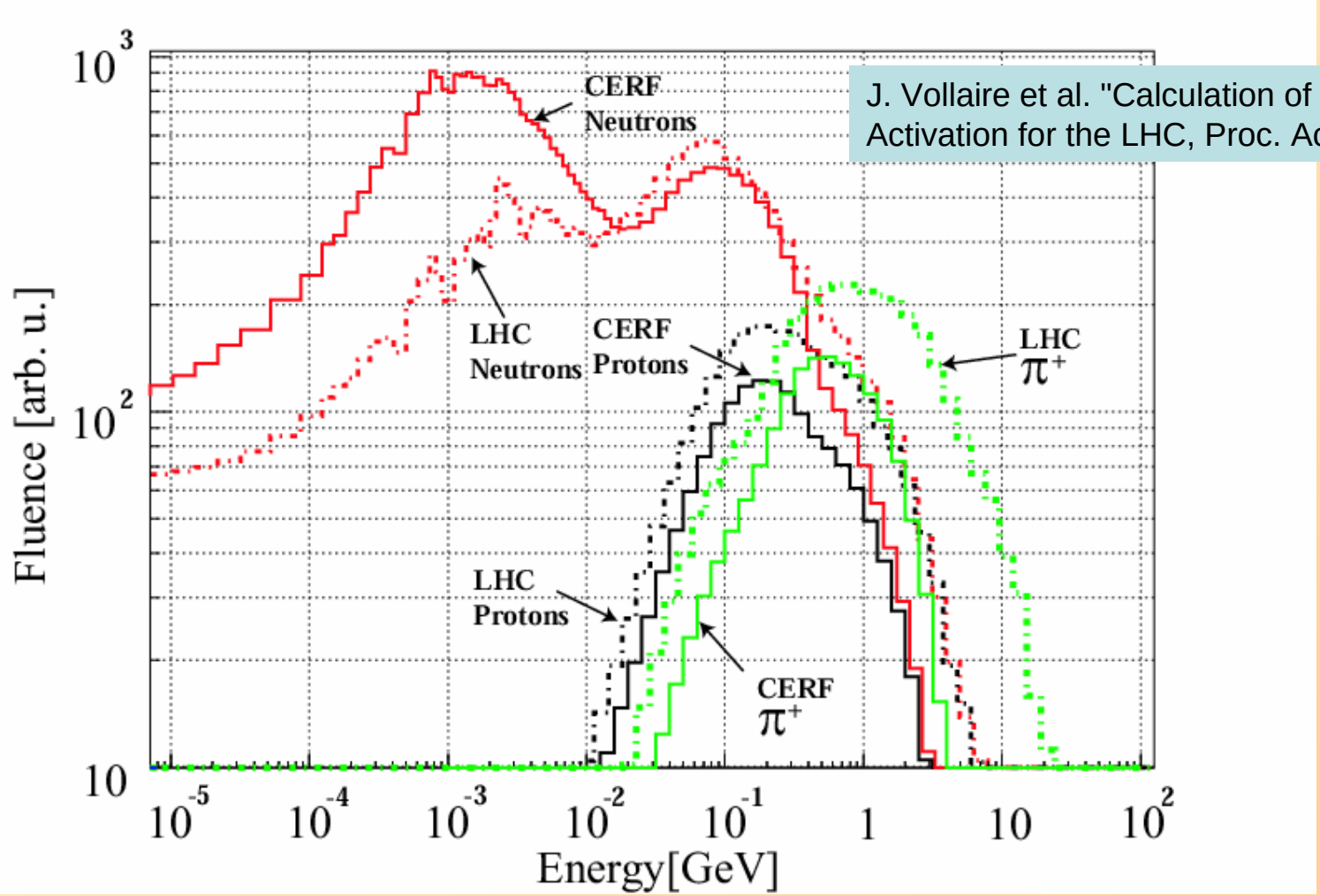
CERN Radiation Protection Group

Radiation in the LHC machine and experiments
Passive monitoring
TLD
HLD (RPL, PAD)

Radiation in the LHC



Radiation in the LHC



J. Vollaire et al. "Calculation of Water Activation for the LHC, Proc. AccApp05

When will passive dosimetry be needed?

- Sector test → very limited radiation ($5x10^{13}$ total protons, $5x10^{9}$ protons per SPS extraction), no needs for passive dosimetry, RAMSES monitors operational in TI8 and octant 8
- LHC start up → reduced luminosity expected in the first year (max 10^{33}), comparatively low integral doses
- Routine LHC operation → full monitoring needed for the:
  - machine
  - experiments

Types of passive dosimeters

- Thermo Luminescent Dosimeters, TLD (for low to intermediate doses, LHC experiments)
- Radio Photo Luminescent dosimeters, RPL (for high-level dosimetry, LHC machine)
- Polymer-Alanine Dosimeters, PAD (for LHC machine)

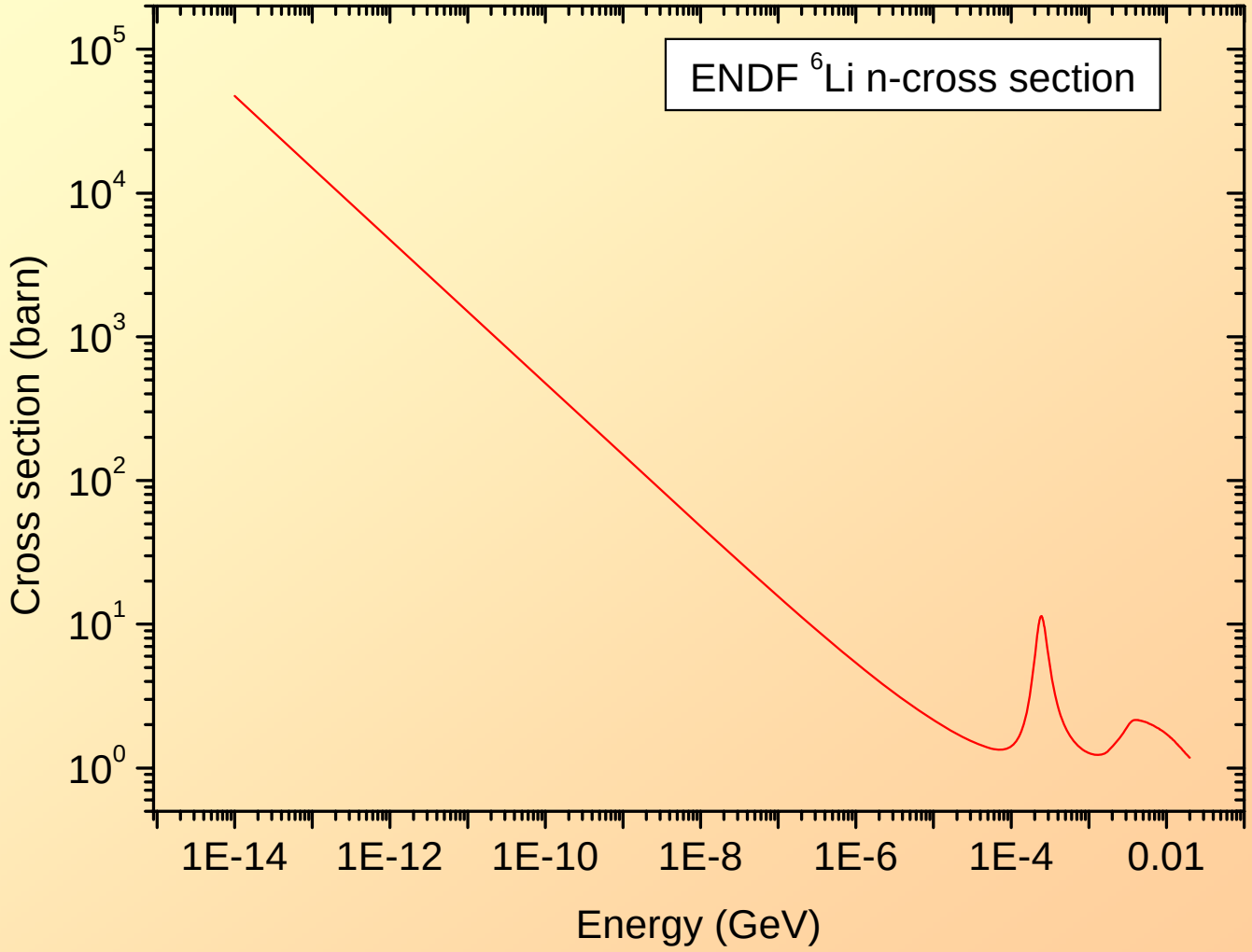
Thermo Luminescent Dosimeters

- Low to intermediate doses (natural background to a few Grays)
- Used routinely at CERN for ambient and personal dosimetry
- Response known for 'common' type of radiation like gammas, neutrons and beta particles, but little knowledge in mixed fields as those encountered around the LHC.
- Calibrated in kerma in air

TLD Lithium Fluoride

- Almost negligible fading at room temperature
- Low atomic number, which does not differ much from that of air or tissue → energy deposited in LiF is correlated to gamma dose
- Constant response over a wide range of photon energies
- Because natural lithium contains 7.4% ^{6}Li, LiF dosimeters are sensitive to slow neutrons via (n,α) reaction
- The main reaction of ^{6}Li TLD with neutrons is via radiative capture, $^{6}Li(n,\alpha)^{3}H$. The sensitivity of the TLD material to neutrons follows the cross section
- The response to neutrons can be enhanced by using lithium enriched in ^{6}Li, or suppressed by using lithium consisting entirely of ^{7}Li
- Response to high-energy neutrons via reactions other than (n,α) to be assessed

Energy response of ^{6}Li to neutrons



The TLD service of the RP group

Size of the dosimeter:
3.1 mm x 3.1 mm x 0.9 mm (23 mg)

Dose range: 10 µGy – 100 Gy
(used in practice in the interval:
10 µGy – a few mGy)

At CERN for radiation protection and environmental monitoring, use of Harshaw TLD 600 (95.6% Li-6) and TLD 700 (0.01% Li-6)

The TLD service of the RP group

One automatic reader, ALNOR (10 µGy – 2 Gy), very old instrument, very old software

One semi-automatic reader, HARSHAW, for high doses

Cross-calibration of TLDs with the environmental monitoring stations
→ TO BE IMPROVED!

The TLD service of the RP group

Number of measurements in 2003:

211 gamma measurement locations (1688 TLD readings)

442 neutron measurement locations (10608 TLD readings)

TLD requirements of the LHC users

	TLD type	TLD #	total
ALICE	^{6}LiF, ^{7}LiF	32 x 2	64
ATLAS	^{6}LiF, ^{7}LiF	88 x 2	176
CMS	under study	160 to 320	Min. 160 Max. 320
LHCb	^{6}LiF, ^{7}LiF	118 x 2	236
TOTEM	no	0	0
total			Min. 636 Max. 796

Status as of September 2005

Replacement frequency: once or twice per year

One or two sets of dosimeters

→ Rounded to 1000

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TLD outsourcing

- A contract can be placed with IFJ in Krakow, which can supply TLDs for use both in radiation protection and environmental monitoring, and for monitoring of high doses around the LHC machine and experiments
- At each measurement location:
  - one “test” dosimeter to check dose level
  - two dosimeters for intermediate dose
  - one dosimeter for high dose (to be read by special procedure)

Price estimate of TLDs outsourcing to IFJ

TLD ^{6}LiF – ^{7}LiF Material cost	SC/RP 2260 TLDs: 40.6 kCHF Experiments 796 TLDs: 14.3 kCHF
Reading (frequency = once per year)	3056 x 8 CHF= 24.5 kCHF 3056 / 4 x 8 CHF ~ 6 kCHF
Investment max 1^{rst} readout Per supplementary readout	~ 80 kCHF 6 to 24.5 kCHF

Price per slide, one to four TLDs per slide

5 euros (8 CHF):
- repacking
- reader calibration
- readout
- calculation of doses
- preparation of final certificate
- packing annealed dosimeters
- dispatch to the client

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Evaluation time: realistic to expect results one week after shipping the dosimeters to IFJ

High level dosimetry for LHC machine

Why HLD:

Determination of the total dose to material, in particular to insulation materials

Why do we need this information:

- Planning for preventive maintenance (e.g. cable exchange)
- Indicator to determine the reason of machine element faults

Where to be installed:

In areas of potentially elevated radiation doses

HLD requirements of the LHC

LHC – accelerator

- Injection lines (5 km) + warm sections of the LHC (estimated 4 km)
- About 1500 locations to be monitored (based on SPS experience)
- Dosimeter type: Radio Photo Luminescence (RPL) or Alanine dosimeters

LHC – experiments

- Clear requirements need to be posted by the experiments (estimate: several hundred dosimeters per year)

Additionally required manpower: 0.3 person/year

Progress in HLD since December 2004

Alanine

Dosimeters

Prototype of new dosimeters were manufactured and successfully tested.

13000 dosimeters were produced and are ready to be used.

New calibration curve will be available soon.

Readout devices

New dosimeter type allows an efficient EPR analysis

Dose range covered by alanine: 3 Gy – 200 kGy

Progress on RPL Dosimetry

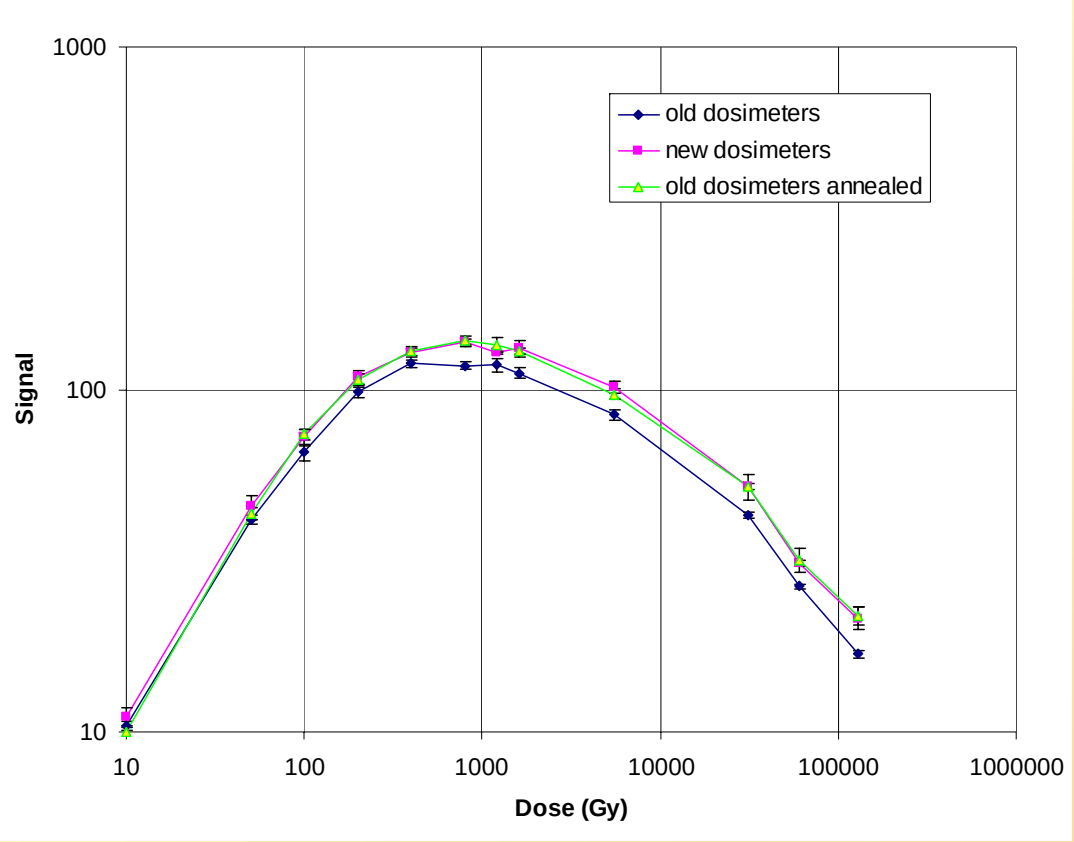
Production of cost efficient RPL dosimeters

100 RPL glass dosimeters were manufactured in China according to our specifications.

Dosimeters were irradiated to study their response. First results: response is similar to the one of the old dosimeters ➔ further analysis is ongoing.

In case of a fully satisfactory test campaign, SC-RP will purchase 20000 pieces for a price of 1 US$ per piece *(to be compared with about 20 US$ per commercially available dosimeter).*

Reuse of irradiated RPL dosimeters



First tests to anneal the dosimeters were successful. Dose stored on dosimeter after annealing process could be reset in most cases to less than 0.1% of the initial dose. Annealed dosimeters were irradiated to study the change of the dosimeter response.

➔ first results show no difference between new and annealed samples

Gamma irradiations performed at RISØ, Denmark

New RPL read-out system

The new RPL analysis machine is based on two principles:

- RPL readout by pulsed laser excitation
- measurement of optical density of the dosimeter (for the dose range 500 – 2000 Gy)

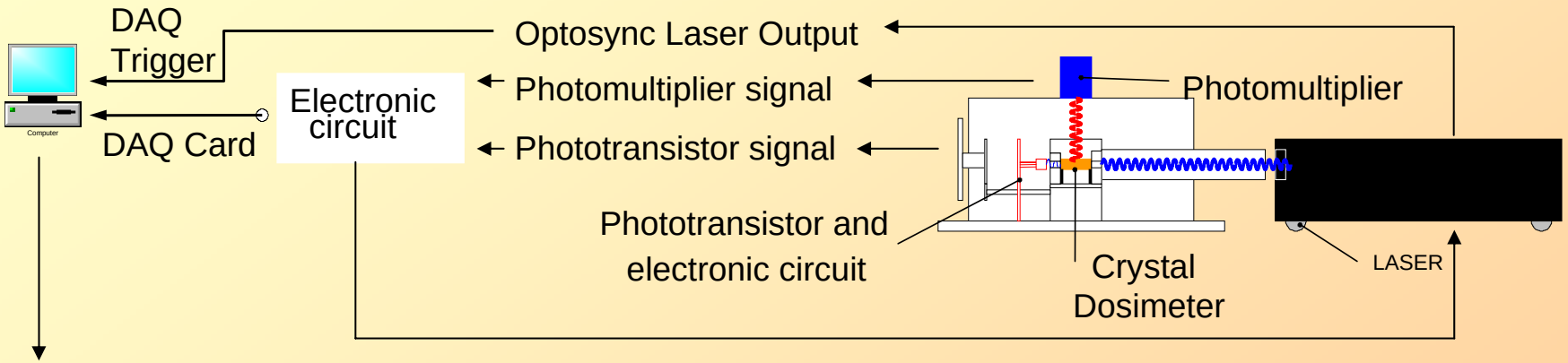
The prototype of the RPL reader is currently assembled in the Ecole d'Ingénieurs de Genève under CERN supervision (M. Fuerstner)

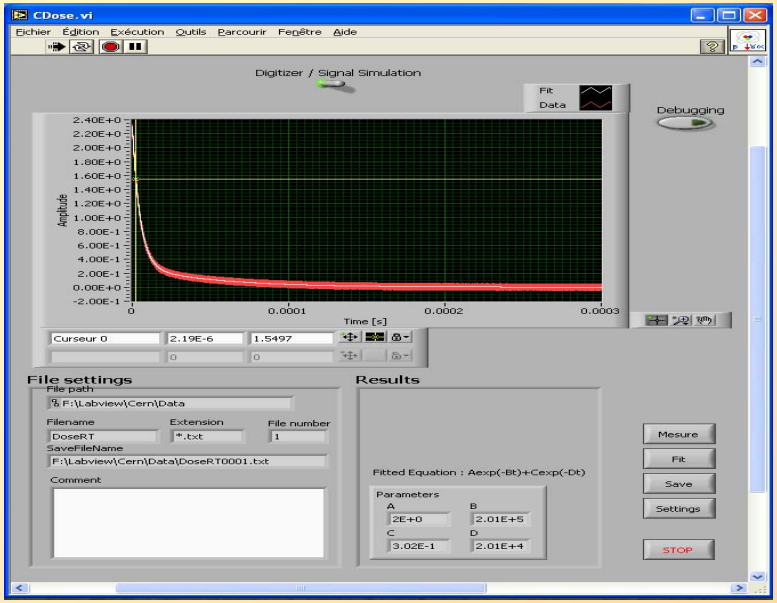
Dose range successfully tested with first prototypes:

0.1 Gy and 1 MGy

High probability to extend the dose range to both directions

Scheme and first screen shot of new RPL read-out system

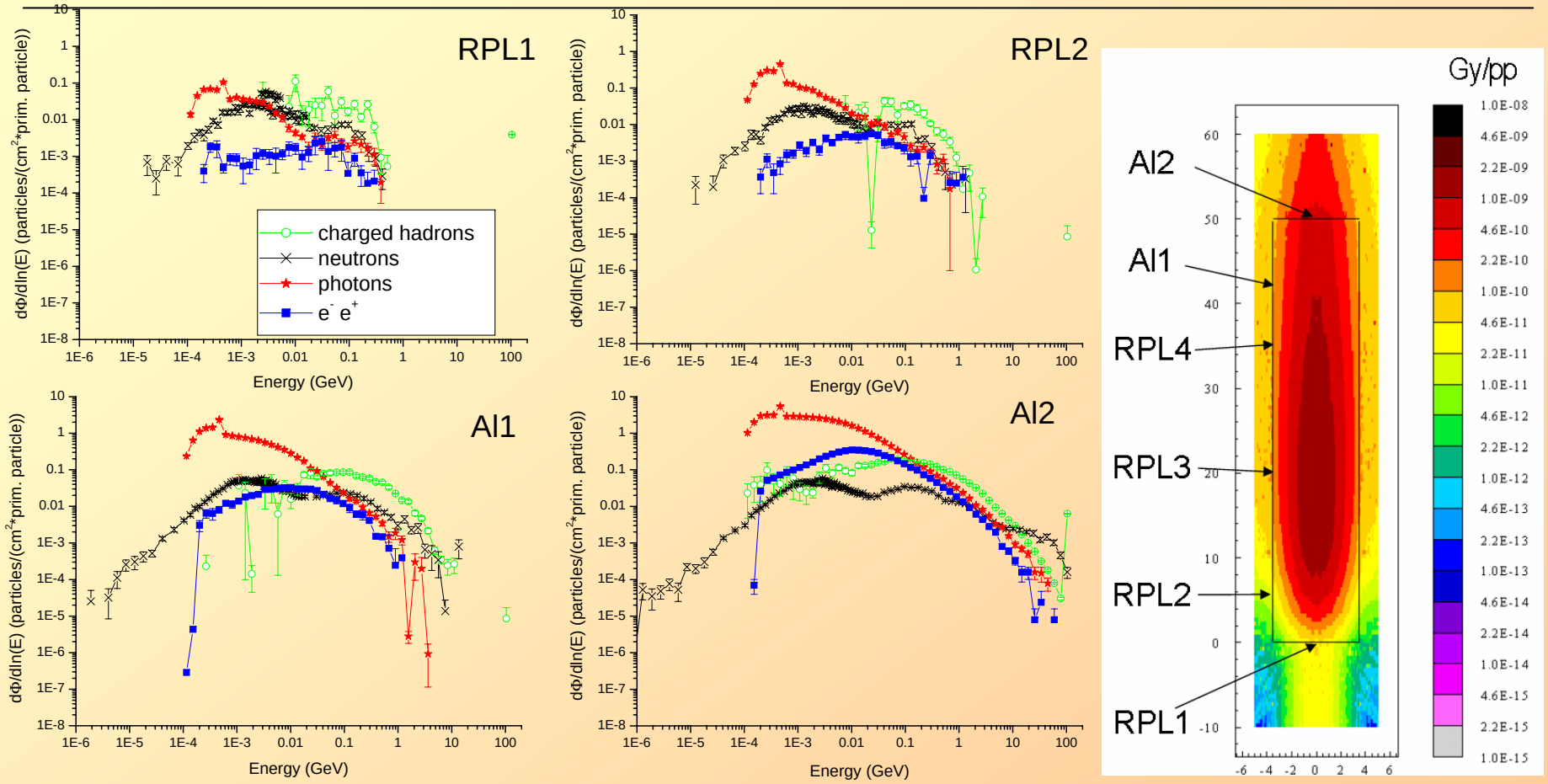




Dose (Gy)

Measurement of dose at a copper target intercepting beam (120 GeV/c)

The fluence spectra close to the beam loss points in the LHC will be similar to those present at the CERF experiment



Comparison between simulation and measurement presented last year. Agreement very good. ➔ Dose close to beam loss point can be measured in a reliable way.