I R I D E

Interdisciplinary Research Infrastructure with Dual Electron linacs&lasers

Massimo.Ferrario@lnf.infn.it
on behalf of the IRIDE design study group

IRIDE aims and potentials

- Science with Free Electron Lasers (FEL) from infrared to X-rays,
- Nuclear photonics with Compton back-scattering g-rays sources,
- Science with THz radiation sources,
- Advanced Neutron sources by photo-production,
- Fundamental physics investigations with low energy linear colliders
- Physics with high power/intensity lasers,

- R&D on advanced accelerator concepts including plasma accelerators and polarized positron sources
- ILC technology implementation
- Detector development for X-ray FEL and Linear Colliders
- R&D in accelerator technology and industrial spin – off

D. Alesini[1], M. Alessandroni[51], M. P. Anania[1], S. Andreas[56], M. Angelone[14], A. Arcovito [26], F. Arnesano [25], M. Artioli[14], L. Avaldi [40], D. Babusci[1], A. Bacci[3], A. Balerna[1], S. Bartalucci[1], R. Bedogni[1], M. Bellaveglia[1], F. Bencivenga [50], M. Benfatto[1,46], S. Biedron[66], V. Bocci[2], M. Bolognesi [27], P. Bolognesi [40], R. Boni[1], R. Bonifacio[7], M. Boscolo[1], F. Boscherini [43], F. Bossi[1], F. Broggi[3], B. Buonomo[1], V. Calò [25], D. Catone [41], M. Capogni[14], M. Capone[14], M. Castellano[1], A. Castoldi[17], L. Catani[4], G. Cavoto[2], N. Cherubini[14], G. Chirico [28], M. Cestelli-Guidi[1], E. Chiadroni[1], V. Chiarella[1], A. Cianchi[4], M. Cianci [29], R. Cimino[1], F. Ciocci[14], A. Clozza[1], M. Collini [28], G. Colo'[3], A. Compagno[14], G. Contini [41], M. Coreno [40], R. Cucini [50], C. Curceanu[1], S. Dabagov[1], E. Dainese [30], I. Davoli[24], G. Dattoli[14], L. De Caro [31], P. De Felice[5], S. Della Longa [32], G. Delle Monache[1], M. De Spirito [33], A. Di Cicco [44], C. Di Donato[57], D. Di Gioacchino[1], D. Di Giovenale[1], E. Di Palma[14], G. Di Pirro[1], A. Dodaro[14], A. Doria[14], U. Dosselli[1], A. Drago[1], R. Escrinabo[23], A. Esposito[1], R. Faccini[2], A. Ferrari[52], M. Ferrario[1], A. Filabozzi[4], D. Filippetto[18], F. Fiori[53], O. Frasciello[1], L. Fulgentini[15], G. P. Gallerano[14], A. Gallo[1], M. Gambaccini[11], C. Gatti[1], G. Gatti[1], P. Gauzzi[2], A. Ghigo[1], G. Ghiringhelli [49], L. Giannessi[14], G. Giardina[54], C. Giannini [31], F. Giorgianni[2], E. Giovenale[14], L. Gizzi[15], C. Guaraldo[1], C. Guazzoni[17], R. Gunnella [44], K. Hatada [1,44], S. Ivashyn[12], F. Jegerlehner[58], P.O. Keeffe [40], W. Kluge[58], A. Kupsc[60], L. Labate[15], P. Levi Sandri[1], V. Lombardi [34], P. Londrillo[20], S. Loreti[5], M. Losacco [25], S. Lupi[2], A. Macchi[15], S. Magazù[54], G. Mandaglio[54], A. Marcelli[1,46], C. Mariani[16], P. Mariani [35], G. Marzo[14], C. Masciovecchio [50], P. Masujan[61], M. Mattioli[2], G. Mazzitelli[1], N.P. Merenkov[21], P. Michelato[3], F. Migliardo[54], M. Migliorati[2], C. Milardi[1], E. Milotti[13], S. Milton[66],V. Minicozzi [24], S. Mobilio [48], S. Morante[24], D. Moricciani[4], A. Mostacci[2], V. Muccifora[1], F. Murtas[1], P. Musumeci[10], F. Nguyen[62], A. Orecchini[55], G. Organtini[2], P. L. Ottaviani[14], E. Pace[1], M. Paci [35], C. Pagani[3], S. Pagnutti[14], V. Palmieri[6], L. Palumbo[2], G.C. Panaccione [45], C. F. Papadopoulos[18], M. Papi [33], M. Passera[63], L. Pasquini [43], M. Pedio [45], A. Perrone[9], A. Petralia[14], C. Petrillo[55], V. Petrillo[3], M. Pillon[14], P. Pierini[3], A. Pietropaolo[14], M. Pillon[14], A. D. Polosa[2], R. Pompili[4], J. Portoles[22], T. Prosperi [41], C. Quaresima[41], L. Quintieri[5], J. V. Rau[15], M. Reconditi [34], A. Ricci [38], R. Ricci[1], G. Ricciardi[57], E. Ripiccini[2], S. Romeo[54], C. Ronsivalle[14], N. Rosato [37], J. B. Rosenzweig[10], G. Rossi [24], A. A. Rossi[6], A. R. Rossi[3], F. Rossi[20], D. Russo[15], A. Sabatucci [30], E. Sabia[14], F. Sacchetti[55], F. Sannibale[18], G. Sarri[19], T. Scopigno [35], L. Serafini[3], D. Sertore[3], O. Shekhovtsova[64], I. Spassovsky[14], T. Spadaro[1], B. Spataro[1], F. Spinozzi [35], A. Stecchi[1], F. Stellato [24,38], V. Surrenti[14], A. Tenore[1], A. Torre[14], L. Trentadue[65], S. Turchini [41], C. Vaccarezza[1], A. Vacchi[13], P. Valente[2], G. Venanzoni[1], S. Vescovi[1], F. Villa[1], G. Zanotti [39], N. Zema[41], M. Zobov[1].

1 INFN-Laboratori Nazionali di Frascati
2 INFN and Universita’ di Roma”La Sapienza”
3 INFN and Universita’ di Milano
4 INFN and Universita’ di Roma”Tor Vergata”
5 Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti, ENEA C R Casaccia. 6 INFN-Laboratori Nazionali di Legnaro
7 INFN Universidade Federal da Paraiba, Brazil8 Universita’ di Camerino9 INFN and Universita’ del Salento10 UCLA, Los Angeles, USA11 INFN and Universita’ di Ferrara 12 TP, NSC “Kharkov Institute of Physics and Technology”, Kharkov, Ukraine
13 INFN and Universita’ di Trieste14 ENEA15 CNR 16 CNISM and Universita’ di Roma”La Sapienza”
17 Politecnico di Milano and INFN sez. Milano18 LBNL19The Queen's University of Belfast, Belfast, UK20INFN-Sezione di Bologna21NSC KIPT, Kharkov, Ukraine[22]instituto De Física Corpuscular, Spain[23]Universitat Autonoma de Barcelona [24] Dipartimento di Fisica Università di Roma *“Tor Vergata”* and INFN Sezione di Roma *“Tor Vergata”* - 00133 Roma, Italia.
[25] Dipartimento Farmaco-Chimico, Università di Bari “A. Moro” - 70125 Bari, Italia
[26] Istituto di Biochimica e Biochimica Clinica, Università Cattolica del Sacro Cuore - 00167 Roma, Italia.
[27] Dipartimento di Scienze Biomolecolari e Biotecnologia, Università di Milano - 20131 Milano, Italia.
[28] Dipartimento di Fisica, Università di Milano Bicocca - 20126 Milano, Italia.
[29] European Molecular Biology Laboratory, Hamburg Outstation - 22603, Hamburg, Germany
[30] Dipartimento di Scienze Biomediche, Università di Teramo - 64100 Teramo, Italia.
[31] Istituto di Cristallografia, CNR – 70125 Bari, Italia.
[32] Dipartimento di Medicina Sperimentale, Università dell’ Aquila - 67100 L’ Aquila, Italia.
[33] Istituto di Fisica, Università Cattolica del sacro Cuore - 00168 – Roma, Italia.
[34] Laboratorio di Fisiologia, Dipartimento di Biologia Evoluzionistica, Università di Firenze - 50019 Sesto Fiorentino, Italia.
[35] Dipartimento SAIFET, Sezione di Scienze Fisiche Università Politecnica delle Marche, Ancona, Italia.
[36] Dipartimento di Chimica Università di Roma *“Tor Vergata”* - 00133 Roma, Italia.
State University’s

[37] Centro NAST, Nanoscienze & Nanotecnologie & Strumentazione - 00133 Roma, Italia, and Dipartimento di Medicina Sperimentale e Scienze Biochimiche, Università di Roma “Tor Vergata” - 00133 Roma, Italia.
[38] Center for Free Electron Laser Science c/o DESY - 22607, Hamburg, Germany
[39] Dipartimento di Chimica Biologica, Università di Padova - 35121 Padova, Italia.
[40] CNR-Istituto di Metodologie Inorganiche e dei Plasmi Area della Ricerca di Roma 1 - 00016 Monterotondo Scalo, Italia
[41] CNR-Istituto di Struttura della Materia Area della Ricerca di Roma 2 – Roma, Italia
[43] Department of Physics and Astronomy, University of Bologna - 40127 Bologna, Italy
[44] CNISM, Scuola di Scienze e Tecnologie, Sezione di Fisica, Università di Camerino, 62032 Camerino Italy
[45] CNR-Istituto Officina Molecolare Lab –TASC area science park - 34149 Basovizza Trieste Trieste
[46] University of Science and Technology of China, Chinese Academy of Science, Hefei 230026, P.R. China.
[48] Department of Science, University of Roma Tre - 10046 Roma, Italy
[49] CNR/SPIN and Dipartimento di Fisica - Politecnico di Milano, Italy
[50] Sincrotrone Trieste area science park Basovizza – 34149 Trieste Italia
[51] RMP Srl
[52] Helmholtz-Zentrum Dresden-Rossendorf
[53] Università Politecnica delle Marche - Di.S.C.O.
[54] Dipartimento di Fisica e di Scienze della Terra dell'Università di Messina
[55] Dipartimento di Fisica, Università di Perugia
[56] Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany
[57] Dipartimento di Fisica dell’Università di Napoli “FedericoII” and INFN Sezione di Napoli, Napoli, Italy
[58] Humboldt-Universität zu Berlin, Institut für Physik, Berlin and DESY, Zeuthen, Germany
[59] Institut für Experimentelle Kernphysik, Universität Karlsruhe, Germany
[60] Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden
[61] Institut f ur Kernphysik, Johannes Gutenberg-Universit at, Mainz, Germany
[62] Laboratório de Instrumentação e Física Experimental de Partículas, Lisbon, Portugal
[63] INFN Sezione di Padova, Padova, Italy

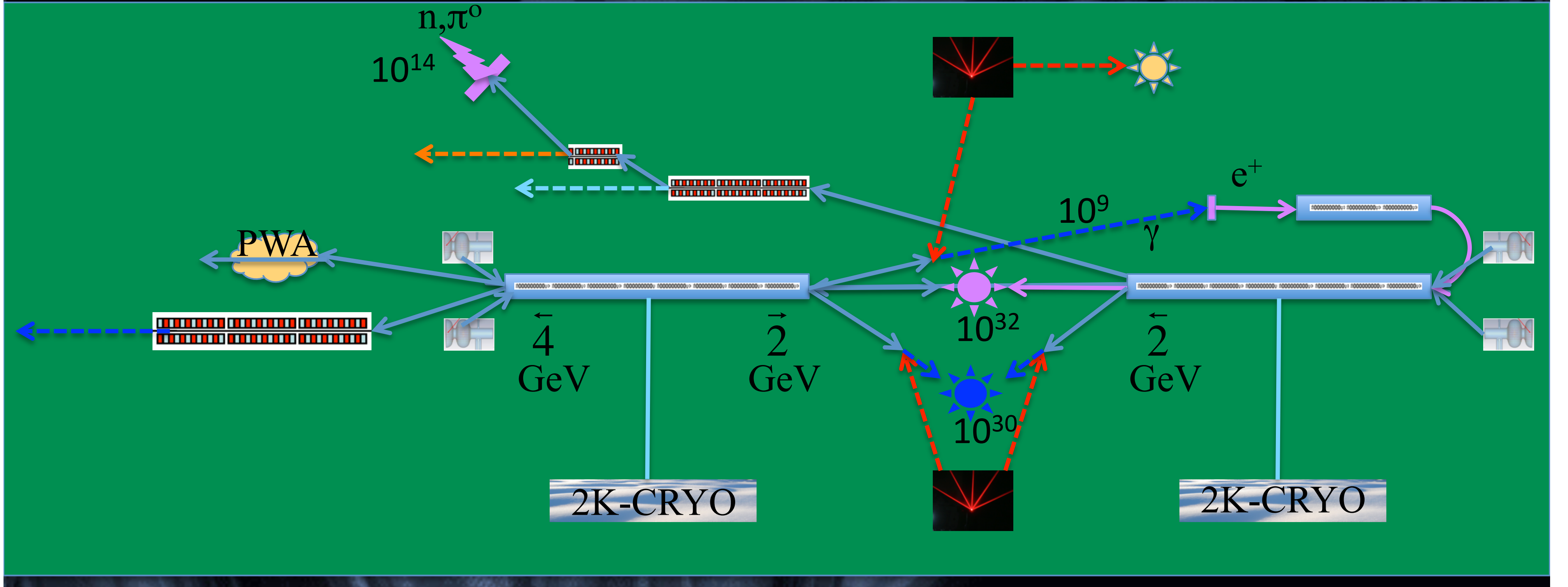
Effective collaboration among Italian and Euopean research institutes !!

Istituzione	# persone	# sezioni
INFN	104	15
CNR	20	6
ENEA	28	2
Altri (Italiani)	40	20
Altri (Stranieri)	43	19

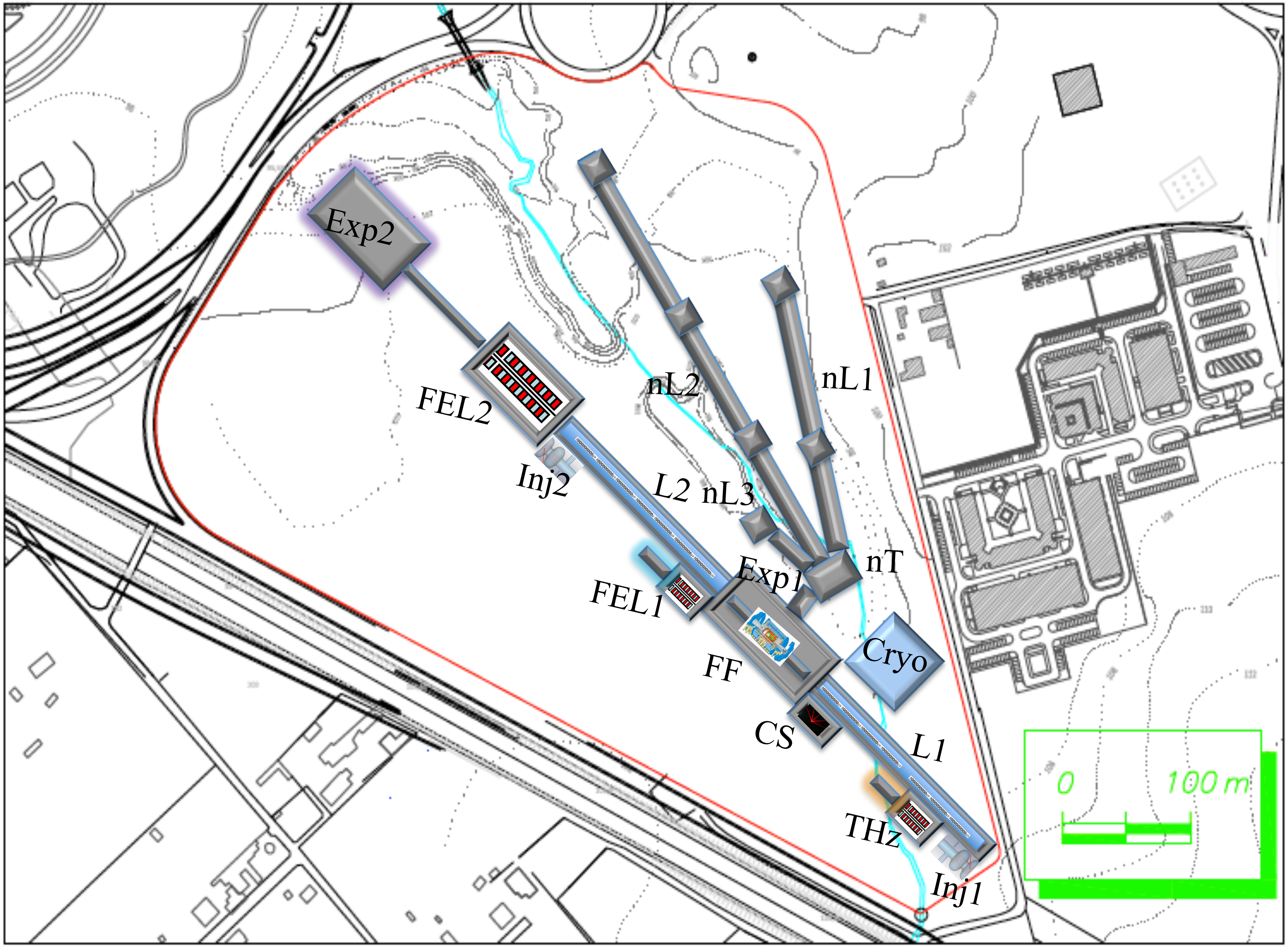
IRIDE White Book delivered on July 17, 2013 available at:

arXiv:1307.7967 [physics.ins-det].

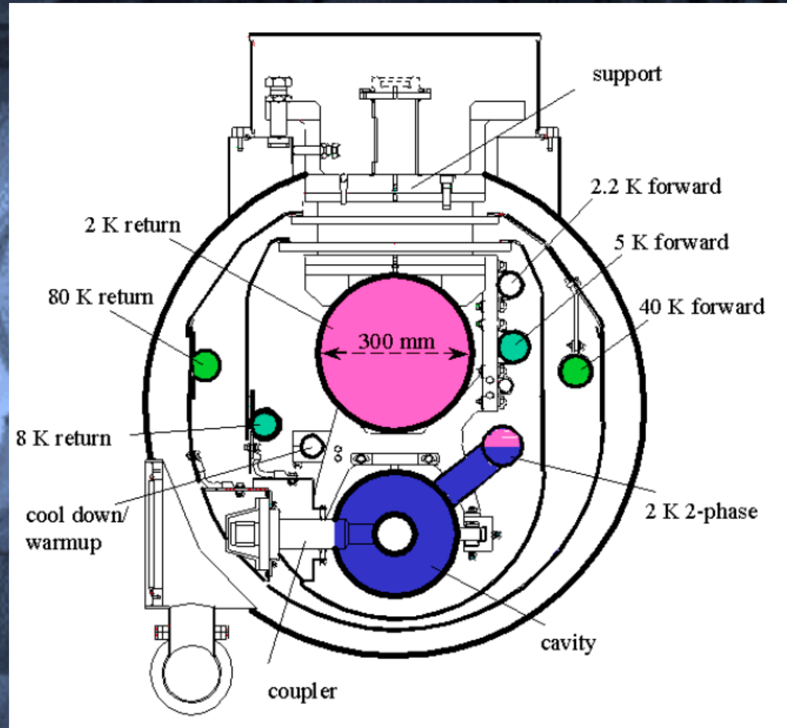
I R I D E is a large infrastructure for fundamental and applied physics research. Conceived as an innovative and evolutionary tool for multi-disciplinary investigations in a wide field of scientific, technological and industrial applications, it will be a high intensity "particle beams factory".



Based on a combination of a high duty cycle radio-frequency superconducting electron linac (SC RF LINAC) and of high energy lasers it will be able to produce a high flux of electrons, photons (from infrared to γ-rays), neutrons, protons and eventually positrons, that will be available for a wide national and international scientific community interested to take profit of the most advanced particle and radiation sources.

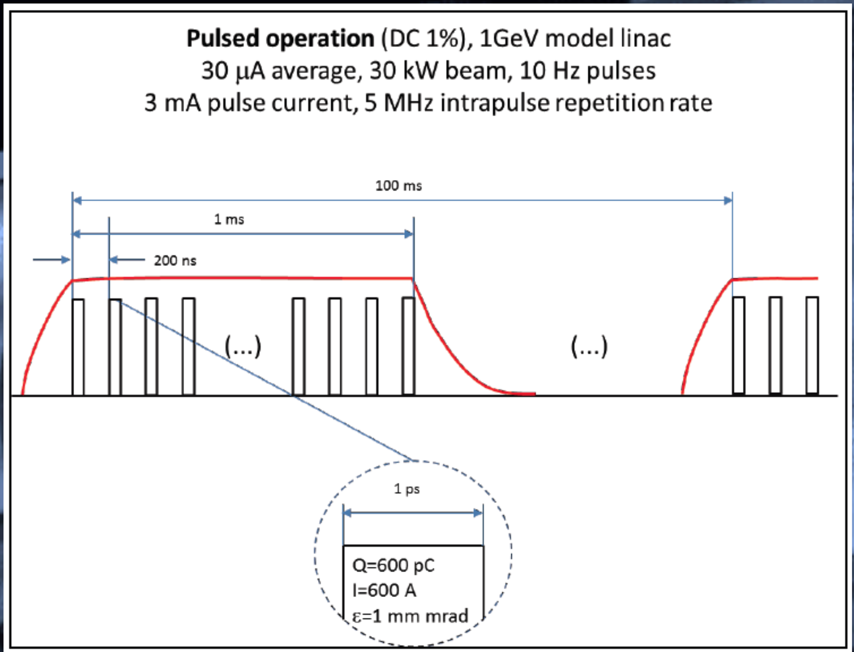

Exp2
FEL2
Inj2
L2
nL2
nL1
nL3
nT
Exp1
FEL1
FF
Cryo
CS
L1
THz
Inj1
0
100 m

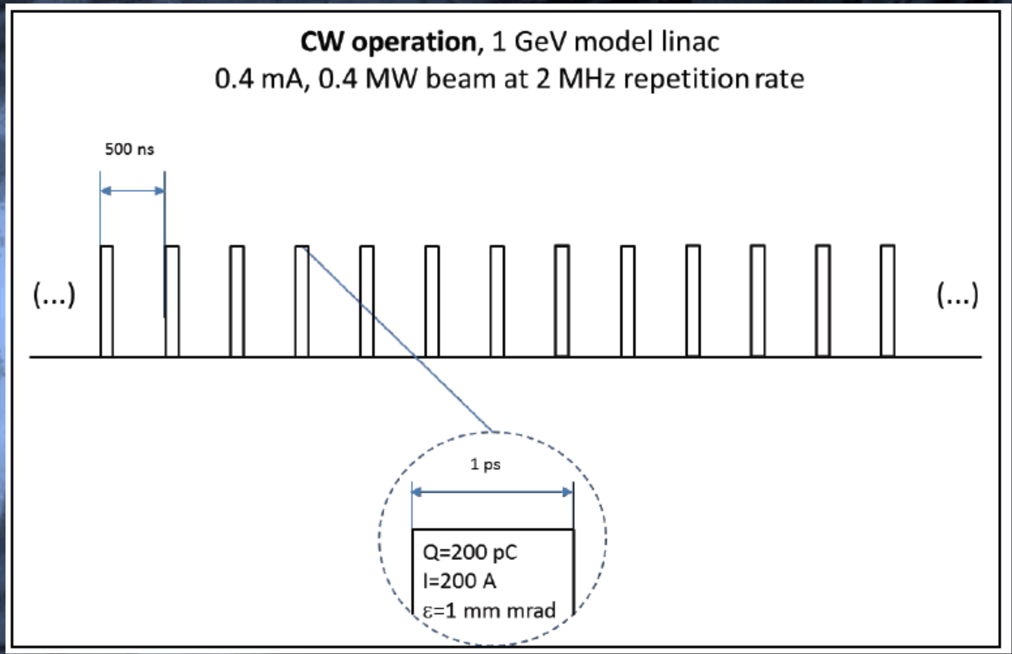
INFN is in a leading position in the SC RF technology, with knowledge and strong capabilities in the design, engineering and industrial realization of all the main component of a superconducting radiofrequency accelerator.



INFN strongly participated to TESLA since the early design stages through the final engineering and shares the know-how and has the recognized intellectual property of several main components one of which is the cryo-module concept and its evolution.

The main feature of a SC linac relevant for IRIDE is the possibility to operate the machine in continuous (CW) or quasi-continuous wave (qCW) mode with high average beam power (>1 MW) and high average current (>300 μA).





The CW or qCW choice, combined with a proper bunch distribution scheme, offers the most versatile solution to provide bunches to a number of different experiments, as could be envisaged in a multi-purpose facility.

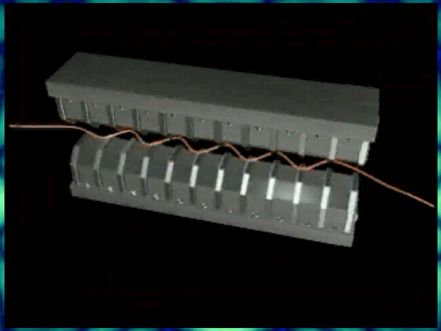
IRIDE linac parameters flexibility

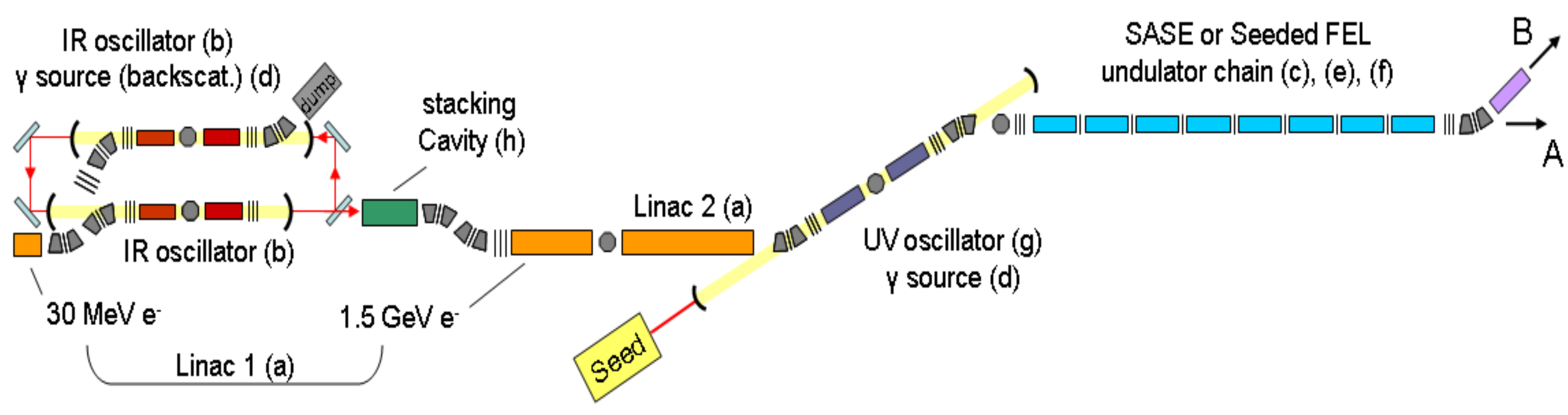
Table 1: Possible SC linac parameters

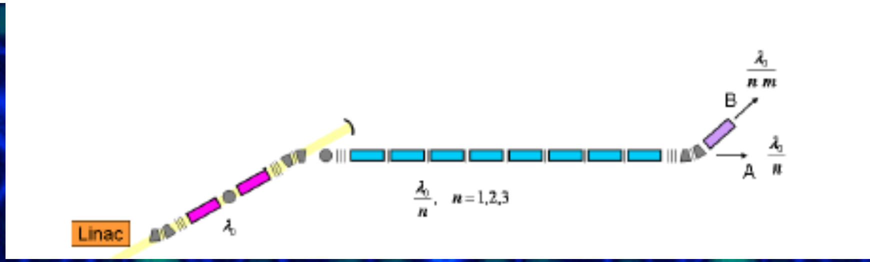
	Pulsed	qCW	CW
Energy [GeV]	2	2	1.5
I (within pulse) [mA]	2.5	0.26	
I (average) [mA]	0.17	0.16	0.35
RF pulse duration [ms]	1.5	1000	CW
RF Duty cycle [%]	15	60	100
E_{acc} [MV/m]	20	20	15
$Q_0 \times 10^{10} / Q_{ext} \times 10^6$	2/4	2/40	2/40
N. of cavities/N. of modules	96/12	96/12	96/12
Beam average power [kW]	334	309	525

IRIDE Free Electron Lasers

The IRIDE project will provide a new concept of FEL facility by merging the two technologies of FEL oscillators and fourth generation radiation sources by developing a facility providing radiation from IR to EUV to the nm region down to Å level using a mechanism of emission already successfully tested at SPARC.







1.5 Gev electron beam energy

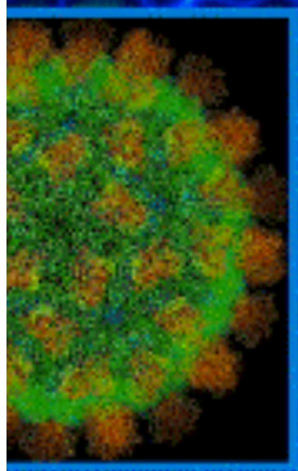
	Fundamental	3° harmonic	5° harmonic
λ(nm/KeV)	4/0.413	1.33/1.23	0.8/2.07
peak flux (n/s/- 0.1%BW)	$2.7*10^{26}$	$2.5*10^{24}$	$1.9*10^{23}$
Peak brilliance	$1.56*10^{30}$	$1.4*10^{28}$	$1.1*10^{27}$
photon/bunch	$5.94*10^{13}$	$5.5*10^{11}$	$4.18*10^{10}$

3.0 Gev electron beam energy

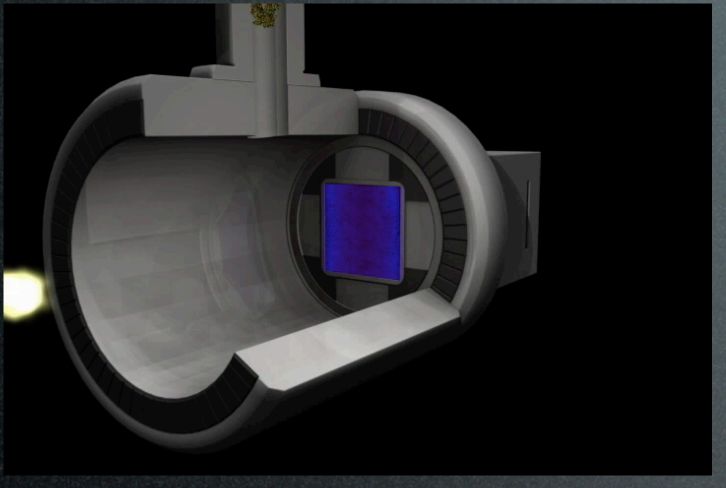
	Fundamental	3° harmonic	5° harmonic
λ(nm/KeV)	1/1.24	0.3/3.72	0.2/6.2
peak flux (n/s/- 0.1%BW)	$4.6*10^{25}$	$4.1*10^{23}$	$3.4*10^{22}$
Peak brilliance	$6.4*10^{31}$	$5.7*10^{29}$	$4.7*10^{28}$
photon/bunch	$1.01*10^{13}$	$9.02*10^{10}$	$7.48*10^{9}$

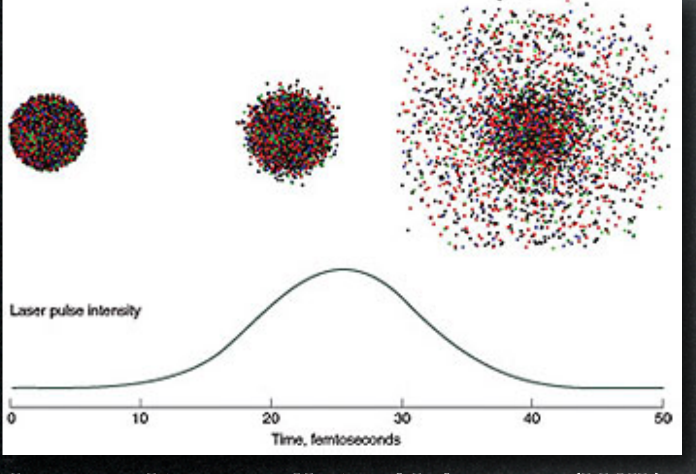
4.0 Gev electron beam energy

	Fundamental	3° harmonic	5° harmonic
λ(nm/KeV)	0.563/2.2	0.188/6.5	0.113/10.9
peak flux (n/s/- 0.1%BW)	$1.2*10^{25}$	$5.9*10^{22}$	$2.8*10^{21}$
Peak Brilliance	$1.92*10^{31}$	$1.8*10^{29}$	$1.2*10^{28}$
photon/bunch	$2.1*10^{12}$	$1.06*10^{10}$	$5.0*10^{8}$



Protein imaging





Lawrence Livermore National Laboratory (LLNL)

Using extremely short and intense X-ray pulses to capture images of objects such as proteins before the X-rays destroy the sample.

Single-molecule diffractive imaging with an X-ray free-electron laser.

Individual biological molecules will be made to fall through the X-ray beam, one at a time, and their structural information recorded in the form of a diffraction pattern.

The pulse will ultimately destroy each molecule, but not before the pulse has diffracted from the undamaged structure.

The patterns are combined to form an atomic-resolution image of the molecule.

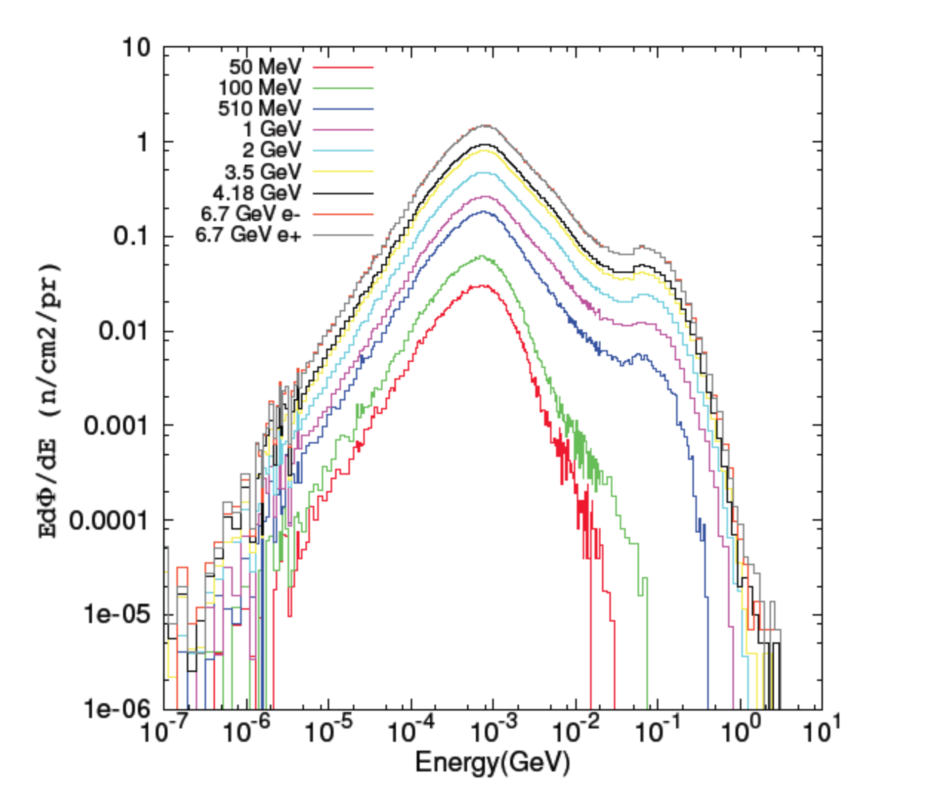
The speed record of 25 femtoseconds for flash imaging was achieved.

Models indicate that atomic-resolution imaging can be achieved with pulses shorter than 20 femtoseconds.

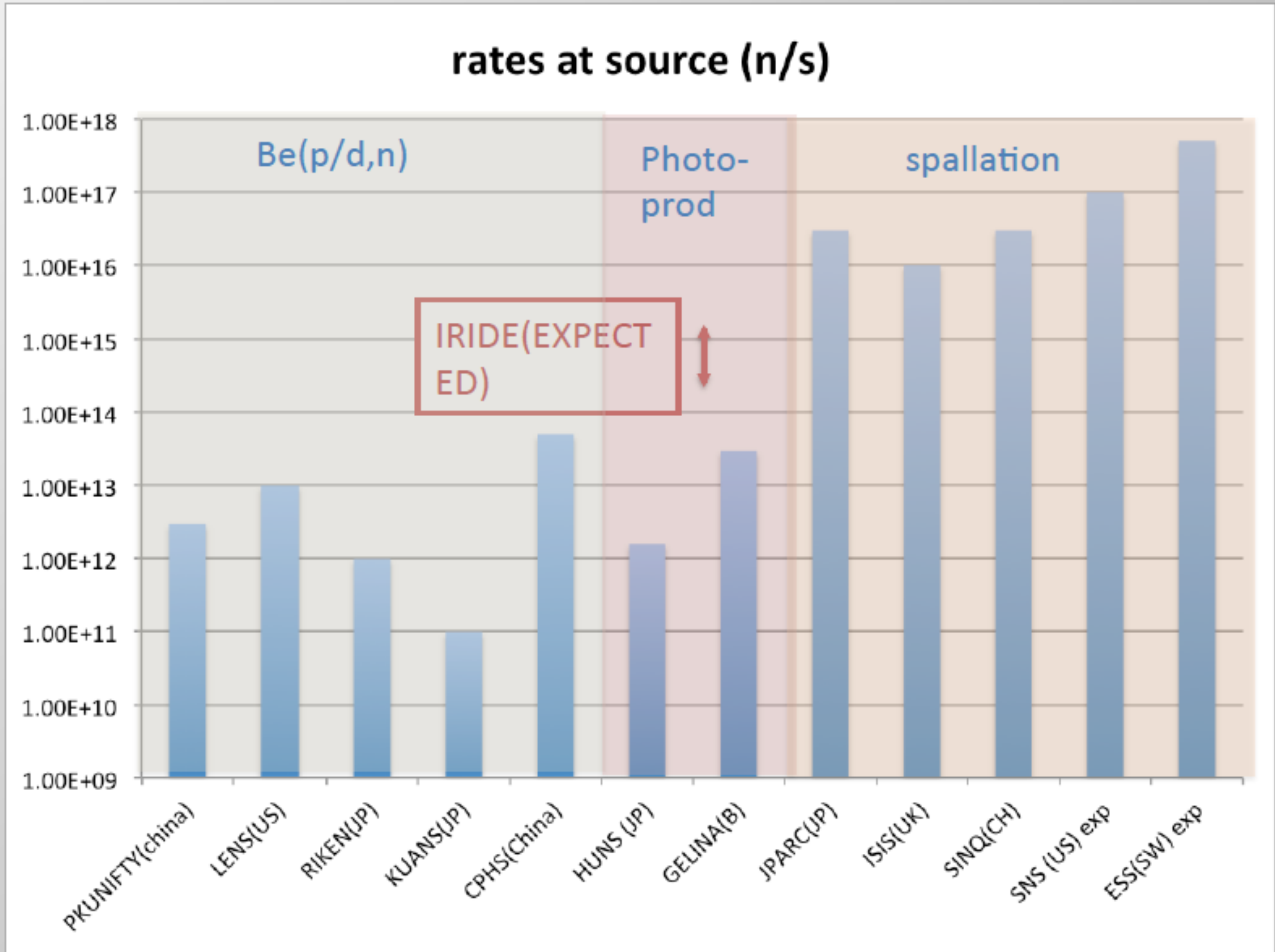
Neutron Source

This source may be suitable for multiple applications, ranging from material analysis for industrial and cultural heritages purposes to chip irradiation and metrology. These applications envisage the development of properly designed beam lines with neutron moderation and possibly cold/thermal neutron transport systems. The proposed new facility will represent a great opportunity for research and development of neutron instrumentation (e.g. detectors) as well as training of young scientist in the use and development of neutron techniques.

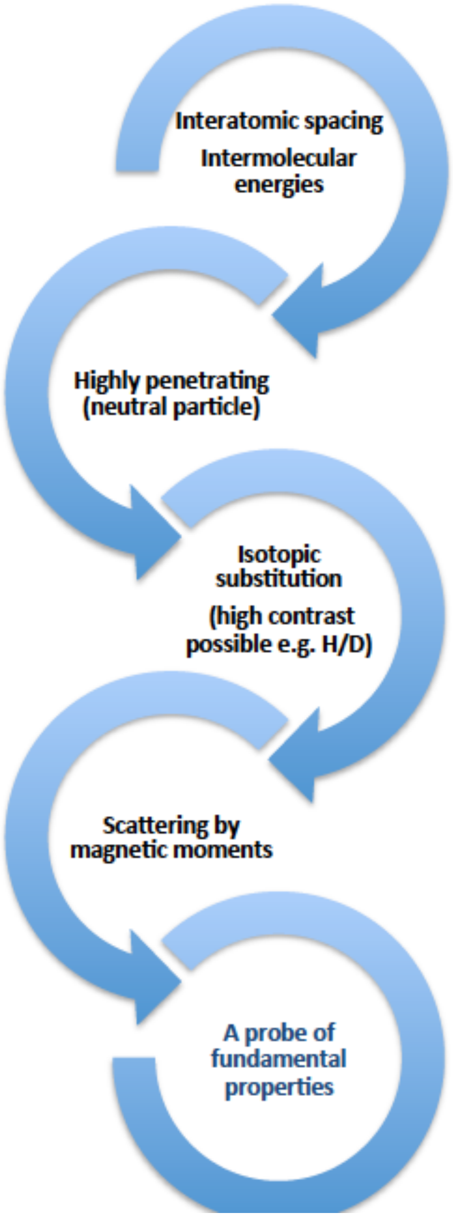
Deposited Power [kW]	Primary Electron Energy [GeV]	Expected Average Neutron Emission rate [n/s]
30	1	1.3 E+14
250	1	1.0 E+15
400	1	1.7 E+15
30	3	4.3 E+13
250	3	3.3 E+14
400	3	5.6 E+14

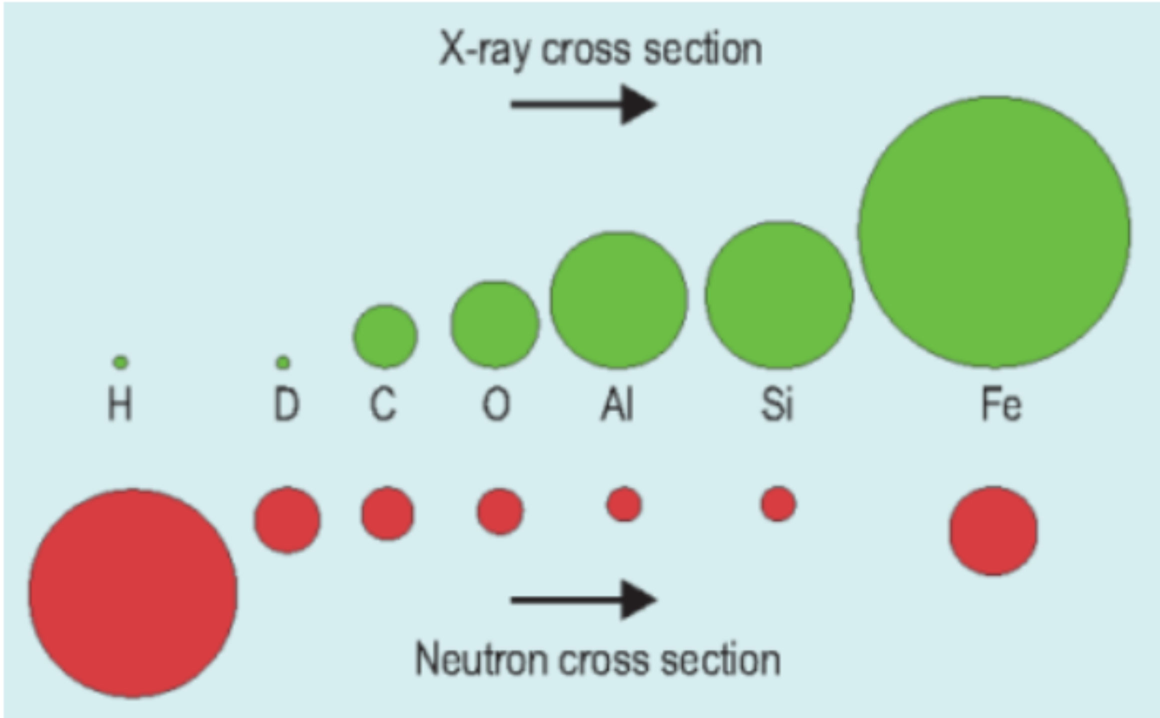


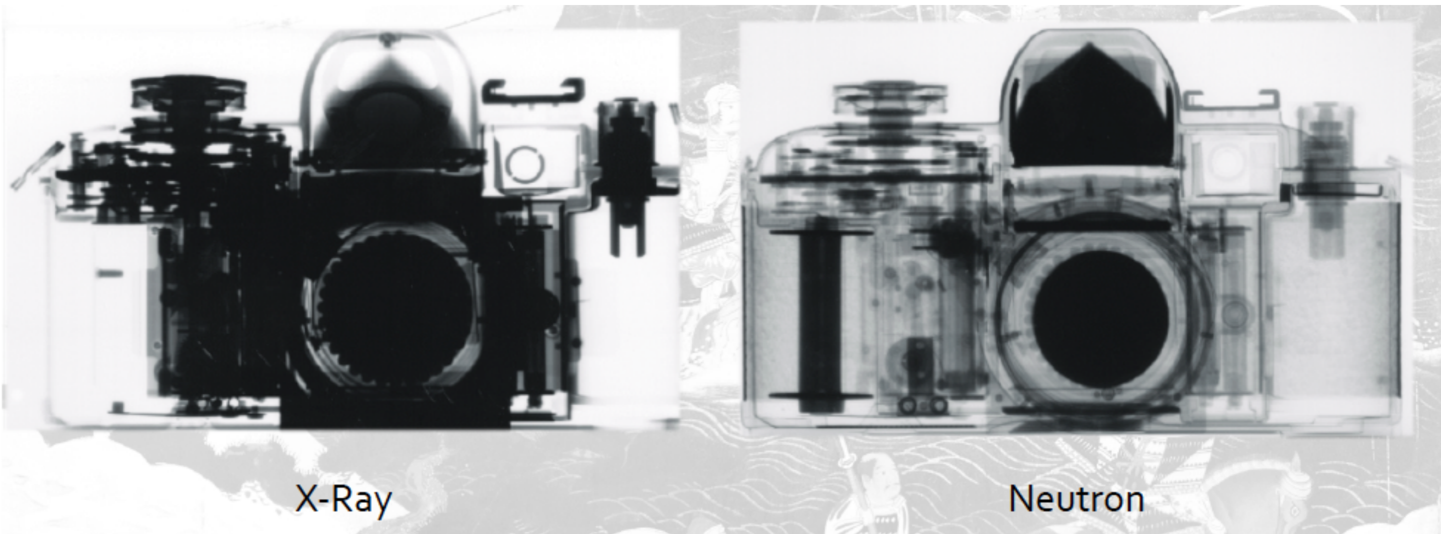
Comparison with other sources



Relevant Neutron Properties







The special feature of Neutrograph is it's intensity together with a moderate collimation.

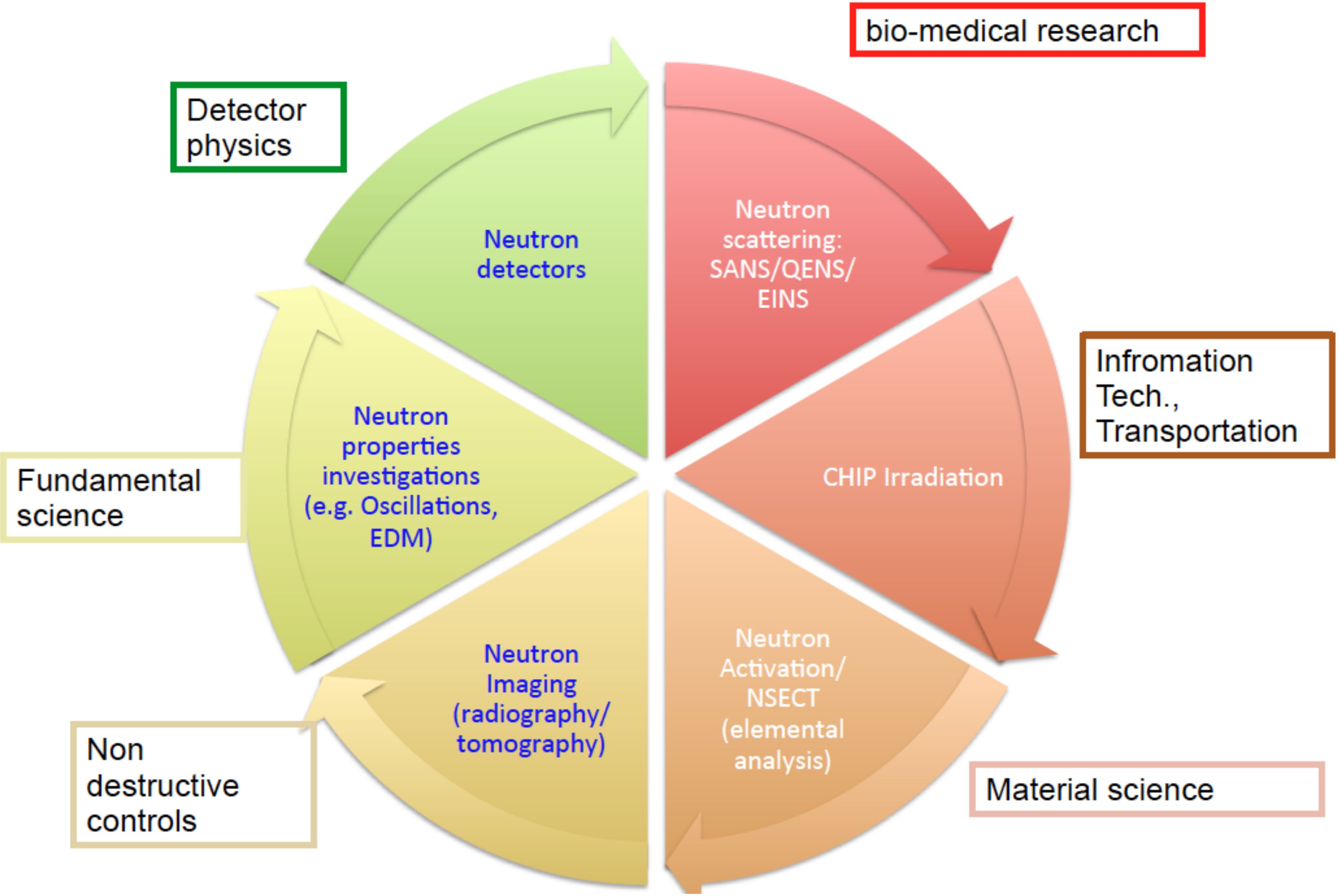
These properties allow the investigation of dynamic processes with an excellent time resolution and the transmittance through strongly absorbing and bulky materials.

A totally new spectrum of scientific and engineering applications could be developed.

Among the experiments are investigations of heat exchangers and combustion engines, parts from aircrafts, fossils and historical heritage.

Institut Laue-Langevin (ILL) in Grenoble

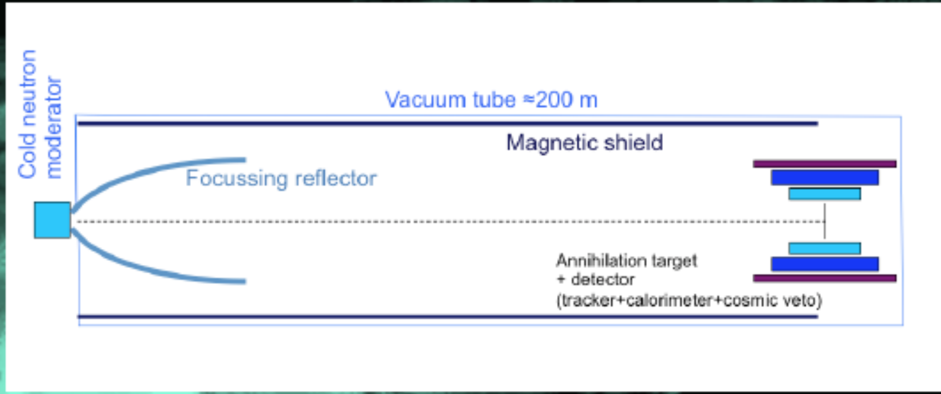
techniques and beamlines



Neutron oscillations

Neutron beam facilities with comparable statistics study:

- neutron-antineutron oscillations
- neutron disappearance:
  - Sterile neutron
  - Mirror baryons …



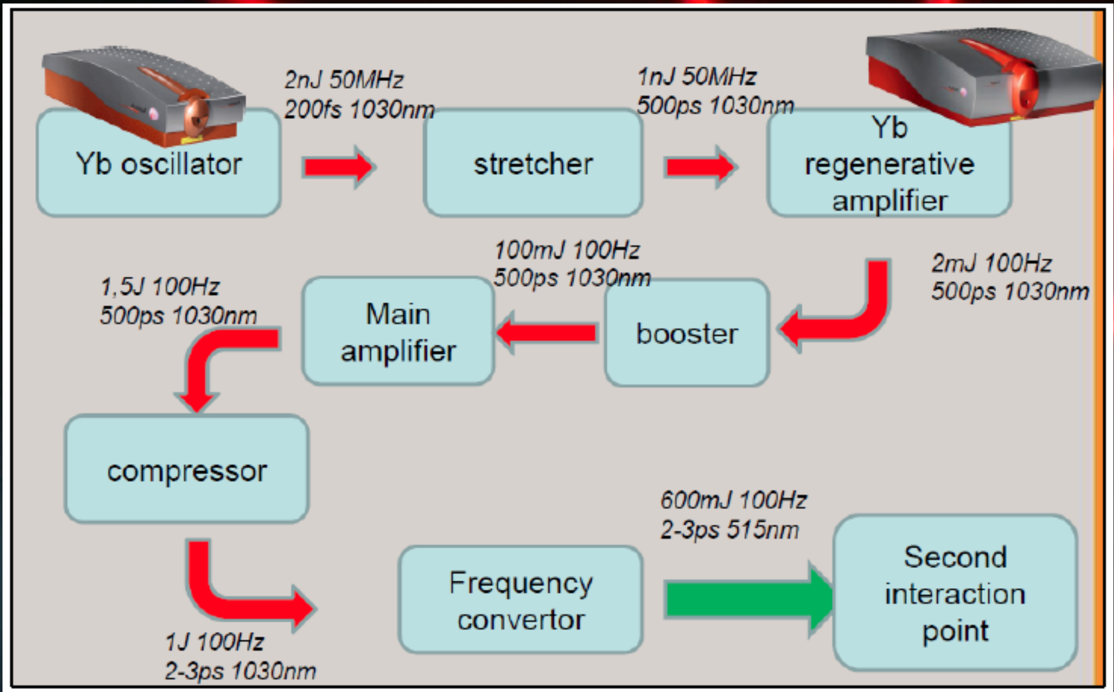
Requirementss:

- Very Cold Neutron moderator + de-magnetized, vacuum tunnel
  - Horizontal arragement: simpler for civil eng., stronger requirements for magnetic shielding
  - Vertical arrangment: "focussing" effect of Earth magnetic field, requires O(100m) well
  - Practically no background
- Ultra Cold Neutron source + magnetic trap
- Sterile neutron apparatus similar to neutron-antineutron experiment: put "regenerator" in the middle of the vacuum tunnel
- With 10^{15} n/s at the target, with cryogenic moderator (solid CH_4 or liquid para-H_2) and with reflector/tunnel optimization, possible to improve ILL result, going in the range of $\tau_{n\text{-}nbar} \approx 10^9$ s

Z. Berezhiani https://agenda.infn.it/getFile.py/access?contribId=9&sessionId=6&resId=0&materialId=slides&confId=6529

Advanced γ-ray Compton Source

The state of the art in producing high brilliance/spectral density mono-chromatic γ-ray beams will be soon enhanced, stepping up from the present performances (γ-ray beams with bandwidth nearly 3% and spectral density of about 100 *photons/s·eV*) up to what is considered the threshold for Nuclear Photonics, *i.e.* a bandwidth of the γ-ray beam lower than 0.3% and a spectral density larger than 10^4 *photons/s·eV*.



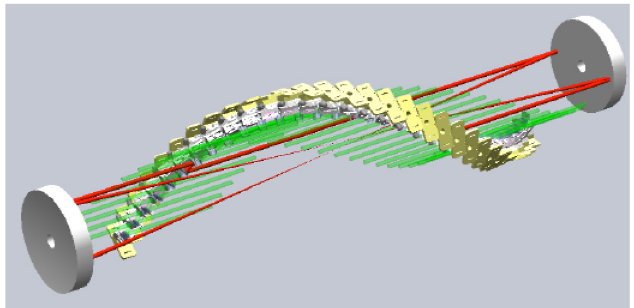


Fig. 133. Schematic view of the re-circulating principle

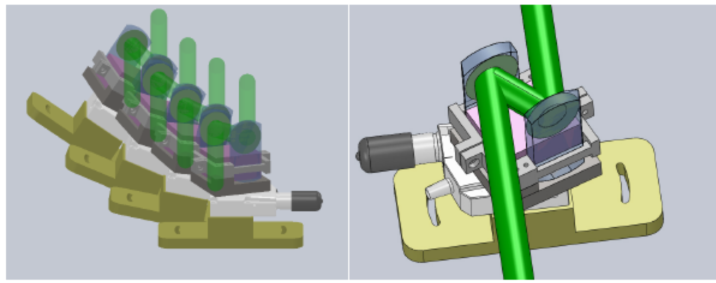


Fig. 134. Schematic view of the motorized mirror pairs used in the re-circulator

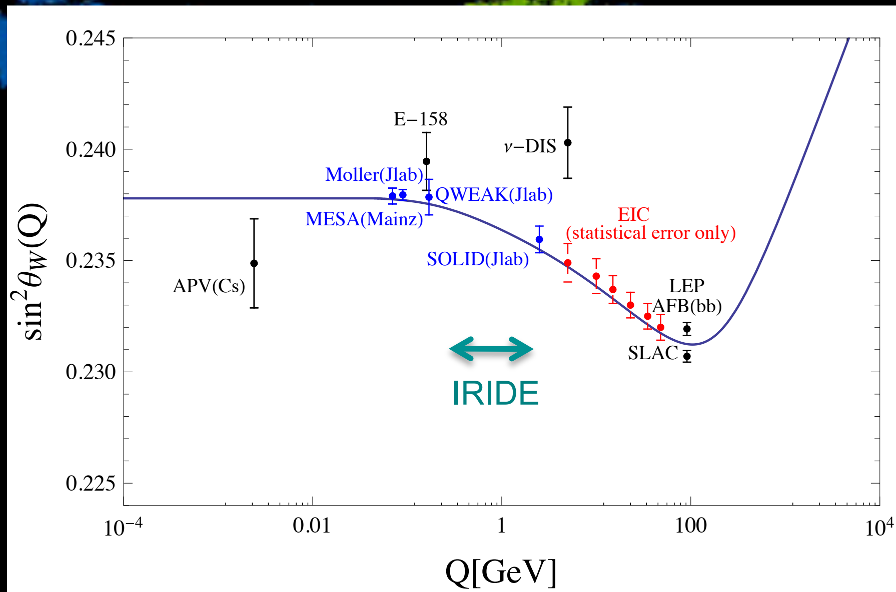
- colliding laser pulses to drive the back-scattering Compton (Yb:YAG, 100 W, 1 J, 0.1% bw)

Advanced γ-ray Compton Source

- studies of the nucleus structure at the Pigmy and Giant Dipole Resonance with unprecedented resolution in reconstructing the nuclear states: this is crucial also to understand some unknown processes in the stellar nucleo-sinthesys
- studies of two level barionc states in the high energy resonance of the nuclei, above 20 *MeV* and up to 60 *MeV*, crucial to reconstruct the equation of state of the nuclear matter
- detection and imaging of fissile and strategic material with isotopic reconstruction of the components with large impact on the national security scenario
- remote sensing and diagnosys of nuclear wastes in containers, with reconstruciotn of the isoptope and nuclear composition of the waste material, with large impact on the atomic energy scenario
- medical imaging and therapy

Electrons on Target

The electron-on-target physics program makes IRIDE a discovery and also a precision physics machine. Among the searched candidates there are the hypothetical particles, like the very-weakly interacting massive U(1) gauge boson (U-boson) as a DM particle candidate and the non-hypothetical, well investigated theoretically, but yet undiscovered, "true muonium" states (TM), which are the bound states of muon and anti-muon with the lifetime of an order of a picosecond.

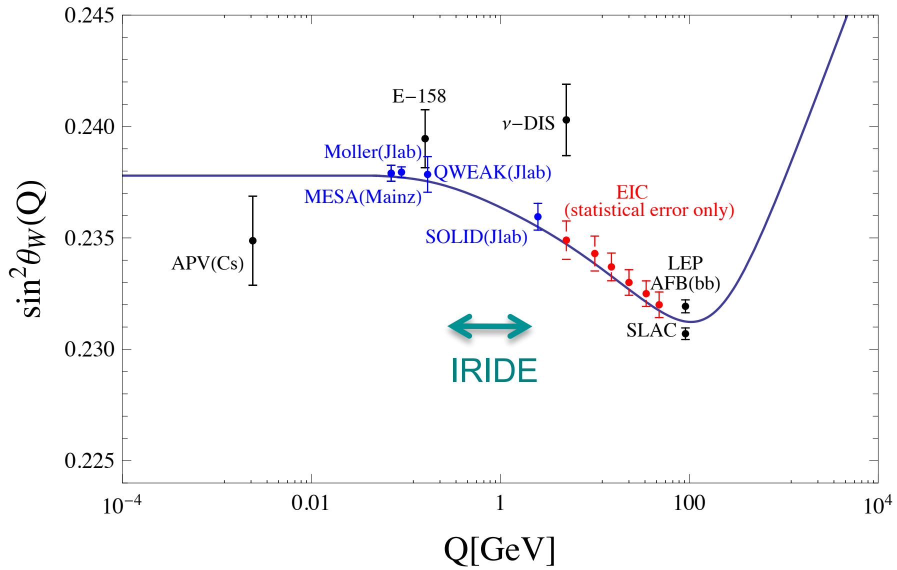


Utilizing the polarized electron beam dumped onto the proton target, one can measure the left-right parity violating asymmetry of electron-proton scattering at the per cent level, and thereby extract precisely the **electroweak mixing angle**.

e^- - target

✓ parity violating asymmetry meas. $e^{\uparrow\downarrow} Z \longrightarrow e\, Z$

- Q^2-evolution of electroweak mixing angle θ_W



$$Q = \sqrt{y\, s}$$

$$\left(y = \frac{1 - \cos\theta_{cm}}{2} \right)$$

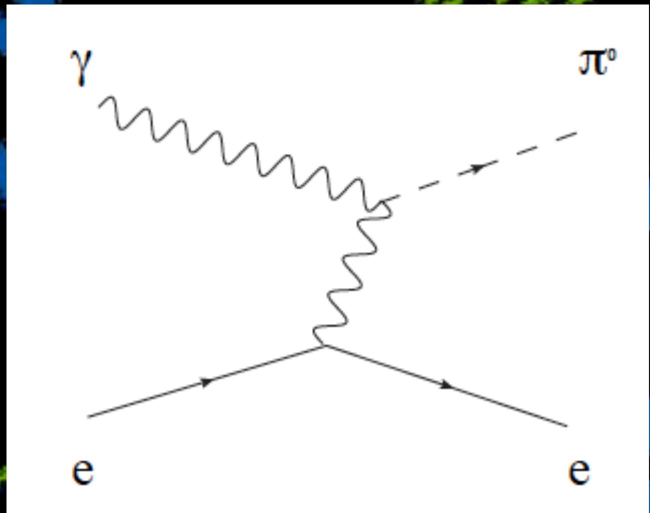
Requests: ✓ polarized beam (P ~ 90%; ΔP ~ 1%)

✓ average current > 200 μA

✓ dark forces searches $e\, Z \longrightarrow e\, Z\, \ell^+ \ell^-$

γ-e Linear Collider

The precise measurement of the π^0 width through the process $e\gamma \to \pi^0 e$ (*Primakoff effect*), and the search for light dark bosons in the energy region of few to hundreds MeV. These measurements, which provide important tests of the Standard Model, are not possible at present electron-photon colliders due to the low photon intensities of the machines.

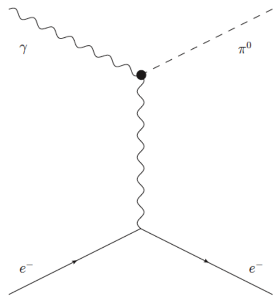


π^0 width measurement: the axial anomaly of Adler, Bell and Jackiw (non-conservation of the axial vector current) is responsible for the decay of the neutral pion into two photons. It bridges in QCD the strong dynamics of infrared physics at low energies (pions) with the perturbative description in terms of quarks and gluons at high energies. The anomaly allows to gain insights into the strong interaction dynamics of QCD and has received great attention from theorists over many years.

Physics case

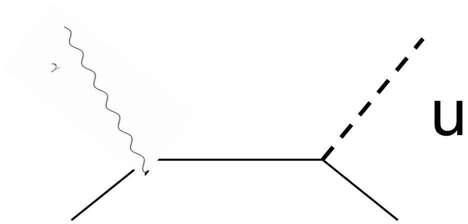
- High intensity electron-gamma interactions at low energy can be a valuable tool for precise tests of the **SM** and discovering physics **BSM**.
- At e–γ collider, with E_e=500-800 MeV and E_γ=10-20 MeV, the c.m. energy available is 140-250 MeV. This is just above the π^0 mass and therefore the $\Gamma(\pi^0 \rightarrow \gamma\gamma)$ can be precisely measured:

$$\gamma + e^- \rightarrow \pi^0 + e^-$$



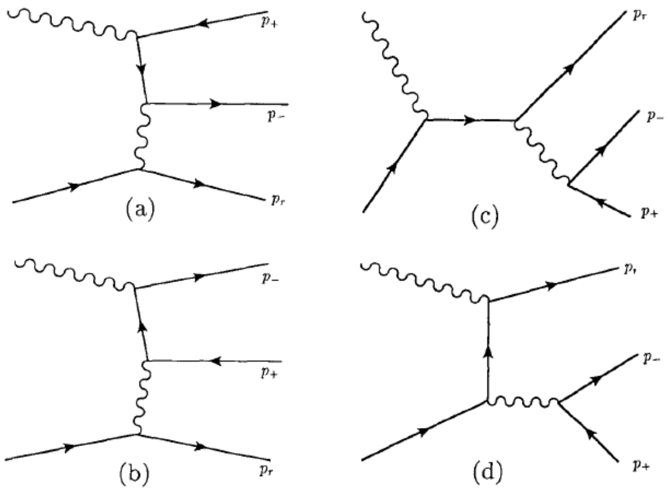
- In addition possible searches for hypothetical light bosons (u bosons) can be done (for M_u<250 MeV):

$$\gamma + e^- \rightarrow u + e^-$$



- There are additional motivations (double and triple Compton, $\mu\mu$ production near threshold, etc…)

Precision test of QED prediction: Triplet photoproduction $e^-\gamma \rightarrow e^-\gamma^* \rightarrow e^-e^+e^-$



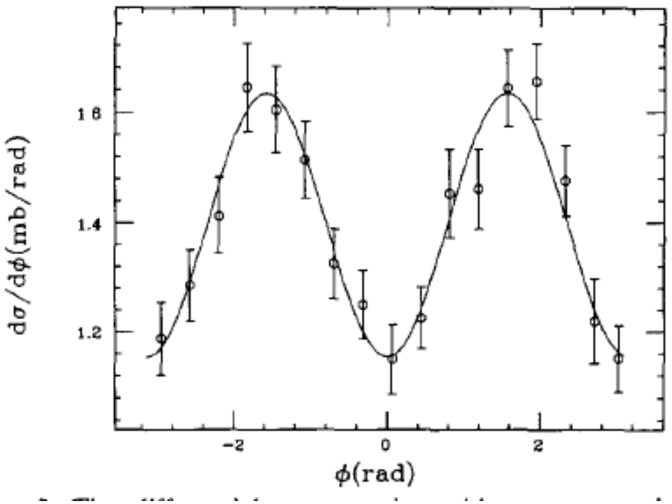
-This process is very important to determine the linear polarization of the photon (at Eγ>500 MeV). It has astrophysical implications (Gamma-rays Polarization)

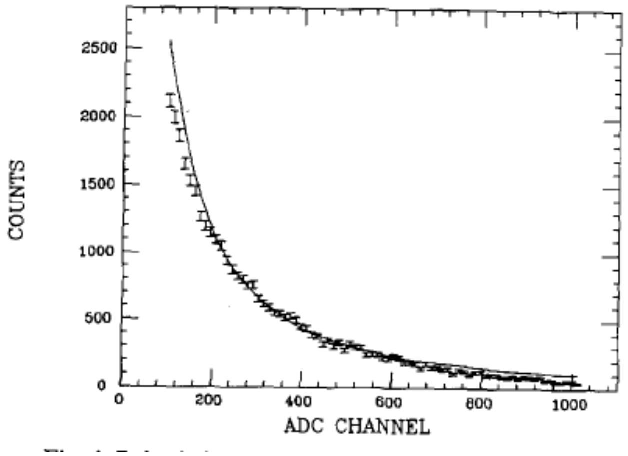
$$\frac{d\sigma}{d\varphi} = \frac{\sigma_0}{2\pi}\left(1 + P_\gamma \lambda \cos(2\varphi)\right)$$

λ=analyzing power

- Existing measurements differ from theor

Azimutal angle of e-





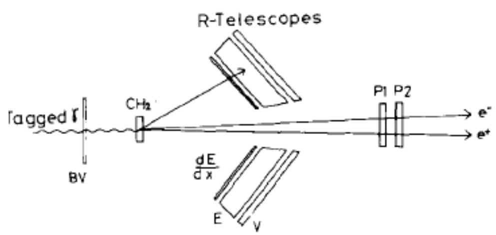


Fig. 1. Experimental layout.

I.Endo et al. NIM A280 (1989) 144

Test of QM at IRIDE?

Triple Compton effect: A photon splitting into three upon collision with a free electron

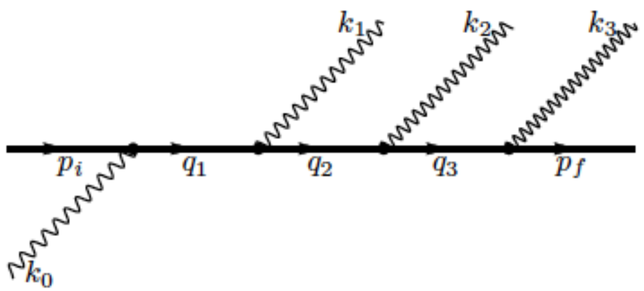
Erik Lötstedt* and Ulrich D. Jentschura

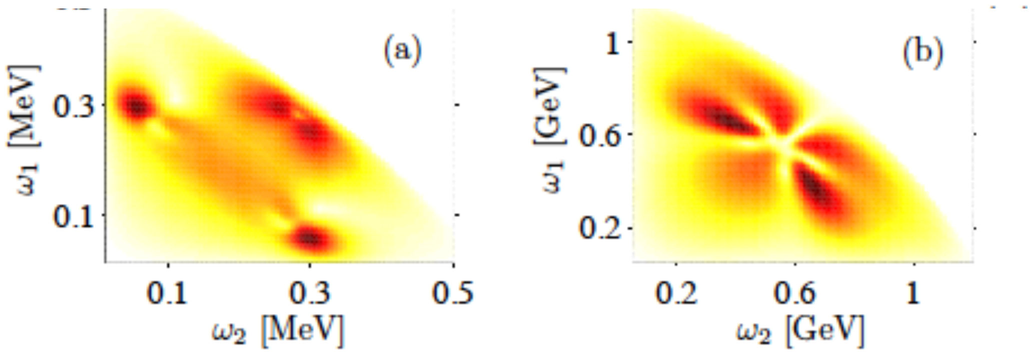
Phys.Rev.Lett. 108 (2012) 233201

The process in which a photon splits into three after the collision with a free electron (triple Compton effect) is the most basic process for the generation of a high-energy multi-particle entangled state composed out of elementary quanta. The cross section of the process is evaluated in two experimentally realizable situations, one employing gamma photons and stationary electrons, and the other using keV photons and GeV electrons of an x-ray free electron laser. For the first case, our calculation is in agreement with the only available measurement of the differential cross section for the process under study. Our estimates indicate that the process should be readily measurable also in the second case. We quantify the polarization entanglement in the final state by a recently proposed multi-particle entanglement measure.

$$e^- + \gamma \longrightarrow e^- + \gamma + \gamma + \gamma.$$

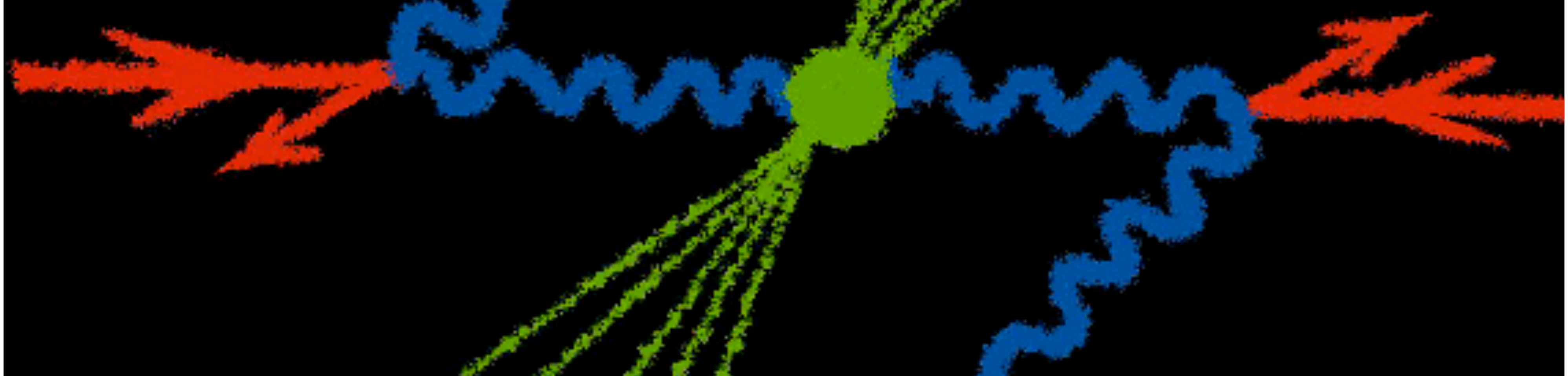
$$\langle \lambda_1 \lambda_2 \lambda_3 | \varrho | \lambda_1' \lambda_2' \lambda_3' \rangle = N \sum_{r_i, r_f} M(\lambda_1 \lambda_2 \lambda_3)\, M^*(\lambda_1' \lambda_2' \lambda_3'),$$





e^{+} e^{-} Linear Collider

An electron-positron collider with luminosity of 10^{32} cm^{-2}s^{-1} with center of mass energy ranging from the mass of the φ-resonance 1 GeV up to ~3.0 GeV, would complement high-energy experiment at the LHC and future linear collider (ILC). Such a machine can easily collect an integrated luminosity of about 5 fb^{-1} in a few years of data taking.



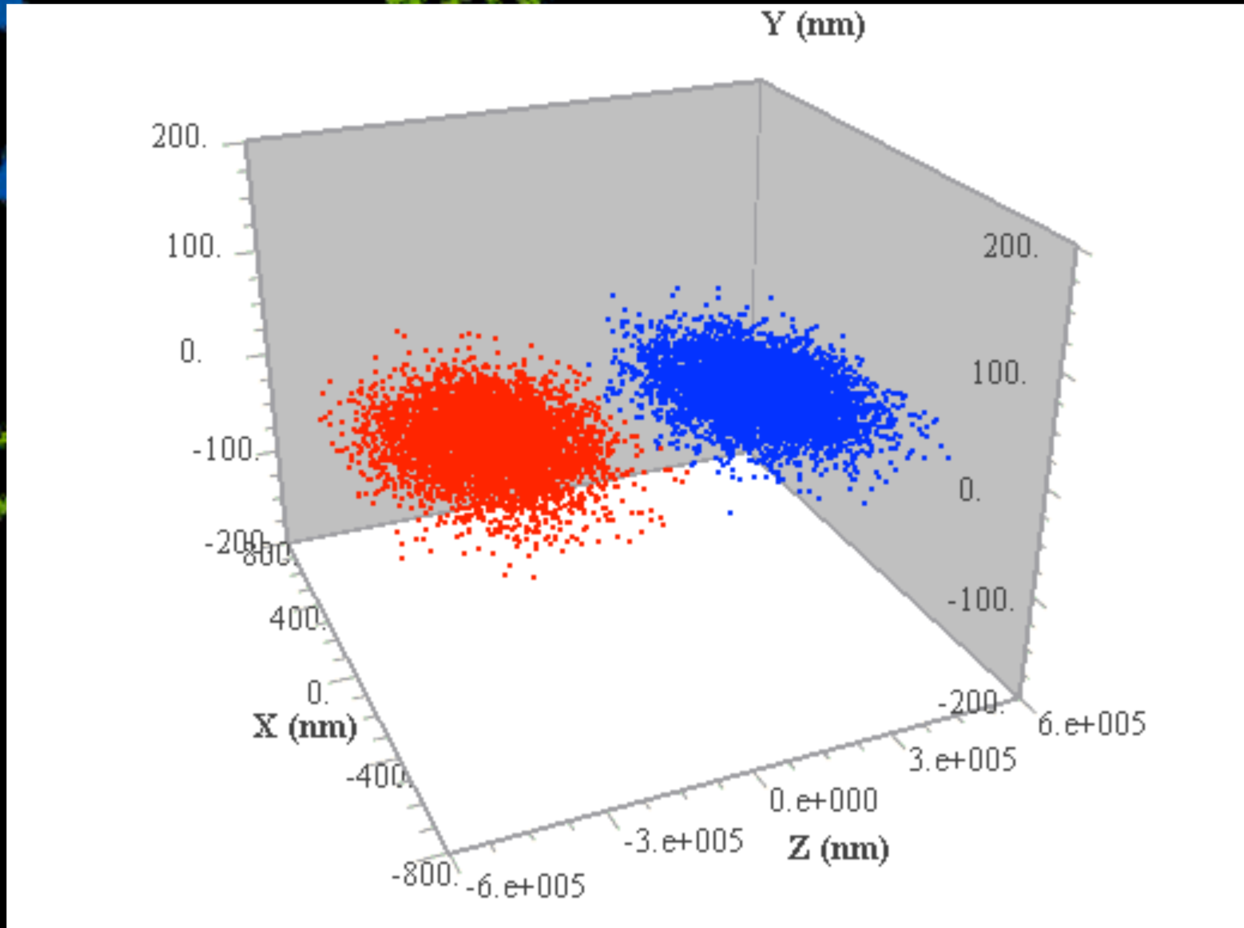
This will allow one to measure the e^+e^- cross section to hadrons with a total fractional accuracy of 1%, a level of knowledge that has relevant implications for the determination of SM observables, like, the *g*-2 of the muon and the effective fine-structure constant at the M_Z scale. The latter are, through quantum effects, sensitive to possible bSM physics at scales of the order of hundred GeV or TeV.

A primary effect of the electron-positron interaction is an enhancement of the luminosity due to the **pinch effect**, i. e. the reduction of the cross section of both beams occurring at the IP due to **self focusing forces** that is included in the luminosity definition through the factor $\mathbf{H_D}$.

$$L = \frac{n_b N_e^2 f_{rep}}{4\pi\sigma_x^*\sigma_y^*} \times H_D = \langle I \rangle \times \frac{N_e}{4\pi\sigma_x^*\sigma_y^*} \times H_D$$

$$H_D = \frac{L}{L^*} = \frac{\sigma_x^*\sigma_y^*}{\sigma_x\sigma_y}$$

$$D_{x,y} \equiv \frac{2N_e r_e}{\gamma} \frac{\sigma_z}{\sigma_{x,y}\left(\sigma_x + \sigma_y\right)}$$



$$\sigma''_{pos,x} + \frac{k_{el}^2}{\gamma}\sigma_{pos,x} = \frac{\varepsilon_{pos,n}^2}{\gamma^2 \sigma_{pos,x}^3}$$

$$k_{el}^2 = \frac{4 I_{el}}{I_A \sigma_{el,x}^{*2}}$$

$$\sigma_{x,pos} = \sqrt[2]{\frac{\varepsilon_{n,pos}}{\sqrt{\gamma} k_{el}}}$$

Under the previous condition the positron beam spot size remains constant during the interaction due to the balance between its own defocusing emittance pressure and the counter-propagating electron beam focusing effect.

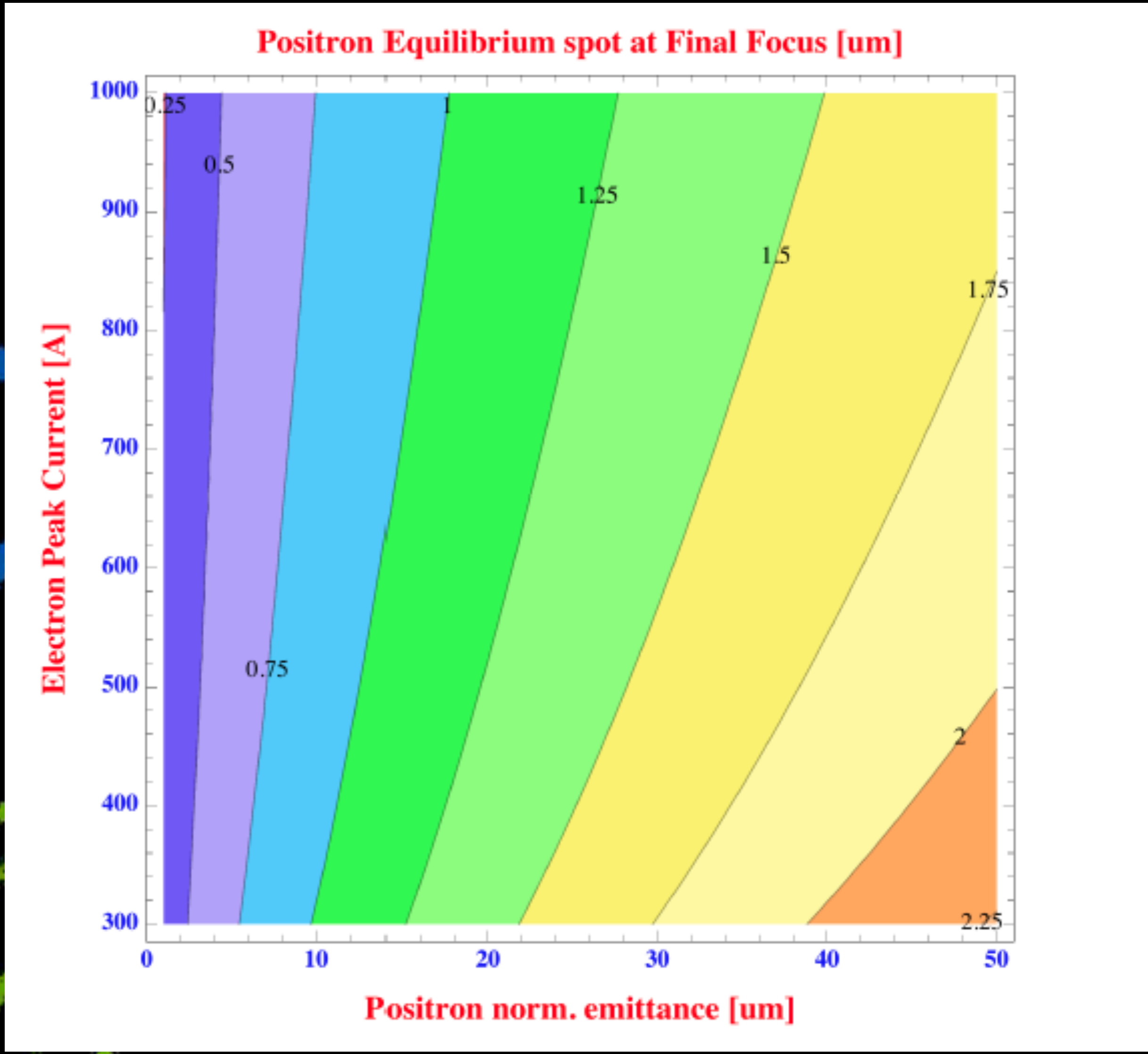
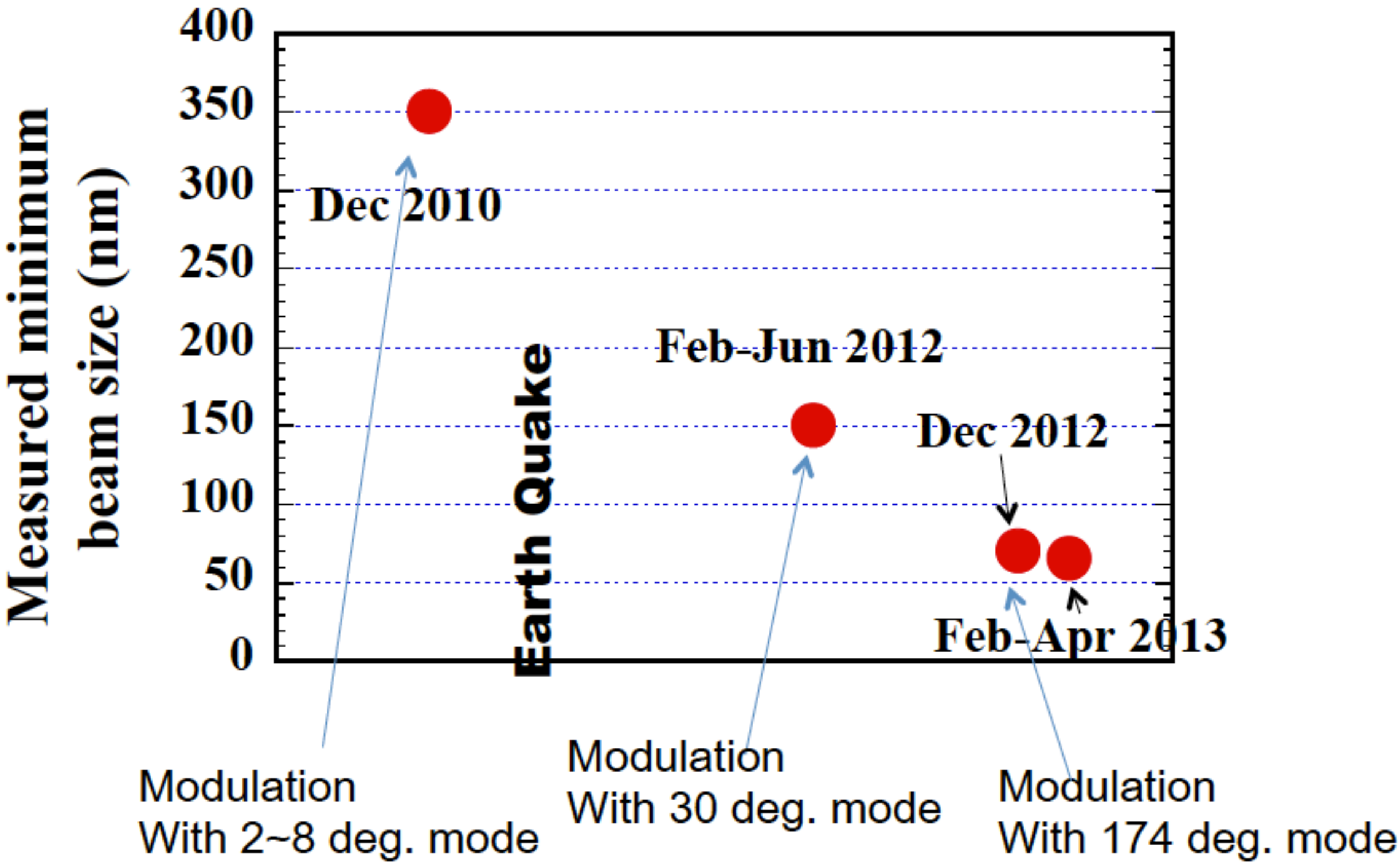


Table 1.8: parameters at the IP of the IRIDE linear collider for 3 GeV c.m. energy

Parameters	**Units**	**Electrons ⨯ Electrons**	**Electrons ⨯ Positrons**
Beam energy	[GeV]	1.5	1.5
Beam power	[MW]	0.45	0.53
Charge	[nC]	0.3	0.35
Bunch length rms	[μm]	270	150
Peak current	[A]	333	700
Rep. rate	[MHz]	1	1
Average current	[mA]	0.3	0.35
Transverse rms spot at IR	[μm]	0.5	0.5
Norm. emittance	[μm]	2	5
Beta at IR	[mm]	0.4	0.15
Disruption parameter	D	2.6	1.23
Beam-strahlung parameter	δ_{ε}	$\sim 10^{-7}$	$\sim 10^{-6}$
Luminosity enhancement factor	H_D		1.2
Luminosity	$cm^{-2}s^{-1}$	$1.1\ 10^{32}$	$1.3\ 10^{32}$


Measured minimum beam size (nm)
400
350
300
250
200
150
100
50
0
Dec 2010
Earth Quake
Feb-Jun 2012
Dec 2012
Feb-Apr 2013
Modulation
With 2~8 deg. mode
Modulation
With 30 deg. mode
Modulation
With 174 deg. mode

e^+e^- collider

Physics opportunities with an e^+e^- collider with c.o.m. energy tunable within [$\sim$ 0.5, $\sim$ 3.0] GeV

✓ hadronic cross-section meas. $e^+e^- \rightarrow \gamma^* \rightarrow$ had.

- hadronic contribution to muon a.m.m. a_μ
- hadronic contribution to α_{em}

✓ two-photon physics $e^+e^- \rightarrow e^+e^- \gamma^*\gamma^* \rightarrow e^+e^-$ + had.

- had. ≡ π^0, η, η' $\rightarrow$ light-by-light contribution to a_μ^{had}
- meson spectroscopy

✓ exotics $e^+e^- \rightarrow \gamma\, U \rightarrow \gamma\, \ell^+\ell^-$,

$\rightarrow \gamma\, E_{miss.}$

- possible existence of low-energy (0.1 ÷ 1 GeV) new gauge interactions (dark forces)

e^+e^- collider

LNF-10/17(P)

see also Eur. Phys. J. C **50** (2007) 729

Proposal for taking data with the KLOE-2 detector at the DAΦNE collider upgraded in energy

D. Babusci[a], C. Bini[b], F. Bossi[a], G. Isidori[a], D. Moricciani[c], F. Nguyen[d], P. Raimondi[a], G. Venanzoni[a], D. Alesini[a], F. Archilli[c], D. Badoni[a], R. Baldini-Ferroli[a,r], M. Bellaveglia[a], G. Bencivenni[a], M. Bertani[a], M. Biagini[a], C. Biscari[a], C. Bloise[a], V. Bocci[d], R. Boni[a], M. Boscolo[a], P. Branchini[d], A. Budano[d], S.A. Bulychjev[e], B. Buonomo[a], P. Campana[a], G. Capon[a], M. Castellano[a], F. Ceradini[d], E. Chiadroni[a], P. Ciambrone[a], L. Cultrera[a], E. Czerwinski[a], E. Dané[a], G. Delle Monache[a], E. De Lucia[a], T. Demma[a], G. De Robertis[f], A. De Santis[b], G. De Zorzi[b], A. Di Domenico[b], C. Di Donato[g], B. Di Micco[d], E. Di Pasquale[a], G. Di Pirro[a], R. Di Salvo[c], D. Domenici[a], A. Drago[a], M. Esposito[a], O. Erriquez[f], G. Felici[a], M. Ferrario[a], L. Ficcadenti[a], D. Filippetto[a], S. Fiore[b], P. Franzini[b], G. Franzini[a], A. Gallo[a], G. Gatti[a], P. Gauzzi[b], S. Giovannella[a], A. Ghigo[a], F. Gonnella[c], E. Graziani[d], S. Guiducci[a], F. Happacher[a], B. Höistad[h], E. Iarocci[a,i], M. Jacewicz[h], T. Johansson[h], W. Kluge[j], V.V. Kulikov[e], A. Kupsc[h], J. Lee Franzini[a], C. Ligi[a], F. Loddo[f], P. Lukin[k], F. Marcellini[a], C. Marchetti[a], M.A. Martemianov[e], M. Martini[a], M.A. Matsyuk[e], G. Mazzitelli[a], R. Messi[c], C. Milardi[a], M. Mirazzita[a], S. Miscetti[a], G. Morello[l], P. Moskal[m], S. Müeller[n], S. Pacetti[a,r], G. Pancheri[a], E. Pasqualucci[b], M. Passera[o], A. Passeri[d], V. Patera[a,i], A.D. Polosa[b], M. Preger[a], L. Quintieri[a], A. Ranieri[f], P. Rossi[a], C. Sanelli[a], P. Santangelo[a], I. Sarra[a], M. Schioppa[l], B. Sciascia[a], M. Serio[a], F. Sgamma[a], M. Silarski[m], B. Spataro[a], A. Stecchi[a], A. Stella[a], S. Stucci[l], C. Taccini[d], S. Tomassini[a], L. Tortora[d], C. Vaccarezza[a], R. Versaci[p], W. Wislicki[q], M. Wolke[h], J. Zdebik[m], M. Zobov[a]

e^+e^- - collider

Requests:

- ✓ luminosity $\sim 10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
- ✓ energy $\sqrt{s} = (0.6 \div 3.0)\ \mathrm{GeV}$ (in steps of ~ 25 MeV)
- ✓ tagging systems for $\gamma\gamma$-physics

Positron source $\longrightarrow$ Bethe-Heitler: $\gamma\, Z \longrightarrow e^+e^-\, Z$

simulation (G4) in progress (collaboration w/ Rm2)

case under study: $E\gamma$ = 60 MeV on Pb (0.4 X_0)

Table 12: Comparison between Conventional and ICS positron source performances

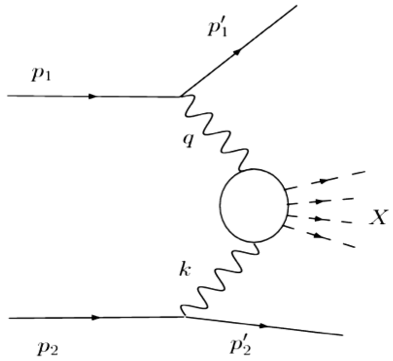
	Conventional	**ICS based**
RMS source size	400 μm	50 μm
N. particles/driving pulse	one 600 MeV electron	one 60 MeV photon
Target thikness	$6X_0$	$0.4X_0$
RMS transverse momentum	5 MeV	1 MeV
RMS emittance	0.001 m rad	$50 \cdot 10^{-6}$ m rad
N. positrons/pulse	1	0.4

For the peak brightness the main advantage of driving the conversion directly with a photon beam relies on the possibility of using thinner targets. The emittance of the positron beam emerging from the target is determined by the source size and the beam divergence.

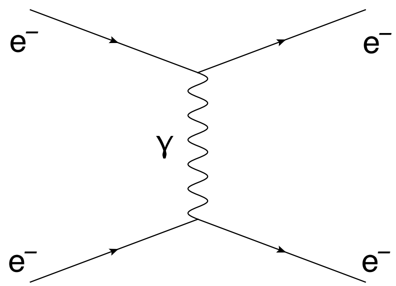
e^-e^- - collider

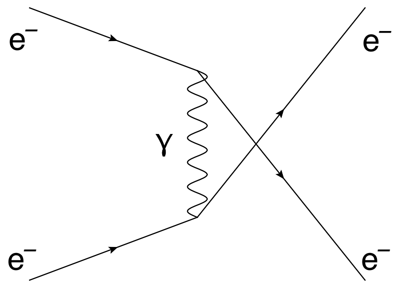
Physics case:

✓ $\gamma\gamma$ physics (as in e^+e^- case)



NB – NO bckg associated to the annihilation channel

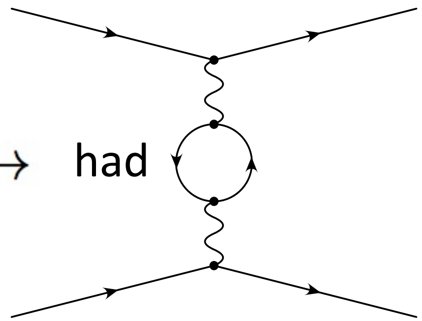




e^-e^- - collider

✓ vacuum polarization → possibility to obtain a_μ^{had} from t-channel diagram in Moller scattering

$\bar{\Pi}^2_{\mathrm{hadr}}(t) \quad \longrightarrow$



(M. Passera, L. 32, G. Venanzoni
in progress)

$$a_\mu^{\mathrm{HLO}} = \frac{\alpha}{\pi} \int_{-\infty}^{0} \mathrm{d}t\, f(t)\, \bar{\Pi}^2_{\mathrm{hadr}}(t)$$

with

$$f(t) = -\frac{1}{t\,\beta} \left[1 - \frac{t}{2\,m^2} (1-\beta) \right]^2$$

need to measure momentum and angle of final e^-

γ-γ Linear Collider

The vacuum of QED poses some still unsolved challenges which are central not only in the context of field theory, but also of super-symmetry and string theory as well. The elastic photon-photon scattering offers unique opportunities to probe the nature of QED vacuum.

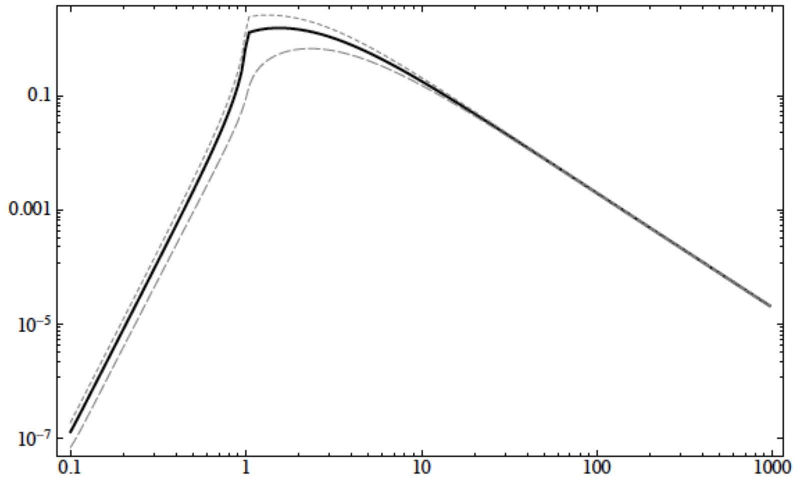
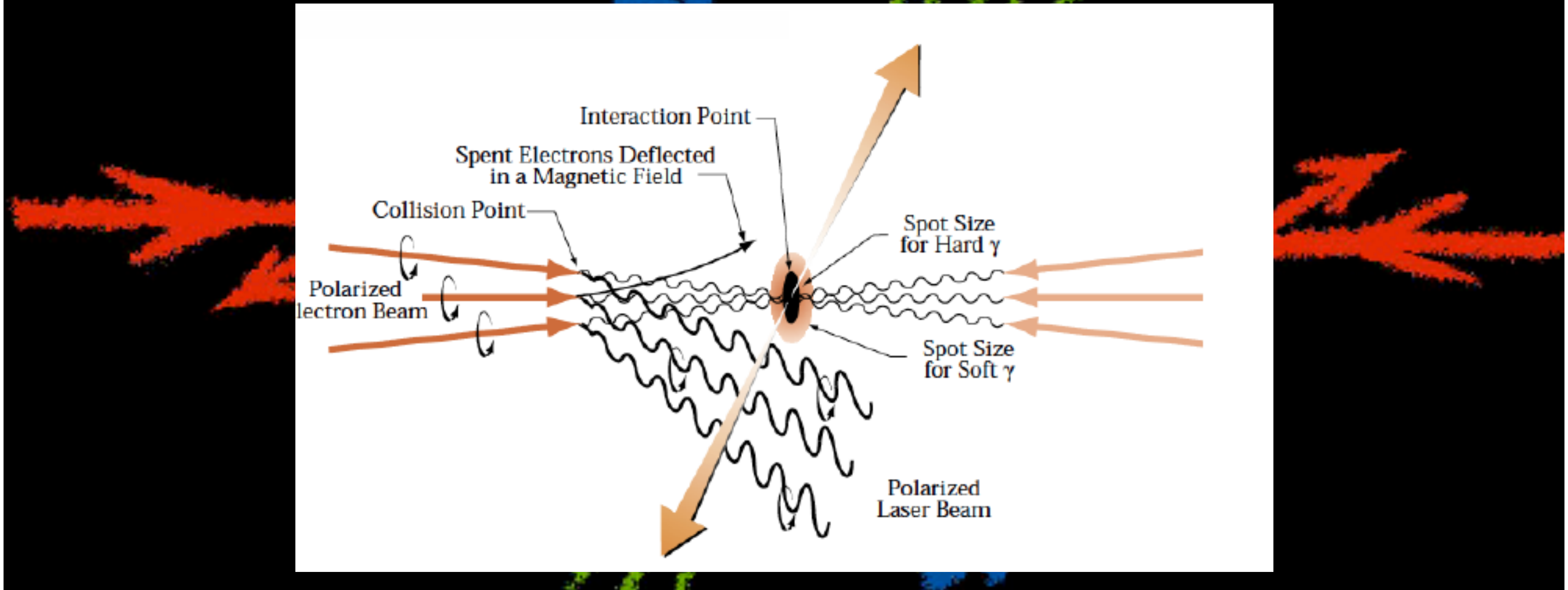


Figure 18: total cross-section (μbar) vs. CM energy (MeV). Solid line: cross-section averaged over initial photon polarizations. Dotted line: incoming photons have the same circular polarization. Dashed line: incoming photons have opposite circular polarization.

We propose an experiment to observe photon-photon scattering in the range 1 MeV – 2 MeV CM energy, i.e., near the peak of the QED cross-section. In addition a low-energy photon-photon collider investigation could lead to the necessary technology developments and prepare the ground for a higher energy complex, while still providing a rich testing ground for QED, and, more generally, QFT.

γ-γ Linear Collider

The most striking failing of QFT is the huge mismatch between the measured energy density of vacuum and the energy density of the ground level of the fundamental fields which is wrong by something like 120 orders of magnitude.



a photon-photon scattering experiment with photon energies in the 0.5-0.8 MeV range – where the cross-section is reasonably large, would be an important test of our understanding of the QED vacuum.

This experiment needs a low-energy photon-photon collider, and a photon detection apparatus which is very similar to that current PET scanners


To be continued ….?
Effective collaboration among Italian and Euopean research institutes !!