

CRC

Beam lines and access

CMS upgrade meeting

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CRC facilities at Louvain-la-Neuve

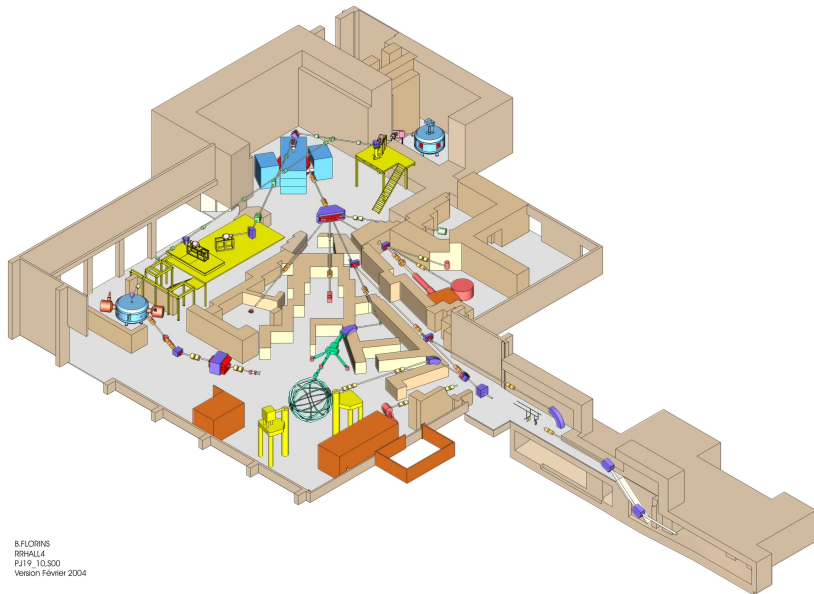
Located at Louvain-la-Neuve (~20 km from Brussels)

Institut de Recherche en Mathématique et Physique (IRMP)
Center for Cosmology, Particle Physics and Phenomenology (CP3)
Centre de Ressources du Cyclotron (CRC)

Three irradiation facilities

- NIF: Neutron Irradiation Facility
 - ▶ Fast Neutrons (0-50 MeV)
 - ▶ Flux: $10^{11}n/(cm^2 s)$
- LIF: Proton Irradiation Facility
 - ▶ Protons 10-60 MeV
 - ▶ Flux: $5 \times 10^8 p/(cm^2 s)$
- HIF: Heavy-Ion Irradiation Facility
 - ▶ Heavy Ion "cocktails"
 - ▶ Electronic failures induced by radiation

CRC facilities at Louvain-la-Neuve



B.FLORINS
RHALL4
PJ19_10.S00
Version Février 2004

1. HIF: Heavy Ion Facility

HIF: Heavy Ion Facility

Facility to measure the response of electronic components to single event effects (SEE).



Single Event Effects

SEE: Effects caused by a single energetic particle. Depends on energy released (LET)

Non-destructive effects (Soft errors)

SET: Single Event Transient

SEU: Single Event Upset

SBU: Single Bit Upset

MBU: Multiple Bit Upset

SEFI: Single Event Functional Interruption

SEL: Single Event Latchup

Destructive effects (Hard errors)

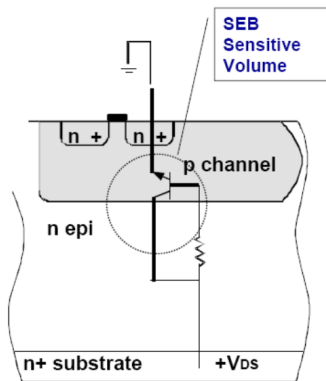
SHE: Single Hard Error (bit stuck)

SEL: Single Event Latchup

SEB: Single Event Burnout

SEGR: Single Event Gate Rupture

SEDR: Single Event Dielectric Rupture



How to measure SEE

$$\sigma = \frac{N_{\text{SEE}}}{\Phi}$$

← Number of SEE

← Fluence $\frac{\text{ions}}{\text{cm}^2}$

→ Φ : $1 - 10^4 \text{ ions/cm}^2 \rightarrow$ dead time

$\Phi \uparrow \rightarrow$ better statistical error
→ Total Dose effects

Weibull function

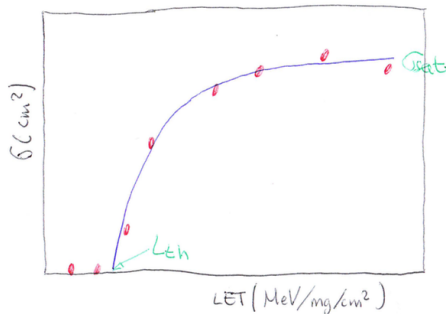
$$\sigma = \sigma_{\text{sat}} \left(1 - e^{-\left(\frac{L - L_{\text{th}}}{w}\right)^s} \right)$$

σ_{sat} : Saturation Cross-section

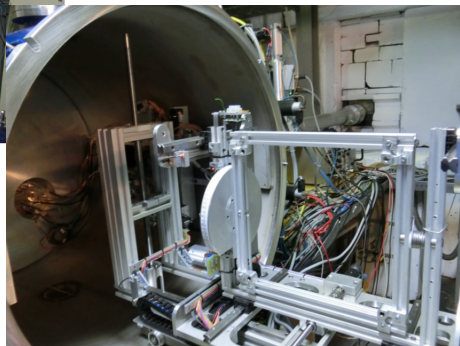
L_{th} : Threshold value

$L < L_{\text{th}} \rightarrow \sigma = 0$

w, s : fit parameters



HIF facility: the pictures



HIF characteristics

- Two heavy ions **cocktails** covering a wide range of LET and ranges.
 - ▶ Fully characterisation of SEE response of electronic components.
 - ▶ Fast ion changing within the same cocktail (few minutes)
- Beam flux is variable between a few ions/s.cm² and $\sim 10^4$ ions/s.cm²
 - ▶ Can be modified from user **station**
 - ▶ Online monitoring → high precision in fluence delivered
- Several and redundant **metrology**
 - ▶ Fluence and energy
 - ▶ Moving frame, alignment system
 - ▶ ESA SEU monitor: 4x4 Mbit SRAM (Atmel AT60142F) arranged in a square region of 24mm x 24mm
- Beam homogeneity of 10% on a 25 mm diameter.
- Standard mechanical interface and feedthroughs
- Irradiations are done in vacuum and for most of the ions naked chips are needed.

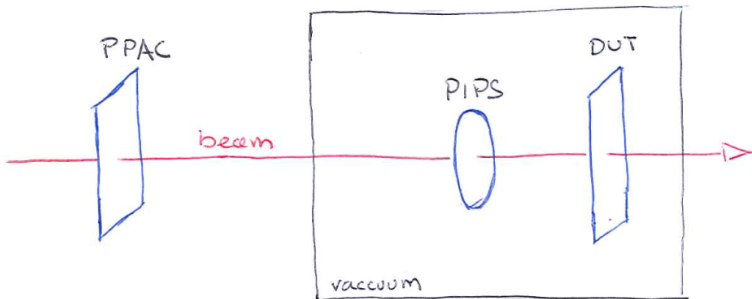
HIF "cocktails"

| | | M/Q | Ion | DUT energy [MeV] | Range [$\mu\text{m Si}$] | LET [MeV/mg/cm ²] |
|------------|------------------|------|----------------------------------|---------------------|-------------------------------|----------------------------------|
| Cocktail 1 | High LET | 5 | ¹⁵ N ³⁺ | 60 | 59 | 3.3 |
| | | 5 | ²⁰ Ne ⁴⁺ | 78 | 45 | 6.4 |
| | | 5 | ⁴⁰ Ar ⁸⁺ | 151 | 40 | 15.9 |
| | | 4.94 | ⁸⁴ Kr ¹⁷⁺ | 305 | 39 | 40.4 |
| | | 4.96 | ¹²⁴ Xe ²⁵⁺ | 420 | 37 | 67.7 |
| Cocktail 2 | High penetration | 3.25 | ¹³ C ⁴⁺ | 131 | 292 | 1.1 |
| | | 3.14 | ²² Ne ⁷⁺ | 235 | 216 | 3 |
| | | 3.33 | ⁴⁰ Ar ¹²⁺ | 372 | 117 | 10.2 |
| | | 3.22 | ⁵⁸ Ni ¹⁸⁺ | 567 | 100 | 20.4 |
| | | 3.32 | ⁸³ Kr ²⁵⁺ | 756 | 92 | 32.6 |
| | | 3.54 | ¹²⁴ Xe ³⁵⁺ | 995 | 73 | 62.5 |

Quality assurance

For each run/cocktail a whole calibration and quality assurance procedure is performed.

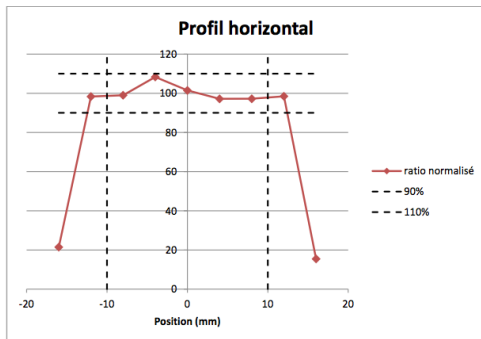
1. Fluence: PPAC+PIPS
2. Profile: PIPS+SEU monitor
3. Energy: PIPS



QA: Beam profile and beam energy

1) Horizontal profile

| | |
|--------------------------|------------------------------|
| Reference beam : | $^{40}\text{Ar}^{8+}$ 151MeV |
| Horizontal homogeneity : | 24 mm |
| Minimum X value(mm) : | -12 mm |
| Maximum X value (mm) : | +12 mm |



| <u>Cocktail</u> | <u>Particle</u> | <u>Energy DUT (MeV)</u> | <u>Measured energy (MeV)</u> |
|-----------------|-------------------------|-------------------------|------------------------------|
| M/Q =5 | $^{15}\text{N}^{3+}$ | 60 | 60 |
| | $^{20}\text{Ne}^{4+}$ | 78 | 76 |
| | $^{40}\text{Ar}^{8+}$ | 151 | 144 |
| | $^{84}\text{Kr}^{17+}$ | 305 | 290 |
| | $^{124}\text{Xe}^{25+}$ | 420 | 410 |

QA: SEU monitor

| | | | | | |
|-----|-----|-----|-----|-----|-----|
| 540 | 518 | 530 | 539 | 552 | 538 |
| 538 | 517 | 583 | 535 | 539 | 508 |
| 562 | 530 | 520 | 534 | 557 | 523 |
| 521 | 532 | 523 | 568 | 525 | 549 |
| 517 | 494 | 536 | 508 | 535 | 553 |
| 510 | 539 | 567 | 541 | 538 | 552 |
| 565 | 560 | 503 | 529 | 540 | 557 |
| 554 | 540 | 589 | 543 | 549 | 576 |
| 540 | 561 | 537 | 563 | | |
| 539 | 575 | 606 | 562 | | |
| 512 | 536 | 551 | 601 | | |
| 582 | 523 | 559 | 568 | | |
| 585 | 576 | 583 | 543 | | |
| 554 | 532 | 529 | 566 | | |
| 536 | 528 | 809 | 567 | | |
| 545 | 585 | 588 | 614 | | |
| 568 | 564 | 543 | 560 | 568 | 540 |
| 566 | 577 | 579 | 551 | 493 | 528 |
| 525 | 609 | 533 | 541 | 579 | 562 |
| 543 | 516 | 554 | 547 | 553 | 561 |
| 574 | 538 | 542 | 531 | 543 | 549 |
| 536 | 508 | 573 | 554 | 565 | 560 |
| 486 | 537 | 576 | 538 | 565 | 579 |
| 569 | 546 | 557 | 563 | 536 | 557 |

DIE 0

| | | | | | |
|-----|-----|-----|-----|-----|-----|
| 551 | 555 | 525 | 568 | 501 | 498 |
| 562 | 548 | 540 | 511 | 521 | 548 |
| 573 | 563 | 583 | 572 | 552 | 482 |
| 558 | 525 | 541 | 514 | 528 | 539 |
| 548 | 554 | 562 | 569 | 519 | 550 |
| 588 | 482 | 545 | 544 | 534 | 548 |
| 570 | 549 | 567 | 513 | 533 | 552 |
| 555 | 561 | 545 | 569 | 537 | 510 |
| 579 | 569 | 549 | 549 | 536 | |
| 527 | 551 | 556 | 553 | | |
| 560 | 571 | 533 | 552 | | |
| 629 | 533 | 534 | 577 | | |
| 651 | 536 | 555 | 533 | | |
| 624 | 536 | 481 | 546 | | |
| 625 | 554 | 532 | 556 | | |
| 545 | 585 | 541 | 537 | 535 | 513 |
| 575 | 607 | 554 | 537 | 537 | 499 |
| 538 | 547 | 527 | 542 | 557 | 487 |
| 531 | 516 | 542 | 529 | 538 | 522 |
| 514 | 560 | 553 | 498 | 497 | 479 |
| 535 | 530 | 536 | 522 | 541 | 544 |
| 559 | 524 | 502 | 552 | 495 | 496 |
| 526 | 497 | 526 | 484 | 526 | 524 |

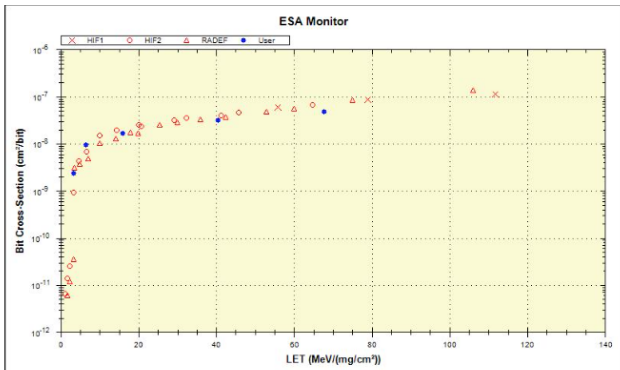
DIE 2

Moyenne 535
110% 589
90% 482

| | | | | | |
|-----|-----|-----|-----|-----|-----|
| 485 | 502 | 502 | 525 | 509 | 543 |
| 436 | 480 | 504 | 476 | 522 | 503 |
| 462 | 514 | 508 | 517 | 527 | 510 |
| 508 | 525 | 502 | 517 | 548 | 554 |
| 486 | 495 | 495 | 483 | 526 | 506 |
| 476 | 568 | 546 | 505 | 522 | 517 |
| 519 | 522 | 538 | 533 | 513 | 527 |
| 522 | 577 | 555 | 579 | 541 | 522 |
| 547 | 545 | 528 | 522 | | |
| 527 | 539 | 534 | 518 | | |
| 490 | 515 | 524 | 571 | | |
| 491 | 518 | 525 | 551 | | |
| 519 | 508 | 553 | 518 | | |
| 521 | 539 | 540 | 567 | | |
| 523 | 534 | 559 | 586 | | |
| 536 | 506 | 542 | 495 | | |
| 563 | 526 | 492 | 544 | 531 | 541 |
| 518 | 535 | 524 | 543 | 543 | 505 |
| 488 | 543 | 526 | 525 | 497 | 554 |
| 533 | 541 | 521 | 560 | 533 | 551 |
| 515 | 517 | 547 | 558 | 558 | 543 |
| 491 | 534 | 518 | 512 | 509 | 548 |
| 515 | 547 | 526 | 563 | 525 | 565 |
| 550 | 537 | 512 | 510 | 500 | 550 |

DIE 1

COKTAIL: M/Q = 5
ION: 40Ar8+
ENERGIE DUT: 151 MeV
LET: 15,9 Mev/(mg/cm²)
TOTAL WORD ERROR: 258944
TOTAL BIT ERROR: 274072
FLUENCE: 1,00E+06 Part/cm²
CROSS SECTION: 1,633E-08 cm²/bit

Courbe des sections efficace $\sigma_{(LET)}$ 

return

User station control panel

BEAM ON/OFF

Time Stamp
12:55:37
14/01/2015

User

VS PIPS call PIPS scan HOME X PIPS scan HOME Y Faraday local

CF1 out tilt angle
run number
4
0

Ion
Kr-305

Energy [MeV] Range [$\mu\text{m Si}$]
305 39

LET [MeV/mg/cm²] LETeff [MeV/mg/cm²]
40,4 40,4

save now

PPAC (part/s)
11863

Normal Flux [part/s cm²]
2673

Desired fluence [part/cm²]
50000

Elapsed Time (sec)
5

Estimated Remaining Time (sec)
0

Device flux [part/s cm²]
2673

Reached Fluence [part/cm²]
13358

Remaining Fluence [part/cm²]
39315

intermeasure time (sec)
1

Run Dose [Rad]
14,5

Mean Device flux [part/s cm²]
2671

Remaining Fluence [%]

Plot 0

Time Device flux

2. NIF: Neutron Irradiation Facility

NIF: Neutron Irradiation Facility

Bulk damage in materials.

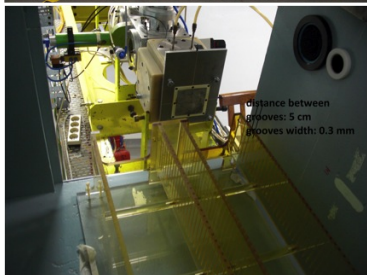
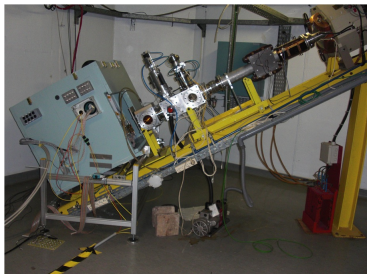
- 50 MeV deuterons on Be target:
- $I_d \sim \mu A$
- Filters for γ and low energy neutrons
 - ▶ 10 mm polyethylene
 - ▶ 1 mm cadmium
 - ▶ 1 mm lead
- Cool box (downto -25 C)

| d(cm) | R(cm) | t(h) |
|-------|-------|------|
| 5 | 2 | 1.6 |
| 20 | 5 | 24 |
| 40 | 8 | 88 |

d : distance to target

R : Radius (80% neutrons)

t : time for $\Phi = 10^{14}$ n/cm² ($I_d = 1\mu A$)



Neutron Energy

- Continuous spectra
- Low energy neutrons removed
- MPV = 23 MeV
- Maximum neutron energy 50 MeV

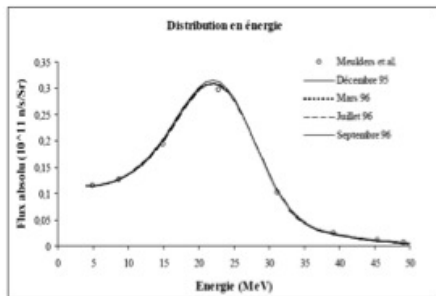


Figure 3.12 : Comparaison des résultats de “déconvolution” ajustés par une fonction « spline » avec quelques points mesurés par Meulders et al. [42].

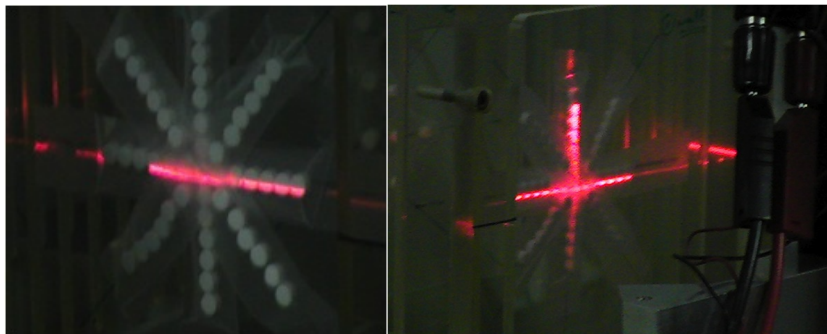
Fluence control

- Deuterons current measured continuously.

$$\Phi(\text{n/cm}^2) = 10^{14} \frac{I(\mu\text{A}) t(\text{h})}{0.079r^{1.902}}$$

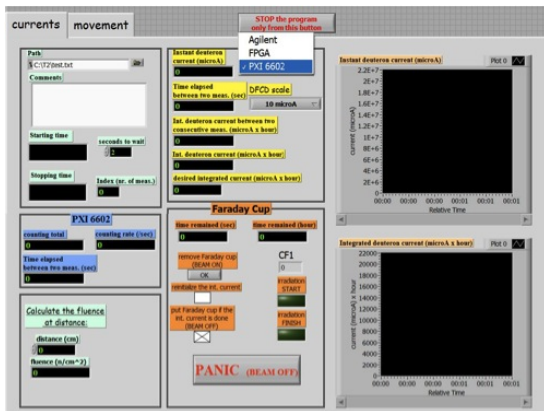
- Alanine dosimeters: present in all irradiations

$$D(\text{Gy}) = \Phi \times K \quad K=4.16 \text{ fGy m}^2$$



NIF control

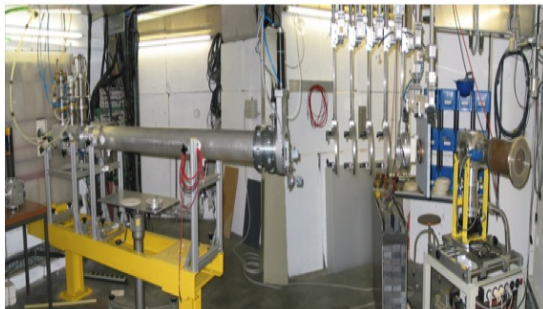
- Control fully automatized
 - Instantaneous and integrated current
 - Beam control
 - Box temperature and movement



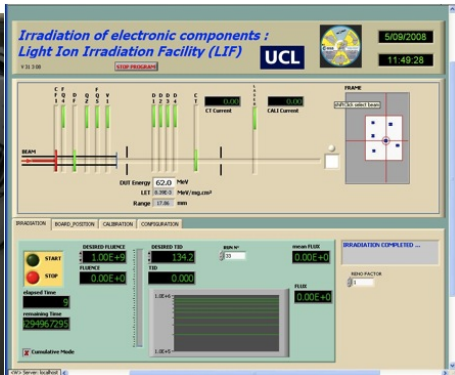
3. LIF: Proton Irradiation Facility

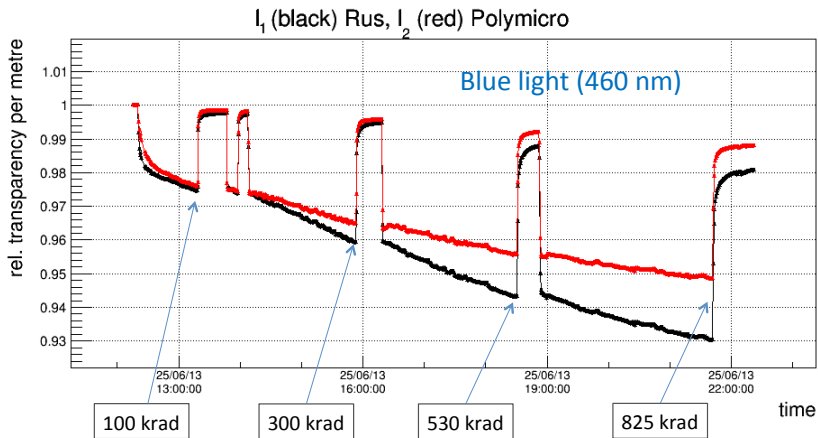
LIF: Proton Irradiation Facility

- Protons 62 MeV + Energy degraders (Polystyrene blocks)
- Max Flux: 10^9 p/(cm² s)
- Homogeneity: $\pm 10\%$ on a diameter of 8 cm
- Spot size: collimator from 1-8 cm
- Dosimetry:
 - ▶ Profile: Water Phantom + diodes
 - ▶ Flux: Ionization chamber
 - ▶ Energy: Faraday cup + SEU monitor from ESA



Energy degraders and control





Tested were two types of pure silica-high OH quartz fibers with 200 μ core, produced by Polymicro (USA) and Fryazino (Russia). Both found to be good enough for the upgrade of LHCb ECAL calibration system.

Transparency loss measured after short (20-30 min) annealing, for LHCb dose rates (< 0.01 rad/s) can be considered as an upper limit.

| dose, krad | transparency loss, % / m | |
|------------|--------------------------|------|
| | Polymicro | Rus |
| 100 | 0.14 | 0.23 |
| 300 | 0.45 | 0.54 |
| 530 | 0.8 | 1.2 |
| 825 | 1.2 | 1.9 |

Access to CRC

- CRC runs from March to December (2-3 weeks break in summer)
 - ▶ HIF 2/3 weeks/month
 - ▶ LIF,NIF 1-2 days/month
- Access cost: ~ 750 EUR/h (for all facilities)
~ 400 EUR/h (for belgian universities)
"Free" for AIDA2020 (belgian institutes not eligible)
"Free" for UCL users
- Contact persons:
Nancy.Postiau@uclouvain.be
Eduardo.Cortina@uclouvain.be (for AIDA2020)