International Associated Laboratory France-Ukraine (2015-2018)

IDEATE LIA

http://ideate.lal.in2p3.fr/en/home/

"IDEATE: Instrumentation Developments for Experiments at Accelerator facilities and accelerating TEchniques"

- Collaboration between CNRS, CEA and Universities from French side and leading research Institutes and Universities from Ukrainian side
- **Research** and **educational** components of the LIA:
  students become major actors in scientific projects
- **> 120 participants, > 30 FTE**

Web site : http://ideate.lal.in2p3.fr/en/home/

LIA partners

- Laboratoire de l'Accélérateur Linéaire (IN2P3/CNRS and Paris-Sud University)
- Laboratoire de Physique Théorique (IN2P3/CNRS and Paris-Sud University)
- Institut de Physique Nucléaire Orsay (IN2P3/CNRS and Paris-Sud University)
- Centre de Sciences Nucléaires et de Sciences de la Matière (IN2P3/CNRS and Paris-Sud University)
- Imagerie et Modélisation en Neurobiologie et Cancérologie (CNRS, Paris Diderot University and Paris-Sud University)
- Laboratoire de Physique Corpusculaire (IN2P3/CNRS and Blaise Pascal University)
- Laboratoire de Physique Nucléaire et de Hautes Energies (CNRS, Paris Diderot and Pierre et Marie Curie University)
- Laboratoire Leprince-Ringuet (IN2P3/CNRS and Ecole Polytechnique)
- Institut Pluridisciplinaire Hubert Curien (CNRS and Strasbourg University)
- Service de Physique des Particules (IRFU, DSM/CEA)
- Service de Physique Nucléaire (IRFU, DSM/CEA)
- Service d'Électronique des Détecteurs et d'Informatique (IRFU, DSM/CEA)

- Taras Shevchenko National University of Kyiv
- V.N. Karazin Kharkiv National University
- O. I. Akhiezer Institute for Theoretical Physics, NSC "Kharkov Institute of Physics and Technology"
- Institute of High-energy Physics and Nuclear Physics, NSC "Kharkov Institute of Physics and Technology"
- Institute of Applied Physics National Academy of Sciences of Ukraine
- Kyiv Institute for Nuclear Research National Academy of Sciences of Ukraine
- M. M. Bogolyubov Institute for Theoretical Physics National Academy of Sciences of Ukraine

Joined recently:

- The E.O.Paton Electric Welding Institute of the National Academy of Sciences of Ukraine
- Institute for Scintillation Materials of the National Academy of Sciences of Ukraine
- Department of Nuclear Physics in Uzhgorod National University

Main axes of the LIA IDEATE

- Virtual laboratory comprising
  22 laboratories/centers/institutes/universities,
  unique combination of expertise

1. **R&D on detector techniques, joint construction and exploitation of experimental platforms**
2. **R&D on accelerator techniques**
3. **Developments for Flavour Physics, Nuclear and Hadron Physics**
4. **Instrumentation for medical imaging**
5. **Pedagogical activities**

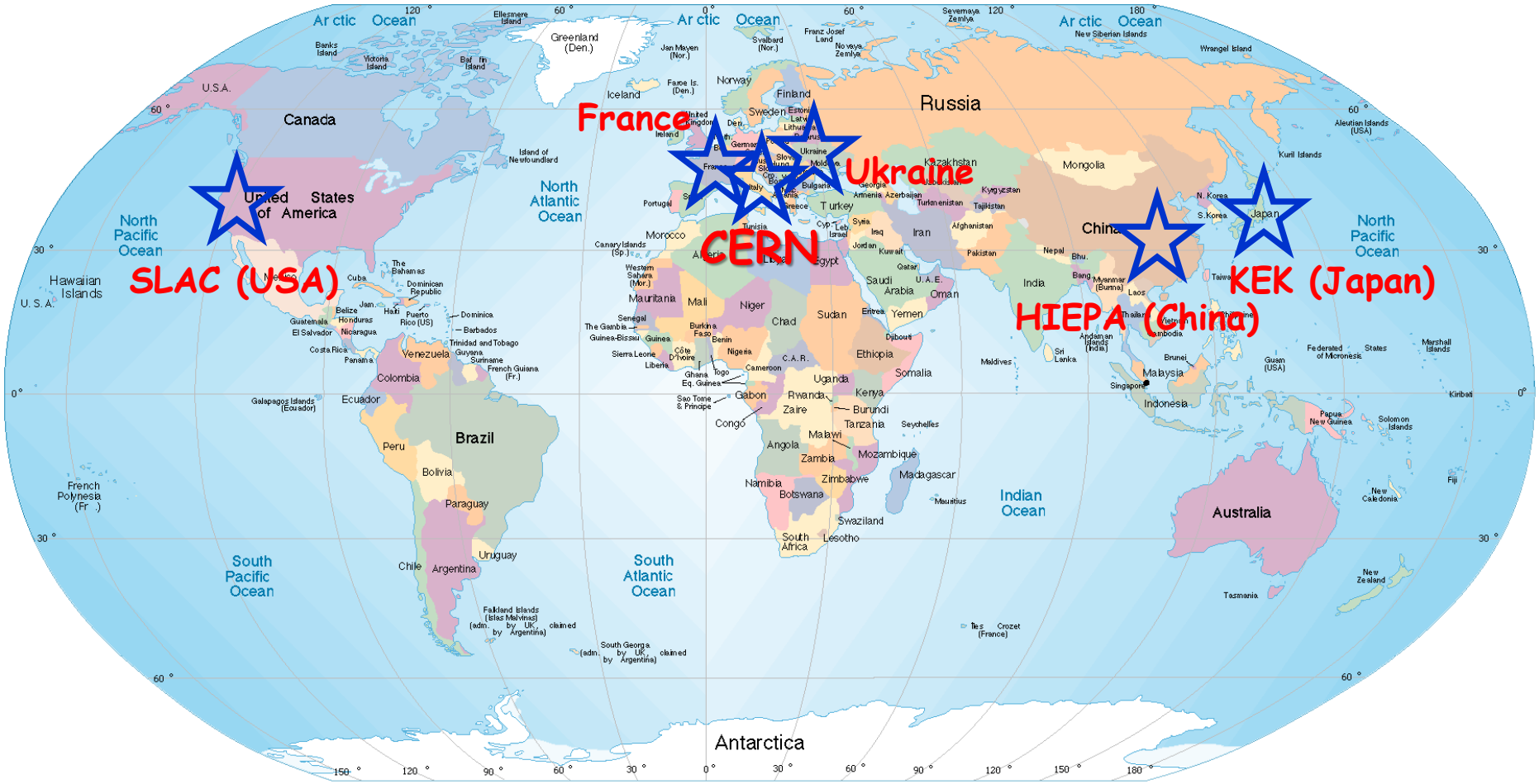
- LIA-Associated European project (STCU) on **R&D of instrumentation for medical physics** hosted by major Ukrainian universities (talk by Oleg Bezshyyko and Sergii Fomin).
- LIA IDEATE was formally associated to the **road map for CERN-Ukraine program**.

LIA IDEATE : basic principles

- Intimate **link between research and educational programs**
- Symbiosis of expertise of senior scientists and research work by the (Bachelor, Master and PhD) students within LIA program :
  - **4 PhD theses under joint supervision**
  - Students regularly enter **UPSud Master** programs (NPAC, GI, …)
- (Other) **exchanges** :
  - ~30 **visits of scientists** (both directions) + participation in the workshops
  - ~50 **student internships**, > 100 student x months of internships

LIA IDEATE on the map

- Joint contributions to the experiments/projects in France and Ukraine, at CERN, SLAC (USA), HIEPA (China), KEK (Japan)



Joint meetings/workshops, 2015-2017

- 3rd French-Ukrainian instrumentation workshop at LAL, October 15-16, 2015, http://french-ukrainian-workshop-2015.lal.in2p3.fr/
- Workshop on magnetic moment of charmed baryons, LAL, February 2, 2016, https://wpsist.lal.in2p3.fr/macumba/
- LIA workshop on medical physics, Kiev University, March 3-4, 2016, http://science.univ.kiev.ua/french-ukrainian/pages/prog.html
- Symposium on new technologies in positron emission tomography, August 31 – September 1, 2016, Kyiv University, http://ntpet.univ.kiev.ua/
- 4th French-Ukrainian instrumentation workshop at LAL, October 19-21, 2016, http://french-ukrainian-workshop-2016.lal.in2p3.fr/
- LIA workshop on medical physics, Kharkiv University, April 20-21, 2017, http://fcuw.univer.Kharkov.ua
- 5th French-Ukrainian instrumentation workshop at LAL, November 6-8, 2017, http://french-ukrainian-workshop-2017.lal.in2p3.fr/ , associated to the meeting of the ERDIT European platform at LAL and SOLEIL, November 8-10, 2017.

IDEATE LIA

French-Ukrainian WORKSHOP

Instrumentation developments for high energy physics

October 19-21, 2016 LAL - Orsay, France

- 50 contributions
- 50 participants

France: CPO, CSNSM, IMNC, IPN, IRFU, LAL, LLR, LPNHE, LPT

Ukraine: IAP-Sumy, KINR, KIPT, KNU, TSNUK

Other world: Frankfurt Uni (Germany), Rutgers Uni (USA), USTC (China)

FRENCH-CERN-UKRAINIAN WORKSHOP ON

MEDICAL PHYSICS and IMAGING

April 20 – 21, 2017

V.N. Karazin Kharkiv National University
Kharkiv, Ukraine

Organizing Committee: -
Vil Bakirov (KKNU, Ukraine)
Sergey Barsuk (LAL/IN2P3, France)
Oleg Bezhyyko (TSNUK, Ukraine)
Manuela Cirilli (CERN)
Sergii Fomin (KKNU, NSC KIPT, Ukraine)
Igor Girka (KKNU, Ukraine)
Borys Grinyov (DFFD, Ukraine)
Serhii Hirnyk (KKNU, Ukraine)
Leonid Davydov (NSC KIPT, Ukraine)
Vyacheslav Sharyy (IRFU/CEA Saclay, France)
Mykola Shul'ga (KKNU, NSC KIPT, Ukraine)
Achille Stocchi (LAL/IN2P3, France)
Maxim Titov (IRFU/CEA Saclay, France)
Dimitris Visvikis (INSERM/University Brest, France)

Invited Speakers:
Oleg AVRUNIN (KNURE, Ukraine)
Oleksandr DYOMIN (ISMA, Ukraine)
Hadi FAYAD (INSERM/University Brest, France)
Rita FERREIRA (CERN)
Igor PAPIROV (NSC KIPT, Ukraine)
Vyacheslav SHARYY (IFRU/CEA Saclay, France)
Maxim TITOV (IFRU/CEA Saclay, France)
Lukas TLUSTOS (CERN)
Artem TROFIMOV (KNURE, Ukraine)
Maxym TYMKOVYCH (KNURE, Ukraine)

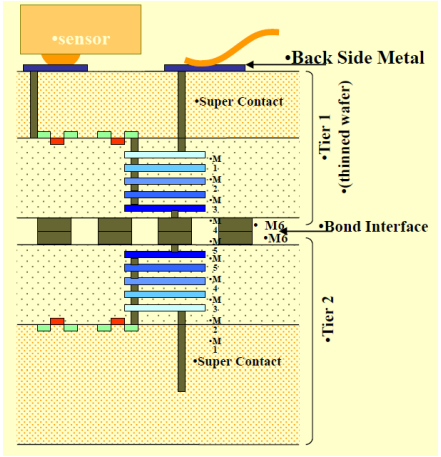
http://fcuw.univer.kharkov.ua

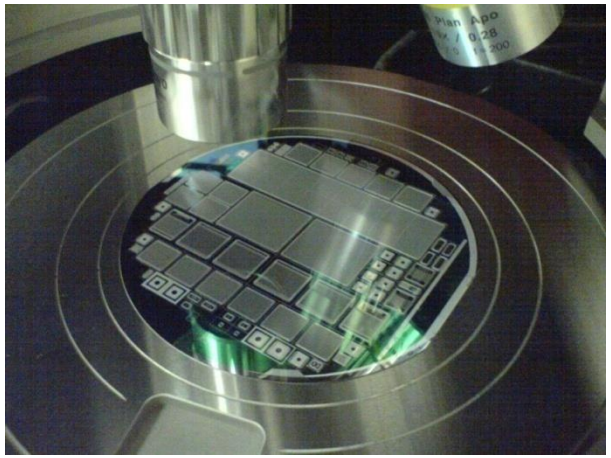
Bruno Mazoyer LAL Orsay 2017

Examples of joint developments

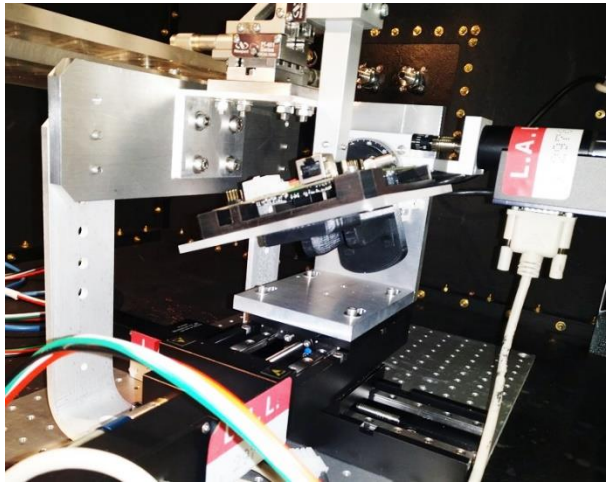
LAL – LPNHE – Kiev U

- Silicon (edgeless) sensors, 3D Front-End Electronics, track reconstruction at the trigger level.





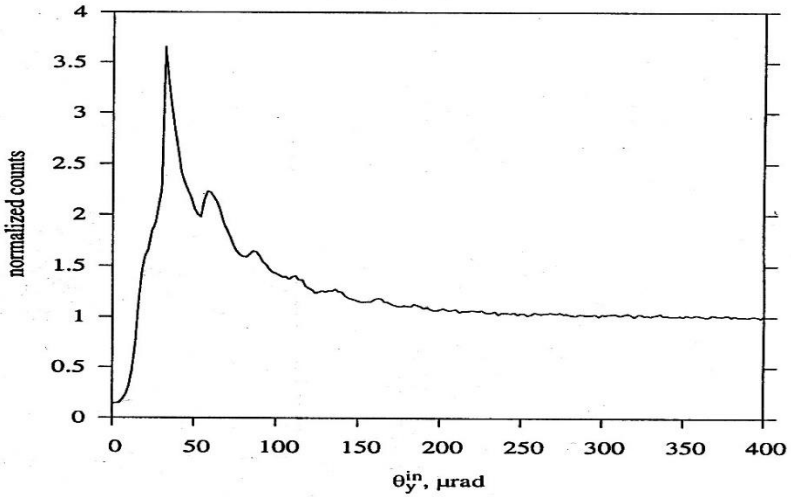
- Activity integrated in projects, involving large community
- Participation of Kiev U via internships (in Paris/Orsay/Kiev)
- Sensor design and test
- Design and implementation of test benches and cards in the framework of 65 nm electronics development



- FastTrack applications for track trigger
- Improvement of Laser testbench for pixel module characterization, tests in inclined pixel position

KIPT – Kharkiv U – LAL – Kiev U – CERN – INFN (joint PhD thesis)

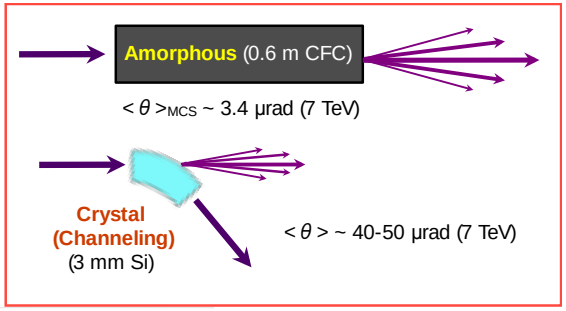
- Beam-beam coherent radiation (applications for beam monitoring)

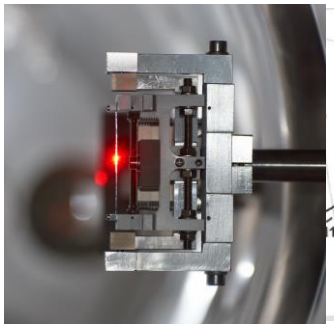


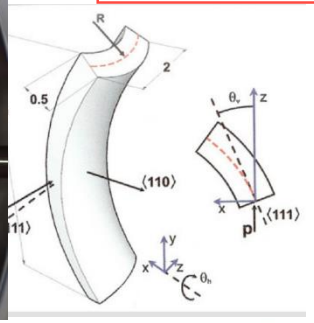
Close q+ collision in bent crystal
Yu. Chesnokov, I. Kirillin, W. Scandale, N. Shul'ga, V. Truten'
(Kharkov-Orsay-CERN-Protvino)
PLB 2014

- R&D for the upgrade of the LHC collimation system

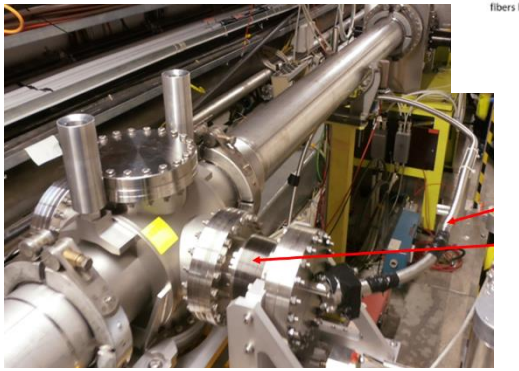
- Beam deflection by bent crystal (UA9)

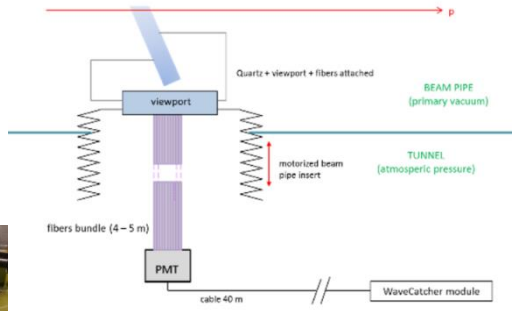






- CpFM detector at SPS

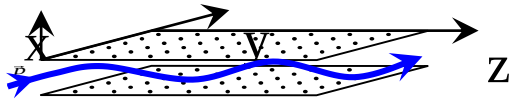




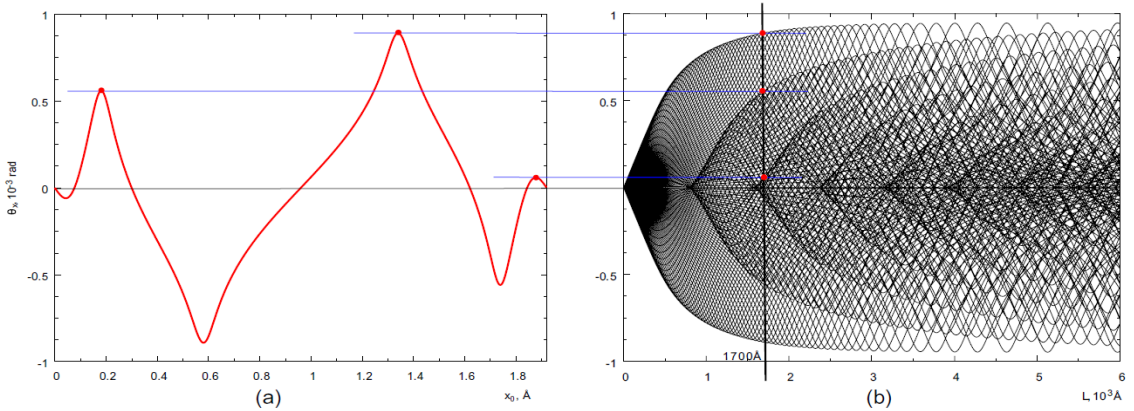
Theory development to propose experiment at electron machines: **electrons in ultrathin Si crystal**

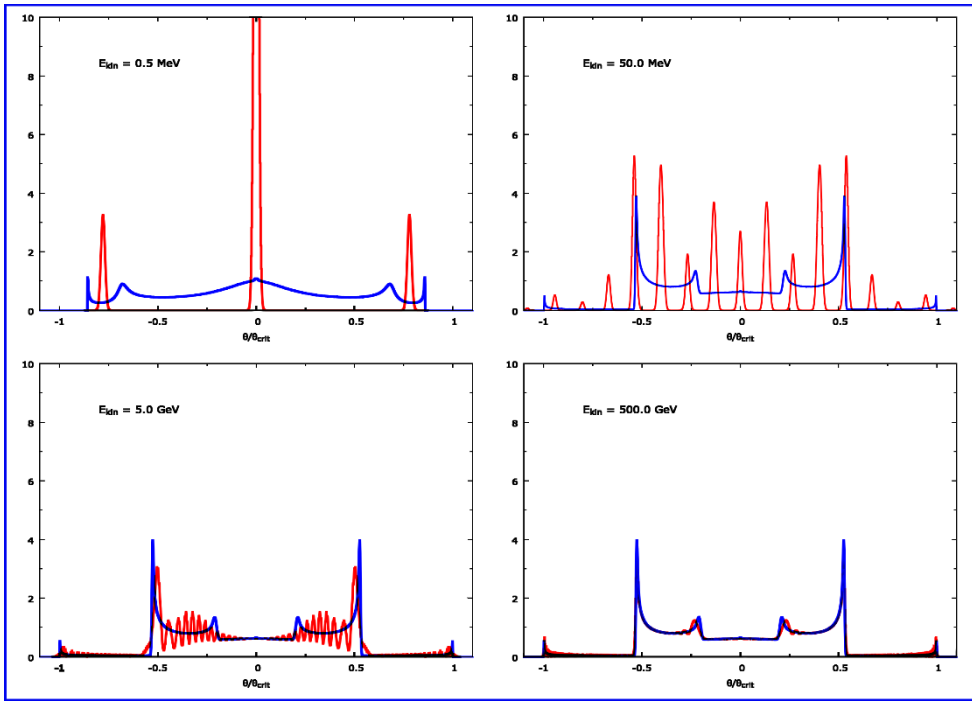
LAL – Kharkiv U – KIPT

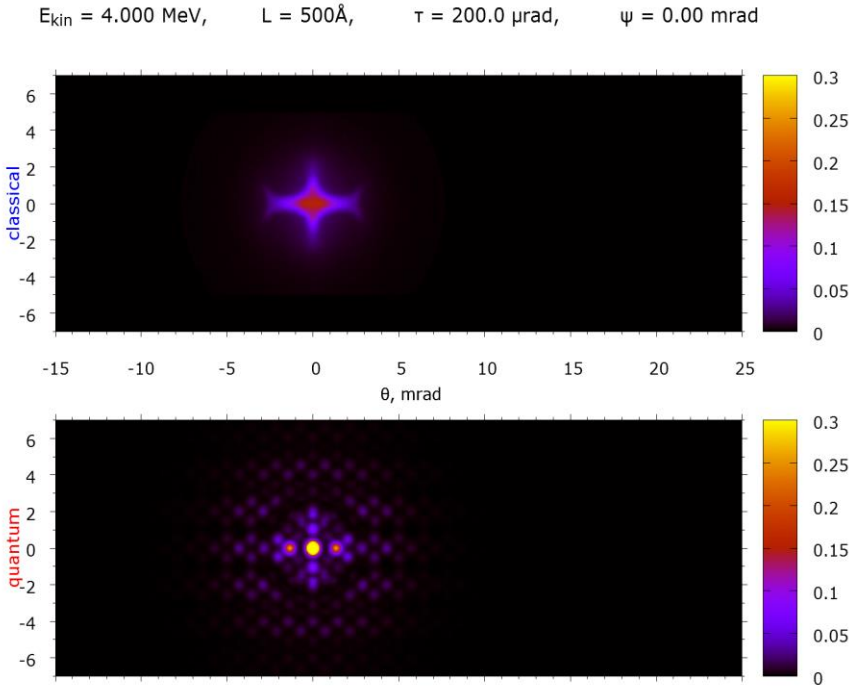
NIM B402 (2017) 16



scattering on
(110) plane



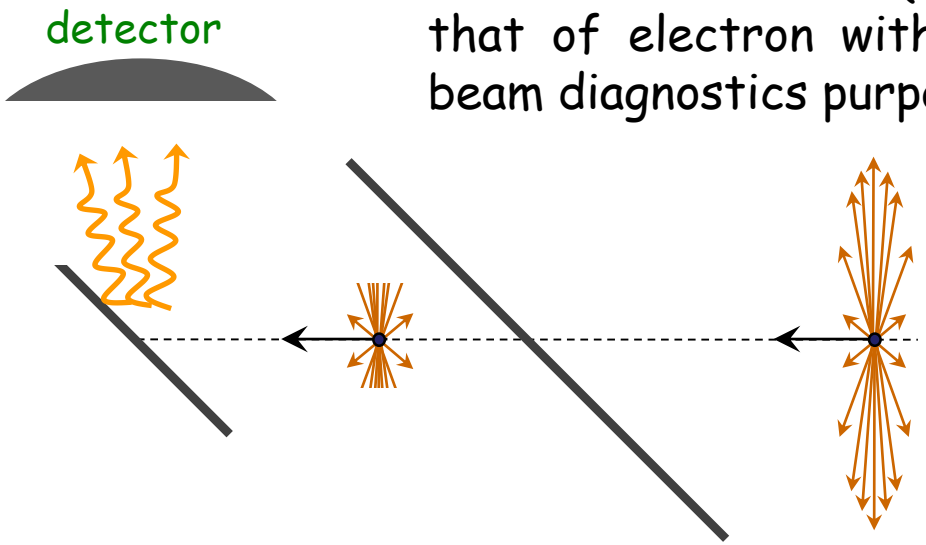




Kharkiv U – KIPT – LAL

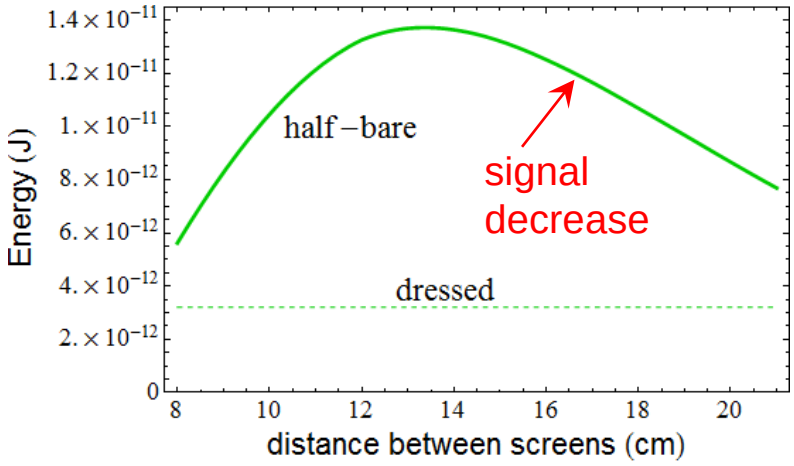
J. Phys. Conf. Ser. (2017) 012076

- Transition radiation (TR) by 'half-bare' electron differs from that of electron with Coulomb field. Valuable for TR-based beam diagnostics purposes.

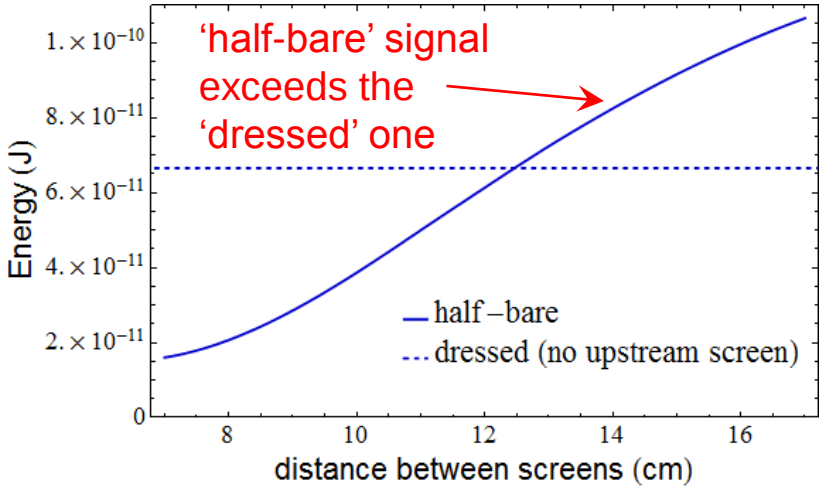


- Signal dependence on the distance between the planes
- Comparison to no upstream screen

Expected signal **at 12.5 MeV**



Expected signal **at 30 MeV** :

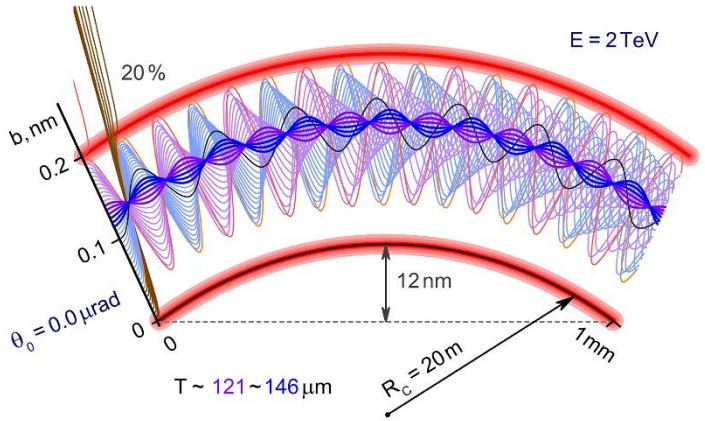


Multiple scattering effects on dynamics and radiation of fast charged particles in crystals

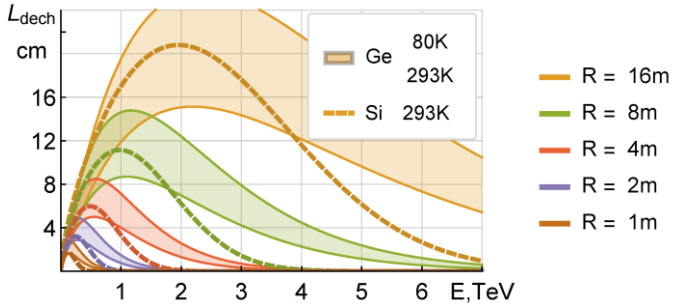
LAL – Kharkiv U – KIPT (joint PhD thesis)

JHEP 1708 (2017) 120

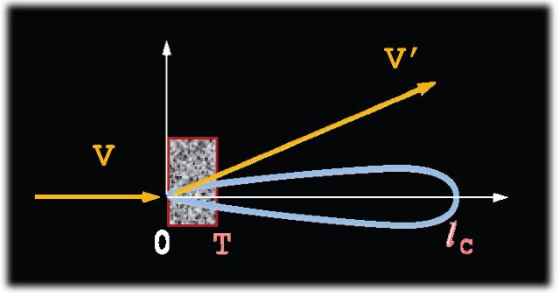
Simulation of particle deflection by bent crystal

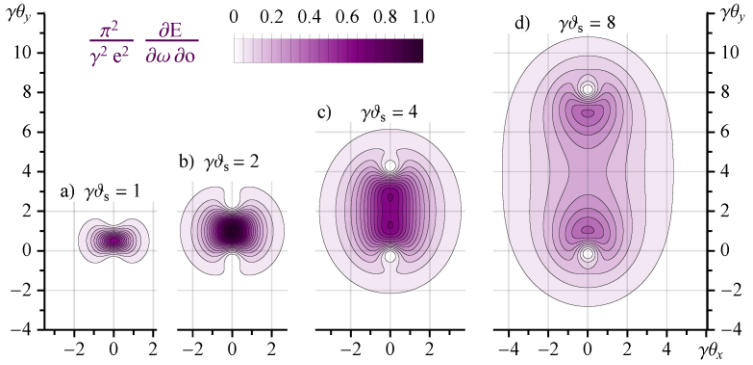


Dechanneling length over energy (Si and Ge crystals)



Relativistic electron radiation in thin target



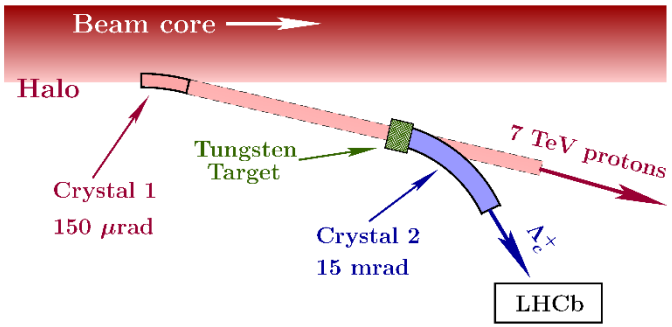


Feasibility of measuring the magnetic dipole moments of the Λ_c at the LHC

LAL – Kharkiv U – KIPT

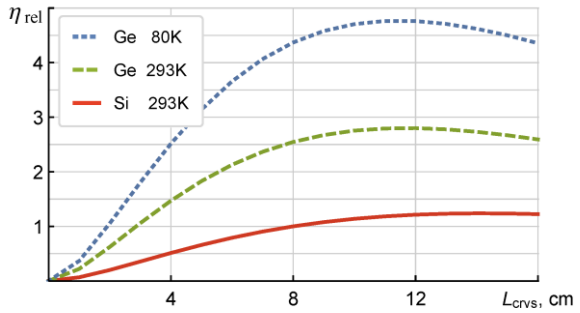
JHEP 1708 (2017) 120

This double crystal scheme

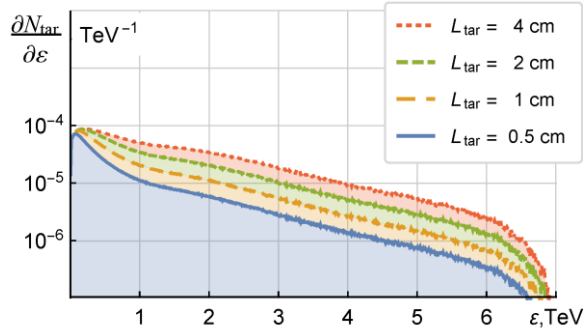


now under study with a 2 years program by UA9 at SPS

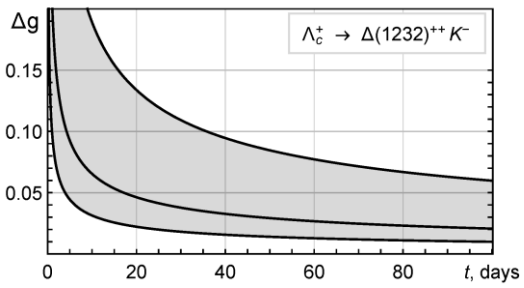
Optimization of crystal parameters



Simulation of Λ_c production at fixed target



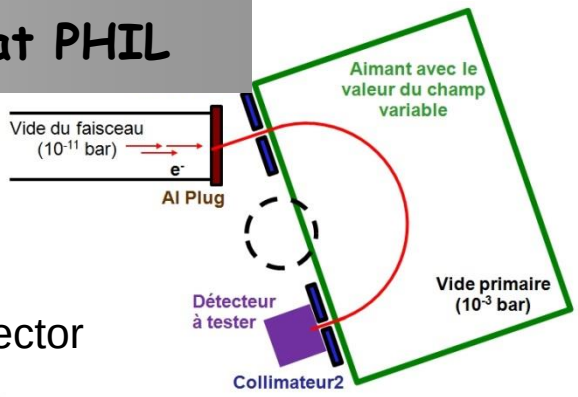
Precision over data taking time



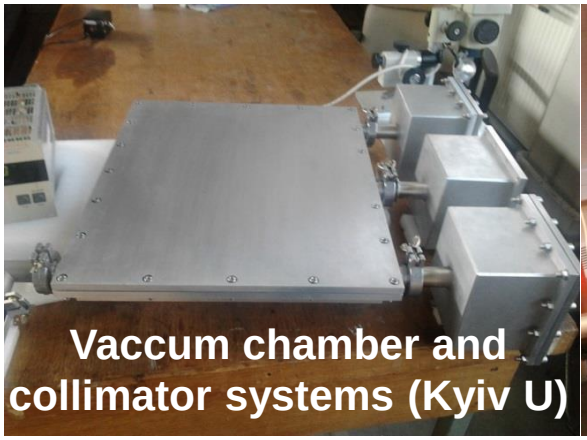
Platforms : Low energy electrons, LEETECH facility at PHIL

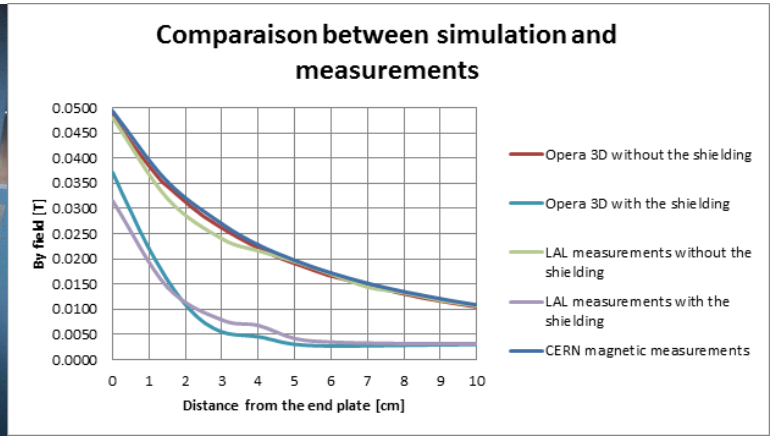
LAL – Kiev U – IRFU – CERN (joint PhD thesis)

Nucl. Phys. At. Energy, 16 vol. 4 (2015) 337

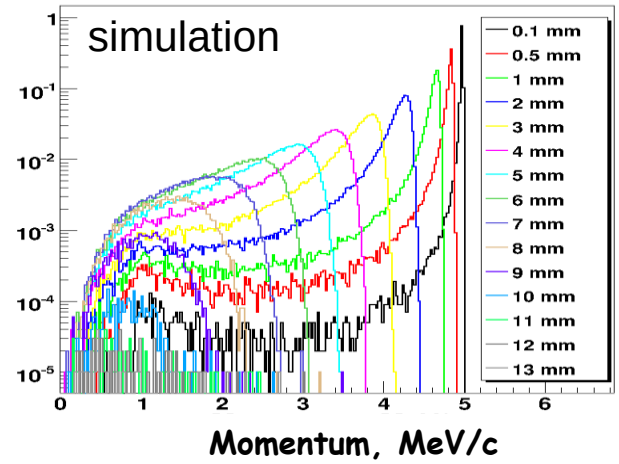


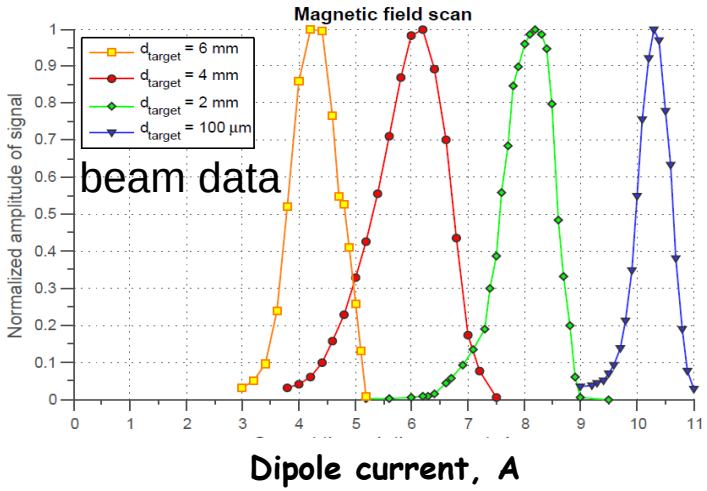
- Versatile platform to deliver quasi-monochromatic samples of low-energy electrons of adjustable energy and intensity using photoinjector PHIL at LAL, in operation

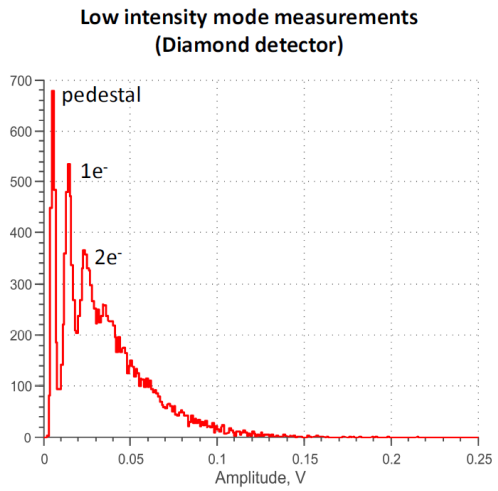




Access to all energy range using attenuators of different thickness



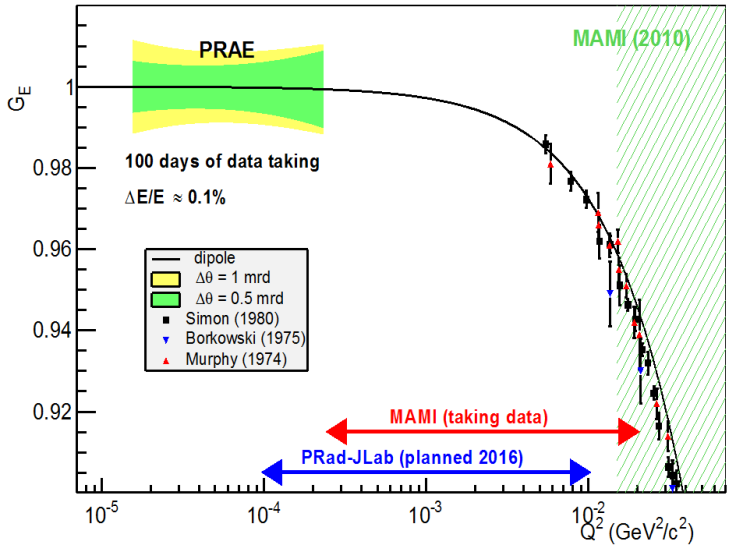




PRAE : Platform for R&D at Accelerator with Electrons

IMNC – IPN – LAL – KINR – TSNUK – Kharkiv U

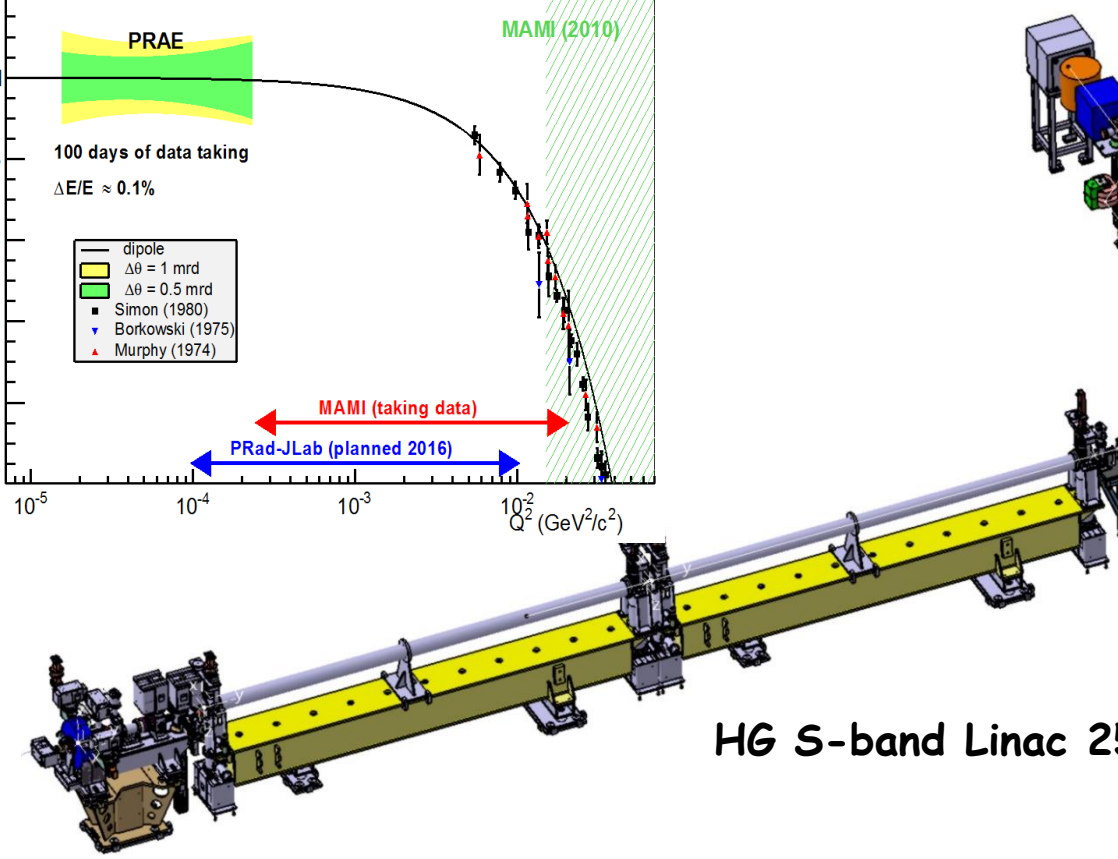
- PRAE: the multi-disciplinary site based on the high-performance electron beam with the energy of 70 MeV and then 140 MeV : accelerator technology; subatomic physics; techniques for radiotherapy; instrumentation.



ProRad

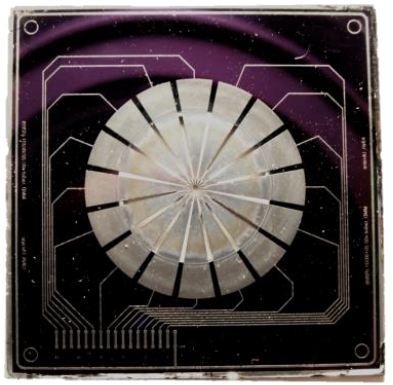
Instrumentation

Radiotherapy



HG S-band Linac 25 MV/m

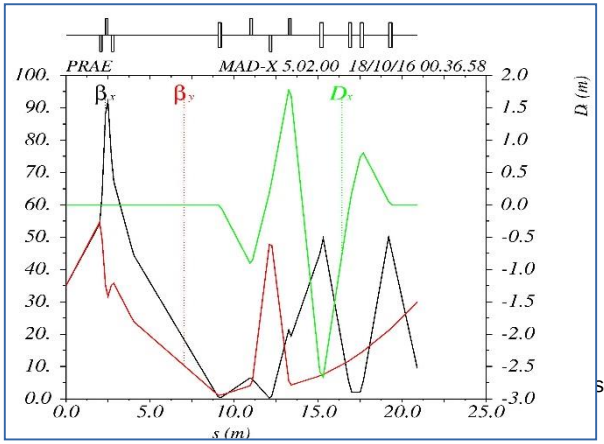
RF gun 5 MeV

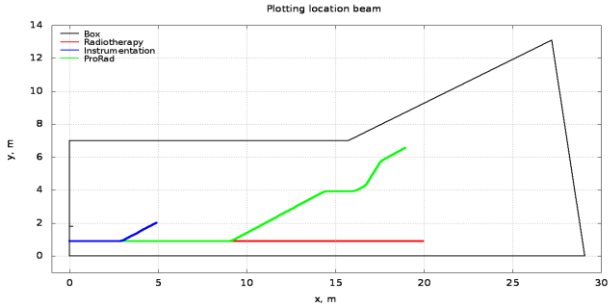


MMD: 16 sectors, 1 µm thick

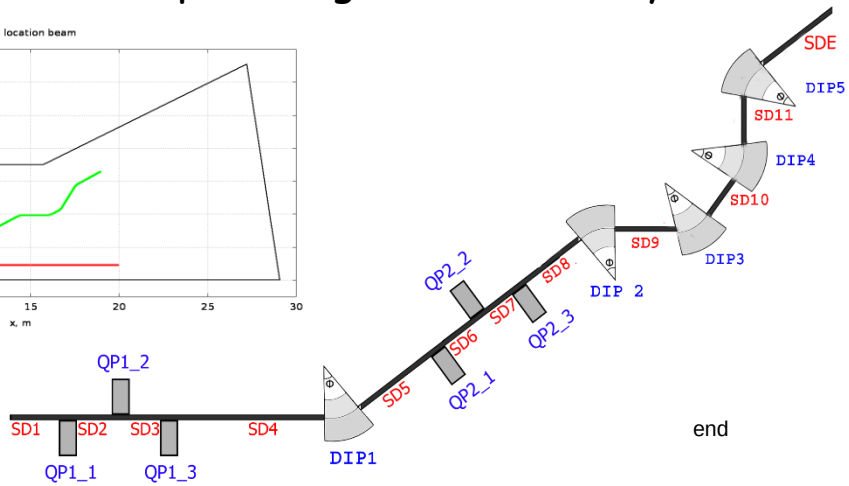
IMNC – IPN – LAL – CPO – KINR – TSNUK

- Optimizing accelerator layout

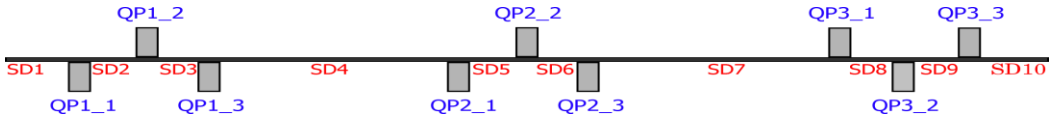




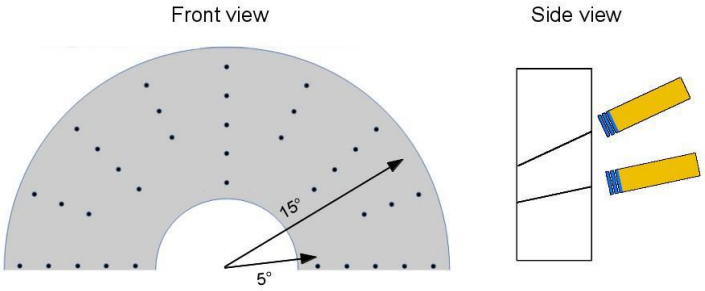
start

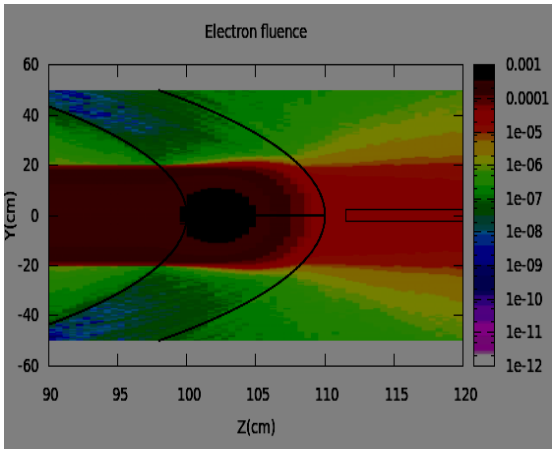


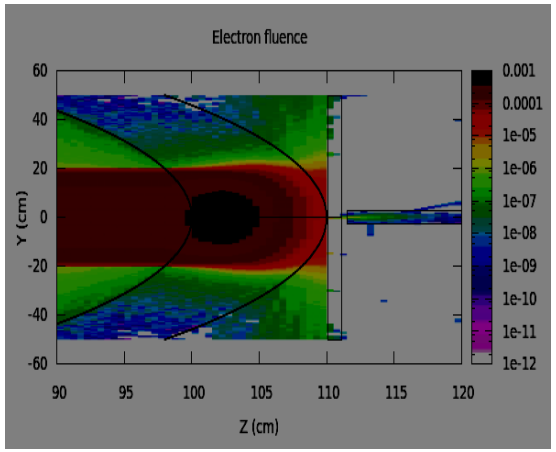
end



- Shielding optimization : energy in the crystal



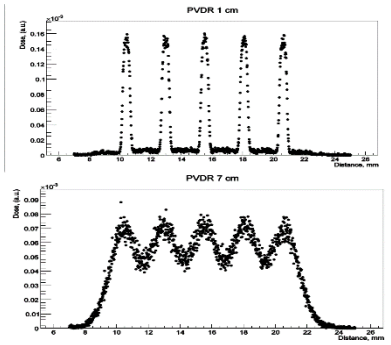


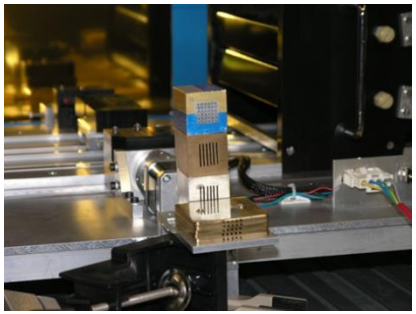


Shaping and imaging minibeams for spatially fractionated radiation therapy

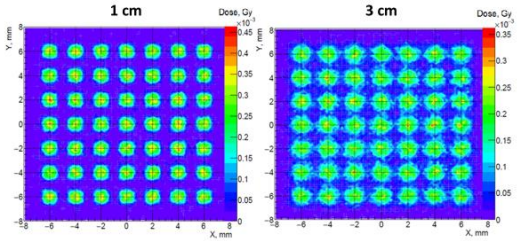
IMNC – KINR

- Monte-Carlo simulation and measurements
- Slit and matrix collimators for shaping
- Metal and hybrid micro-detectors for imaging
- Beam tests ongoing

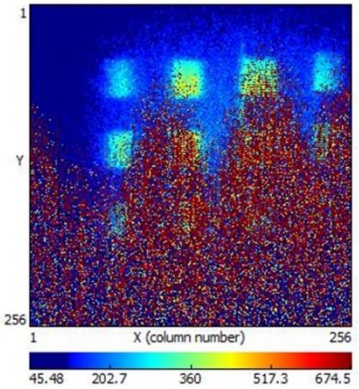




- Monte-Carlo studies for 105 MeV protons at CPO
- Slit and matrix collimators for shaping – prototypes designed and produced
- Metal and hybrid micro-detectors for imaging – under test
- The equipment is characterized by r/a source Sr-90.
- First beam test at Varian accelerator with gamma beam

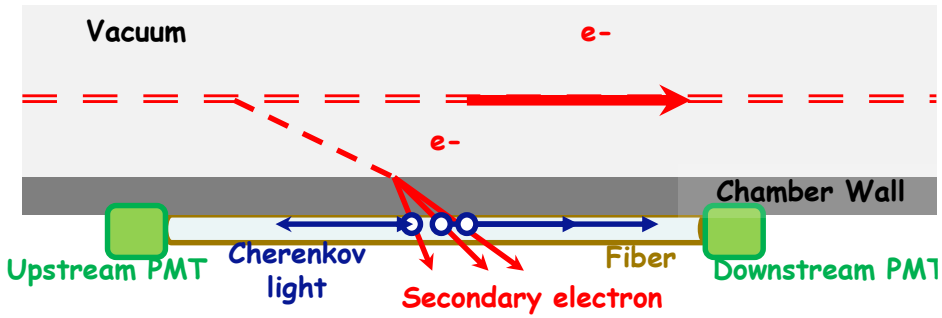


Deposit dose distribution (105 MeV proton beam) after aluminium matrix collimator with 49 apertures in 1 cm and 3 cm phantom depth



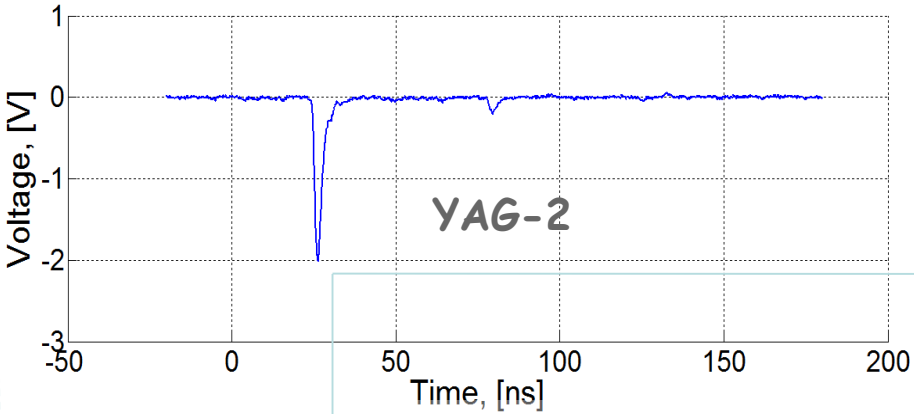
Development of the beam loss system: Fiber Beam Loss Monitor (FBLM)

LAL – TSNUK



Test at photoinjectors PHIL (LAL, Orsay).

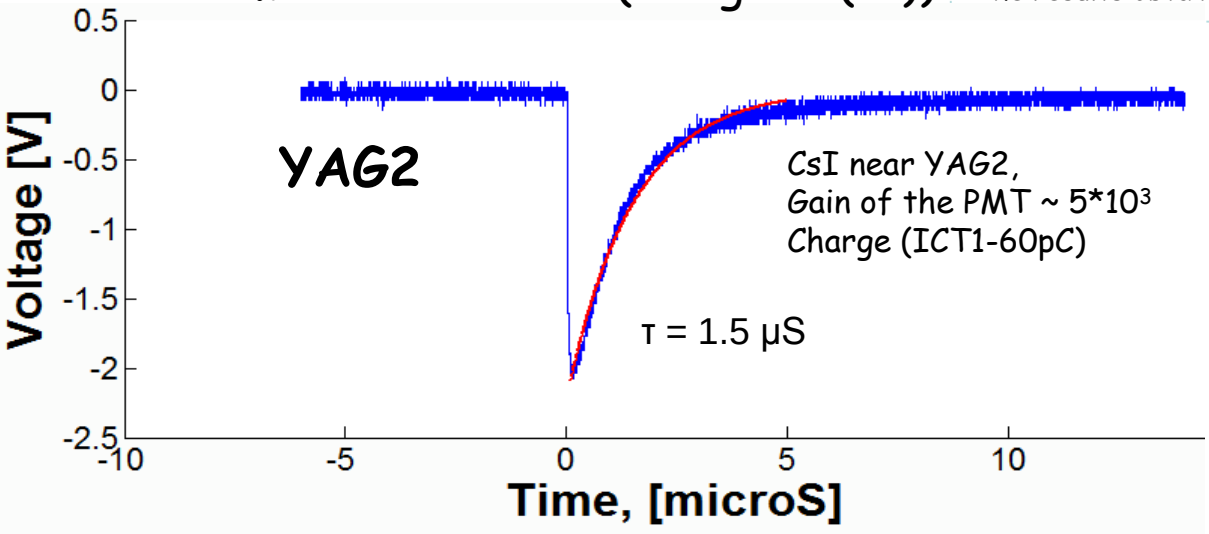
Knowing the speed of the light in the fiber, we can calibrate time between the beam losses measured in seconds to real distance along the accelerator.



Example of the signal obtained during the calibration using YAG-2 screen as the marker (to generate the beam losses at

The results obtained at PHIL show the accuracy ~ 20 cm with 10-12

Beam Loss Monitor (using CsI(Tl)):

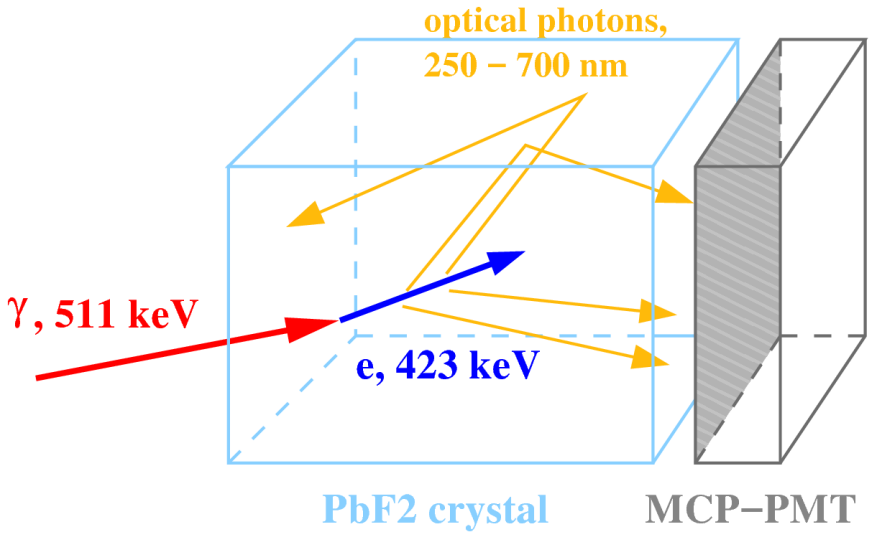


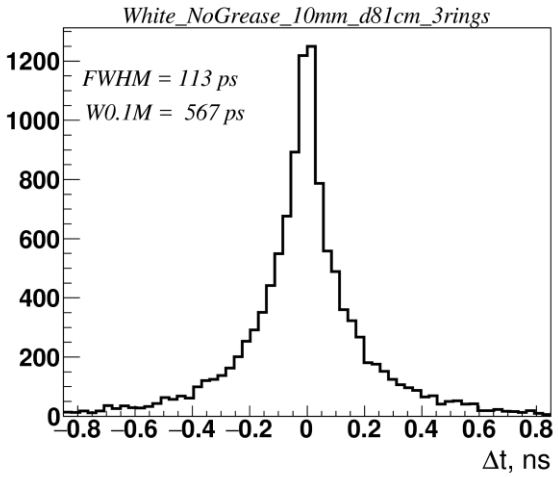
Example of the beam loss signal at PHIL facility (using scintillator)

- Real-time display system for the FBLM designed.

IRFU – TSNUK (joint PhD thesis)

Goal of the project: design a detector with excellent time resolution and high efficiency.
Main idea: using Cherenkov light instead of scintillation.
Approach:develop GATE-based simulation and estimate the main parameters of the scanner



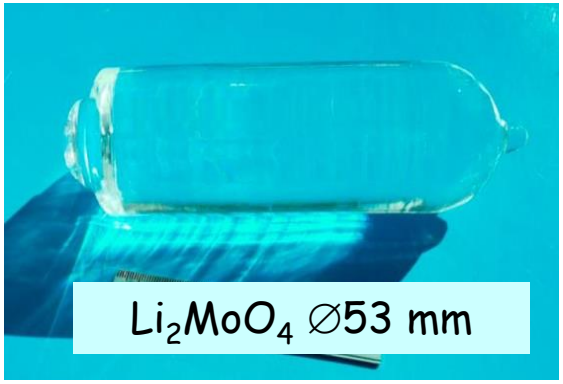


Preliminary results: Cherenkov PET competitive with a scintillation PET

Development of low background scintillation detectors
R&D of $ZnMoO_4$ and Li_2MoO_4 cryogenic scintillation detectors

CSNSM – KINR

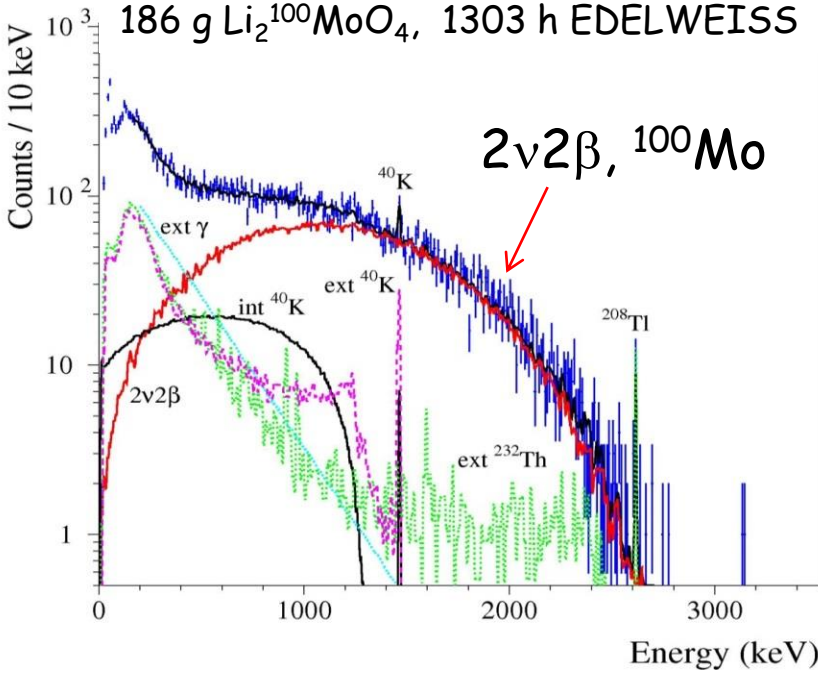
arXiv:1704.01758



Production of high quality zinc ($ZnMoO_4$) and lithium molybdate (Li_2MoO_4) crystal scintillators (including those from enriched ^{100}Mo)

High performance $Li_2{}^{100}MoO_4$ scintillating bolometers:

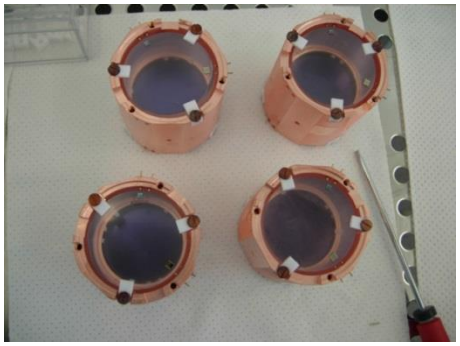
- Energy resolution FWHM = 4-6 keV at 2615 keV
- Particle discrimination capability: $DP_{\alpha/\beta}$ = 9 – 18
- Low radioactive contamination: < 10 μBq/kg of ^{226}Ra and ^{228}Th

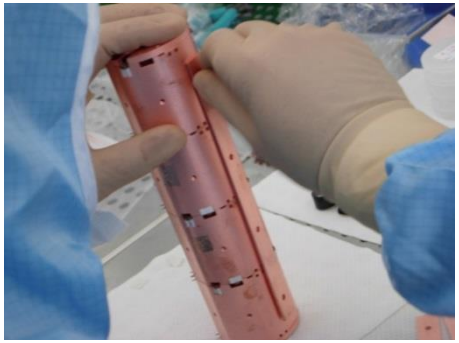


$$T_{1/2} = [6.90 \pm 0.15(\text{stat}) \pm 0.37(\text{syst})] \times 10^{18} \text{ yr [1]}$$

Most accurate $T_{1/2}$ of ^{100}Mo

CSNSM – KINR





- 20 enriched $Li_2{}^{100}MoO_4$ crystals produced
- Assembling of the $Li_2{}^{100}MoO_4$ detectors in progress, pilot experiment - beginning of 2018

- Assumed background: 10^{-3} counts/yr/kg/keV in 10 keV window centered at $Q_{2\beta}$ of ^{100}Mo

Sensitivity to 0ν2β decay of ^{100}Mo over 6 month:

$$\lim T_{1/2}^{0\nu} \sim 1.3\times10^{24}\ \text{yr} \quad \Rightarrow \quad \langle m_\nu \rangle \approx 0.33\ \text{eV} - 0.56\ \text{eV}$$

- Production of next 20 $Li_2{}^{100}MoO_4$ detectors in 2018

Sensitivity with 40 detectors over 3 yr:

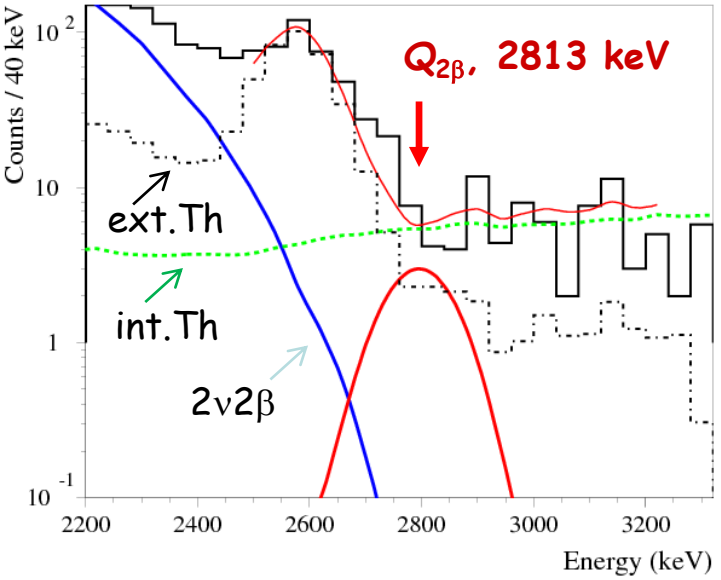
$$\lim T_{1/2}^{0\nu} \sim 1.5\times10^{25}\ \text{yr} \quad \Rightarrow \quad \langle m_\nu \rangle \approx 0.1\ \text{eV} - 0.17\ \text{eV}$$

CSNSM – KINR

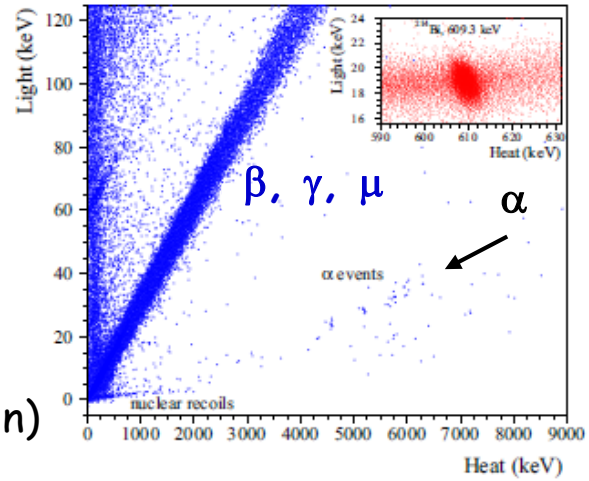
EPJC 76 (2016) 487
Astropart. Phys. 34 (2010) 143

CYGNUS: Cryogenic search for neutrinoless double beta decay of cadmium

- Energy resolution: 130 keV → 5-7 keV at $Q_{2\beta}$
- Background can be reduced: → 1.4 cnts in 10 keV ROI over 3 yr



- Background reduction (mainly ^{208}Tl) expected due to particle discrimination and high energy resolution to αs



$$^{212}\mathrm{Bi} \xrightarrow{\alpha} {}^{208}\mathrm{Tl} \xrightarrow{\beta\ (T_{1/2} \approx 3\ \mathrm{min})}$$

- Search for 0ν2β decay of ^{116}Cd with advanced sensitivity: $\lim T_{1/2}^{0\nu} \sim 8\times10^{23}$ yr
- Demonstration of ^{116}Cd option capability for large scale experiment (CUPID)

Pedagogical collaboration

LIA : Pedagogical collaboration

- Intimate **link between research and educational programs**
- Symbiosis of expertise of senior scientists and research work by the (Bachelor, Master and PhD) students within LIA program :
  - **4 PhD theses under joint supervision**
  - Students regularly enter **UPSud Master** programs (NPAC, GI, …)
- **Internships** in France for Bachelor and Master Students at LAL, LPNHE, CSNSM, IPNO, IRFU, LPC, LPT

~50 **student internships**, > 100 student x months of internships

- **Framework agreements** signed between
  Paris-Sud University and Kyiv T. Shevchenko University
  Paris-Sud University and Kharkiv V. N. Karazine University
  proposed between LPNHE (Paris 6) and Kyiv University

- And **winter and summer schools**

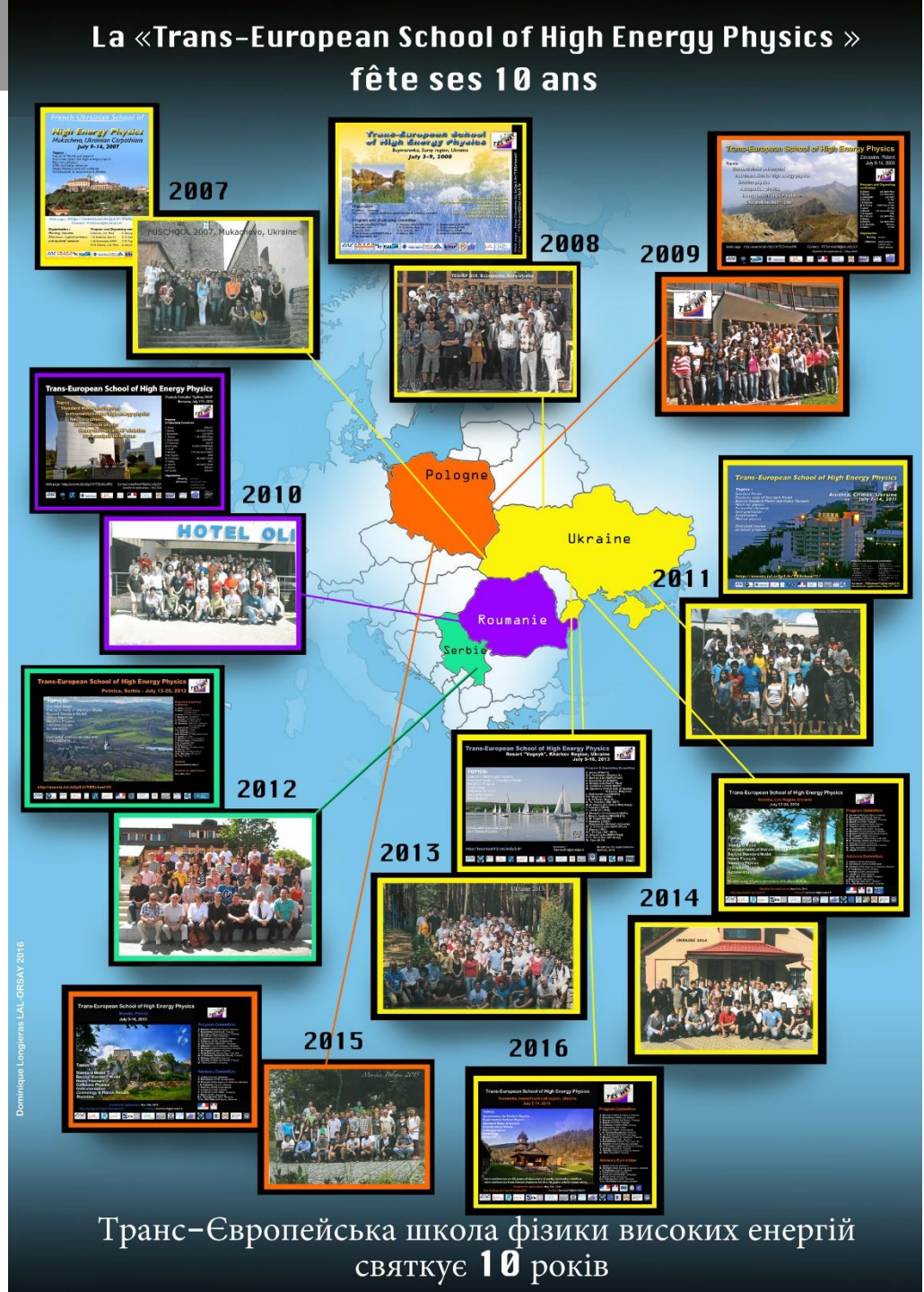
11 years of TESHEP

TESHEP is a platform, aiming at reinforcing East-West Europe scientific and pedagogical links.

Annual **summer school**, one of the main pillars of TESHEP, delivers lectures on high energy physics, mainly focusing on experimental particle physics, and brings together European students from different universities.

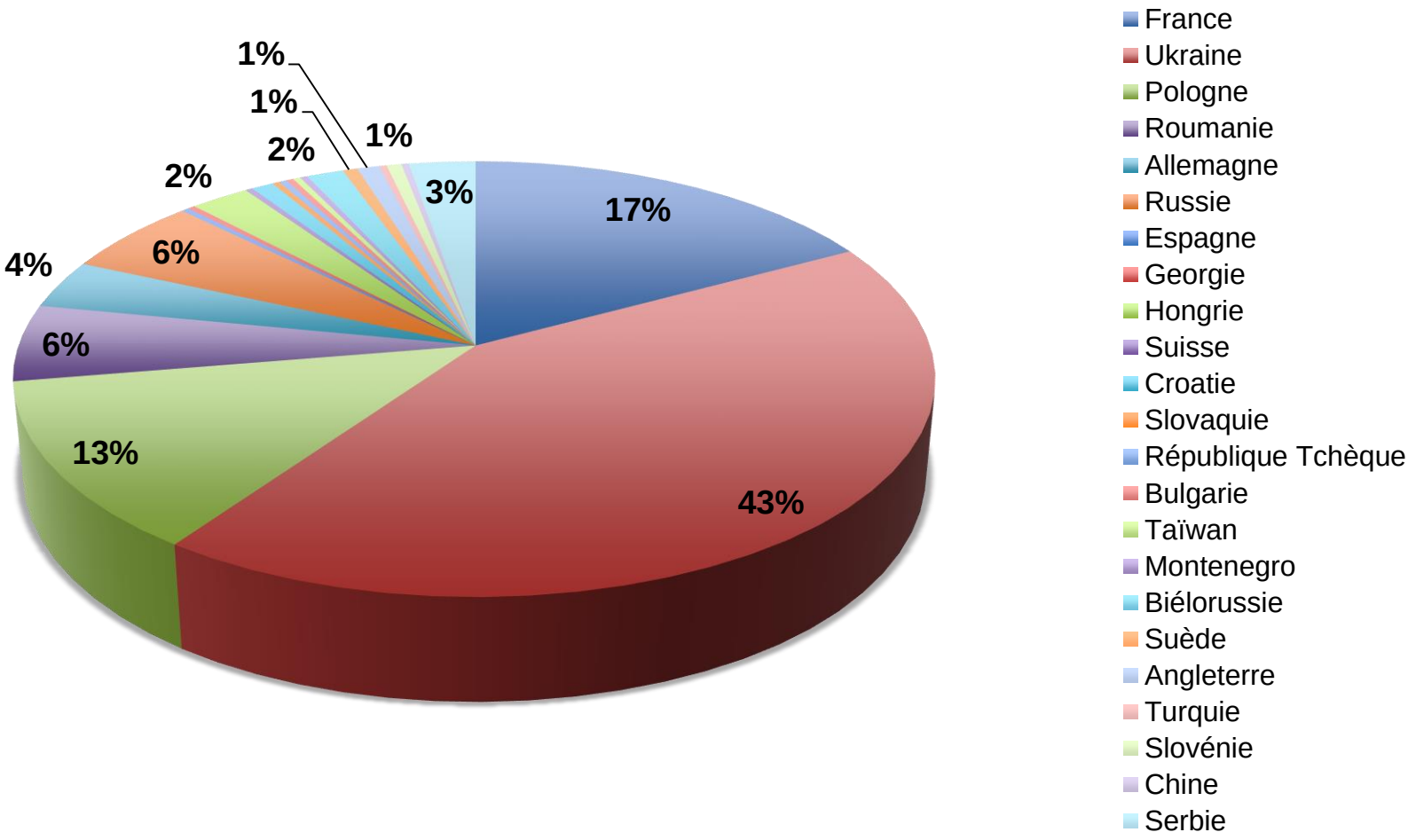
Professors and pedagogical /organising team:
Ukraine, France, UK, Germany, Greece, Italy, Poland, Romania, Serbia, Slovenia, Hungary, US, CERN, …

Students: Ukraine, France, Belarus, Bulgaria, Czech Rep., China, Croatia, Georgia, Germany, Hungary, Italy, Montenegro, Poland, Romania, Russia, Serbia, Slovenia, Spain, Sweden, Taiwan, Turkey, UK, CERN, DESY, …

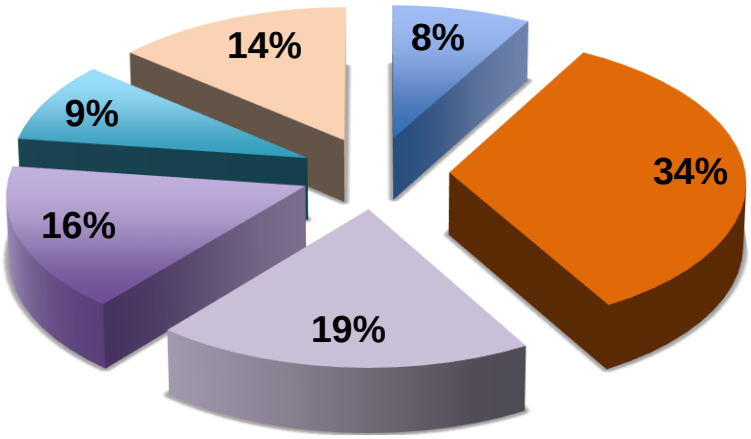


TESHEP on the map

TESHEP: origin of the students



TESHEP: profile and level of the students



- DESY/Tevatron/B Factories
- CERN
- Theory
- Instrumentation
- Phys. Nucléaire
- Others

Interplay with CERN

- CERN participation in TESHEP, and associated conferences

- Joint contribution to CERN projects : ATLAS, LHCb, RD51
- LIA IDEATE formally entered the **road map for CERN-Ukraine program**. Presentations of LIA at the working group CERN-Ukraine at CERN in 2015 and 2016.
- **Ukraine became associated member of CERN** → LIA re-considers its role.