Advanced Crystal Assisted Techniques for EuPRAXIA

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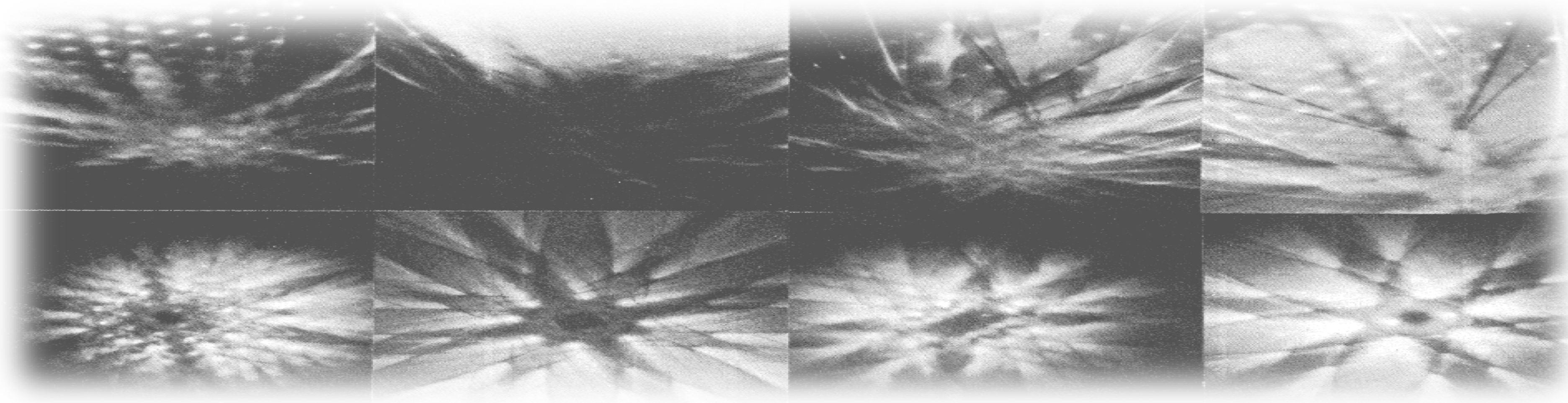


@ Positron source

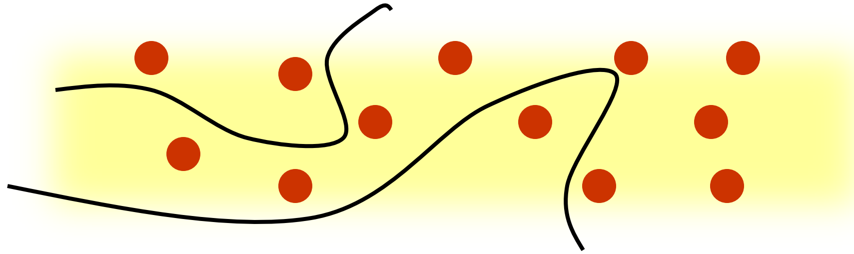
Reasonably effective approach for a positron source known as a “hybrid” solution is to use a sub-GeV or GeV electron beam for production of channeling radiation in a crystalline target (radiator) with its subsequent conversion into electron-positron pairs in amorphous target (convertor). On the contrary to channeling radiation by relativistic particles, coherent bremsstrahlung (for aligned crystals) is characterized by higher radiation frequencies at lower energies of charged particles crossing the crystal, the radiation intensity of which exceeds those for bremsstrahlung. This feature can be also utilized for getting an effective positron source at much lower electron energies.

@ Accelerating technique

Including general aspects of beams channeling in strong external electromagnetic fields, in this report the possibility for a new technique of particles acceleration based on channeling of charged beams in solids will be discussed. The research in this field is of strong interests due to the fact that the field gradients that could be obtained in solids (especially, in aligned crystals) are of the order of 0.1-1 TeV/m or even higher.

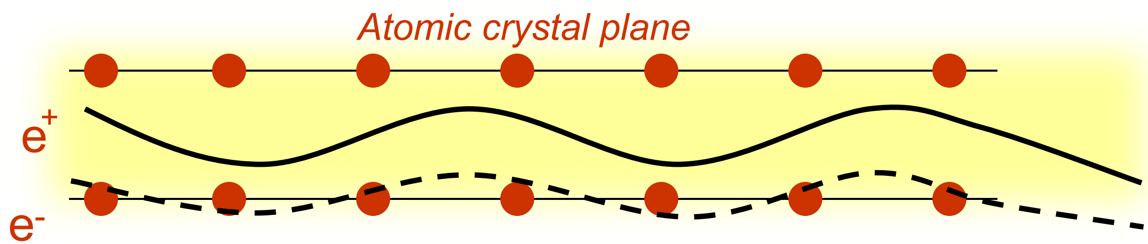
@ channeling of charged particles

@ Amorphous:

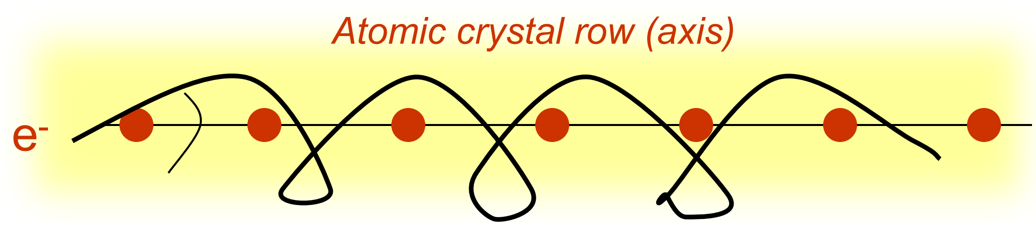


@ Channeling:

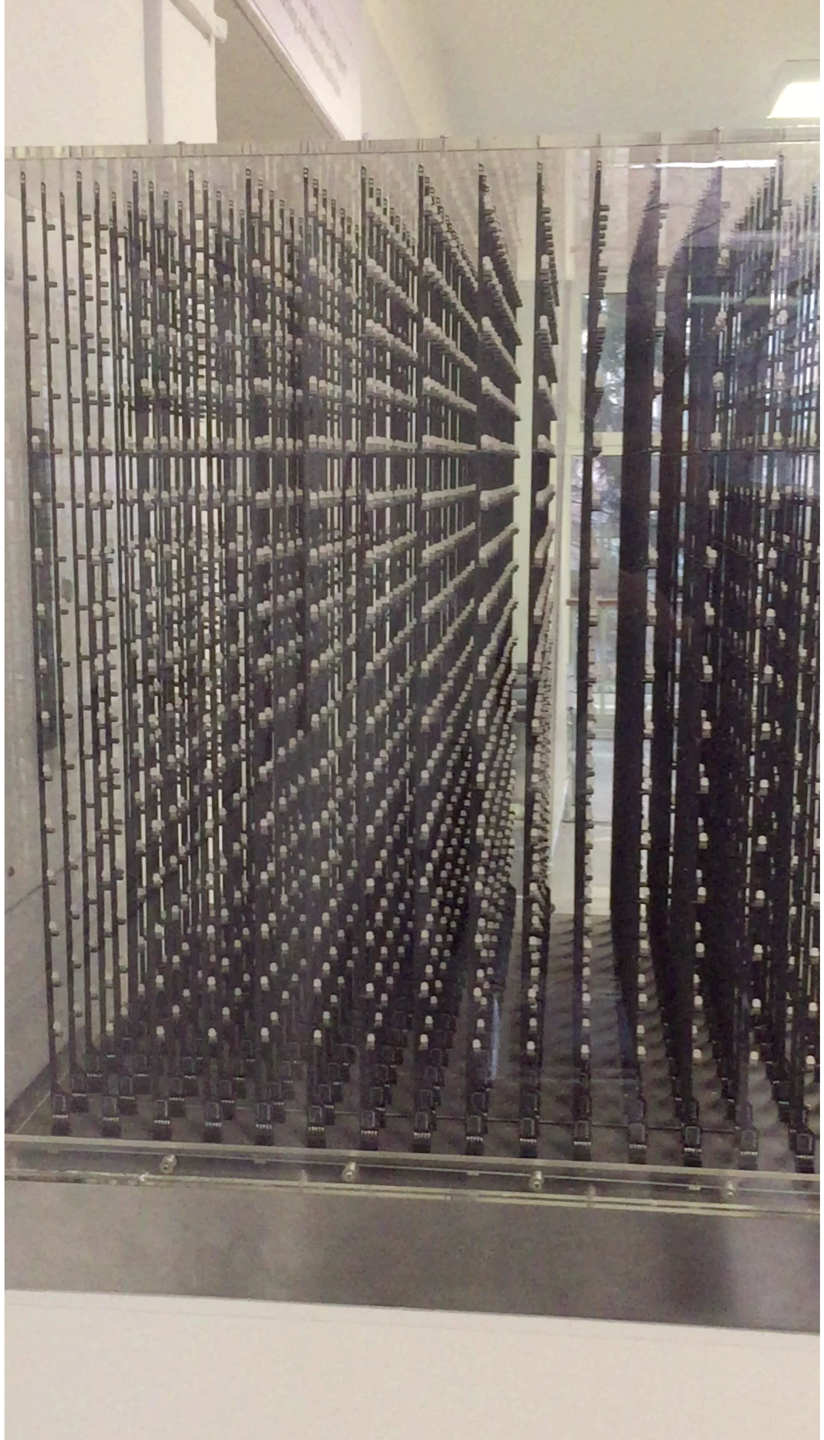
planar channeling



axial channeling

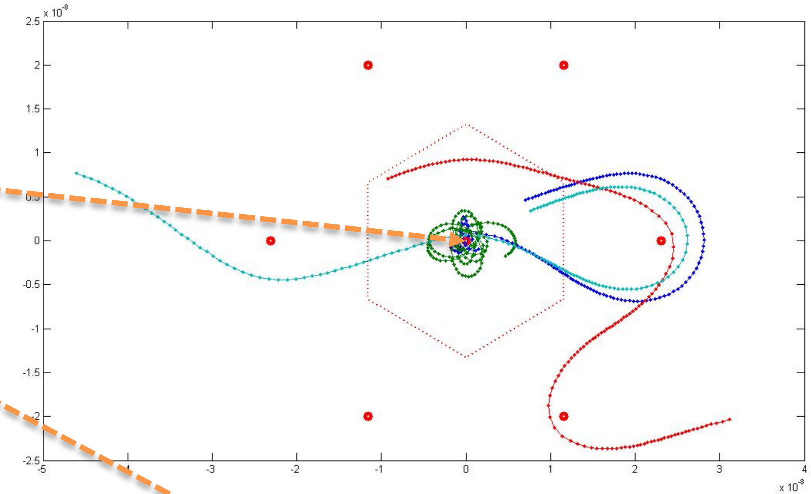


$\phi << 1$ $\quad (\phi < \phi_L \sim \sqrt{U/E})$ - *the Lindhard angle is the critical angle for the channeling*



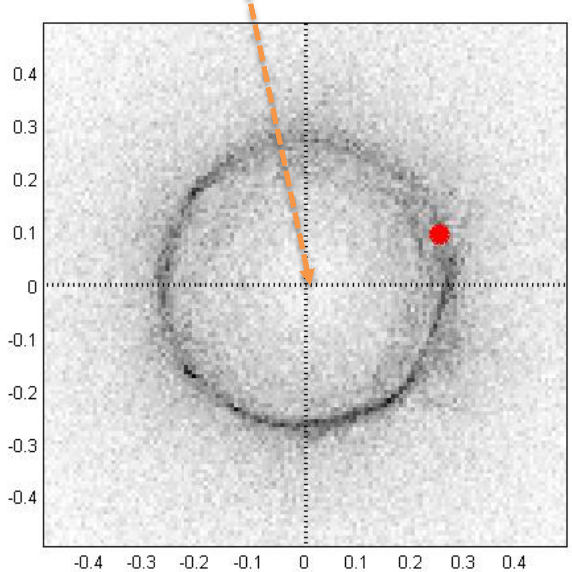
@ electron beam dynamics in crystals: simulations

Ge <111> e- 150 MeV



various trajectories transverse axis cross-section

Computer simulations for angular distribution of a beam vs depth of penetration

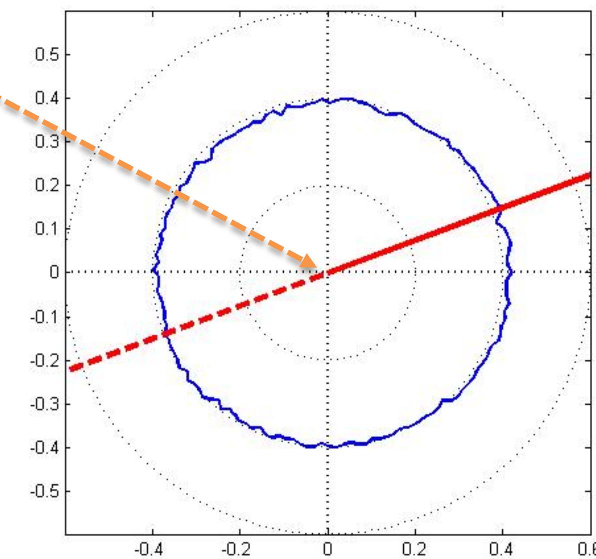


$\Delta\theta = 0$ – beam divergence

$\theta_0 = 0.25\ \theta_c$ – incidence angle

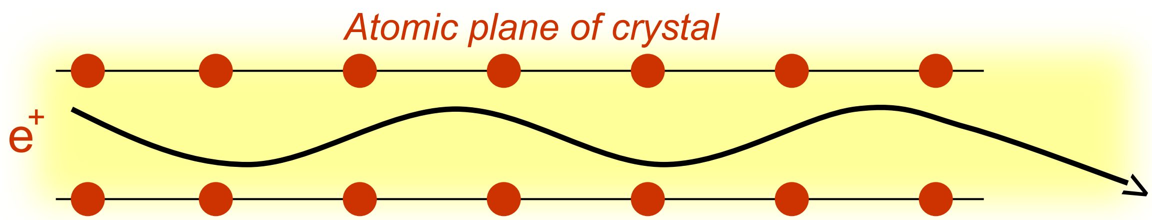
depth evolution

$\Delta t = 81\ nm \div 1.33\ \mu m$



@ channeling of charged particles & channeling radiation

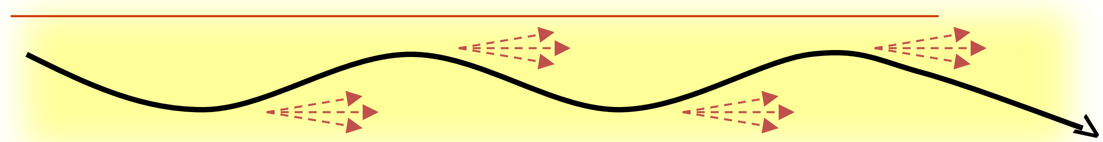
@ Channeling:



$\phi << 1 \qquad (\phi < \phi_L \sim \sqrt{U/E})$ - *the Lindhard angle is the critical angle for the channeling*

@ Channeling Radiation (ChR):

$$\omega = \omega(\theta) = \frac{\omega_{fi}}{1 - \beta_{\|} \cos\theta}$$



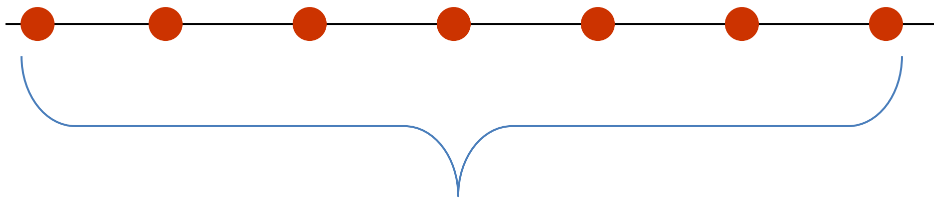
$_{fi}$ - *optical frequency* $\longrightarrow$ *Doppler effect* $\longrightarrow$ $\omega_0\gamma^{3/2}$ - $\omega_0\gamma^2$

$(\gamma >> 1)$

Powerful radiation source of X-rays and gamma-rays:

- polarized
- Tunable (keV - MeV)
- narrow forwarded

@ channeling: continuum potential



fast motion -- averaging

$$V(r) = \frac{Z_1 Z_2 e^2}{r}\varphi(r/a)$$

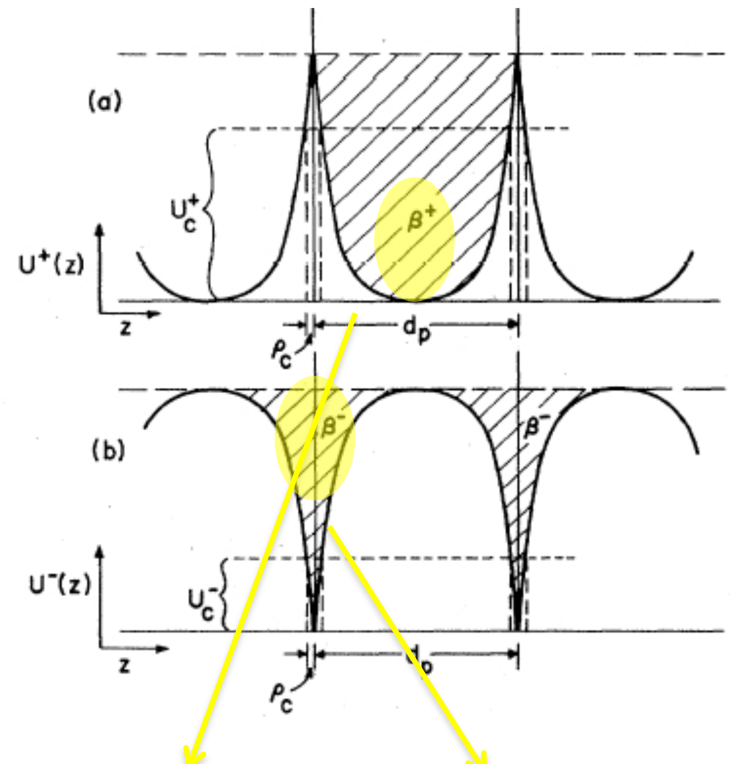
$$a = .8853 a_0 \left(Z_1^{1/2} + Z_2^{1/2}\right)^{-2/3}$$

$$V_{RS}(\rho) = \frac{1}{d}\int_{-\infty}^{+\infty} V\left(\sqrt{\rho^2 + x^2}\right) dx$$

Lindhard:

Continuum model –

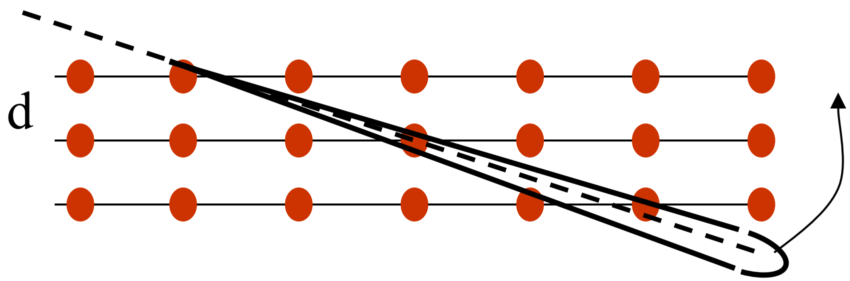
continuum atomic plane/axis potential



$$\left(\frac{\partial U}{\partial x}\right)_{plane} \ll \left(\frac{\partial U}{\partial x}\right)_{axis}$$

@ bremsstrahlung & coherent bremsstrahlung vs channeling radiation

@ crystal: $\alpha \to 0$



Channeling orientation

optical

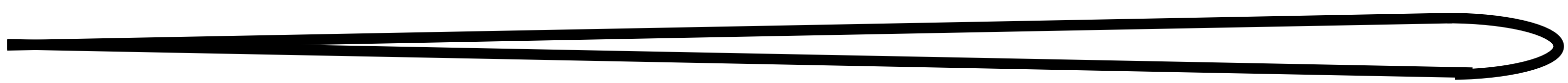
$$\omega = \frac{\omega_{fi}}{1 - \beta_{||} \cos\theta}$$

X and γ

$$\left(\frac{dI}{d\omega}\right)_{CR} \propto \omega \left[1 - 2\left(\frac{\omega}{\omega_m}\right) + 2\left(\frac{\omega}{\omega_m}\right)^2\right], \quad \omega \leq \omega_m \simeq 2\gamma^2 \omega_{fi}$$

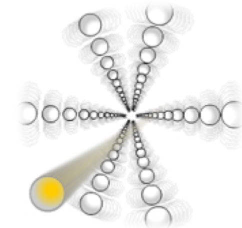
$$\frac{ChR}{B} \propto \gamma^{1/2} Z^{-2/3}$$

at definite conditions channeling radiation
Becomes more powerful than bremsstrahlung

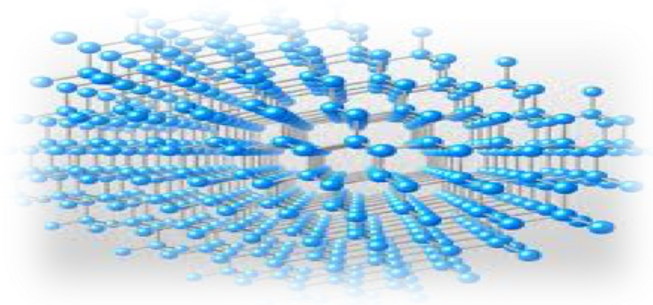


B:	CB:	ChR:
	NZe	$N \leftrightarrow \quad l_{coh} \propto \gamma^2 / \omega \quad N_{eff}$
$\propto NZ^2$	$\propto (NZ)^2$	$\propto (N_{eff} Z)^2$

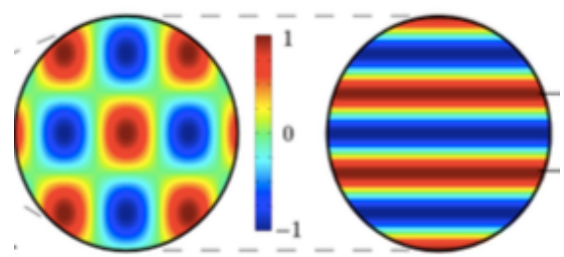
Channeling based applications for Electron beams: from Crystal to Capillary guides

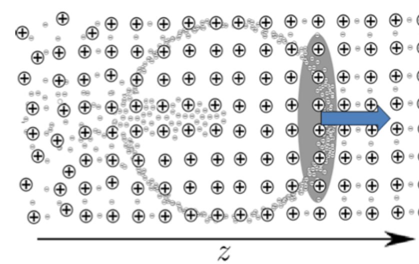


- **Crystal Channeling**
  - Beam shaping;
  - Micro-undulator;
  - Positron source

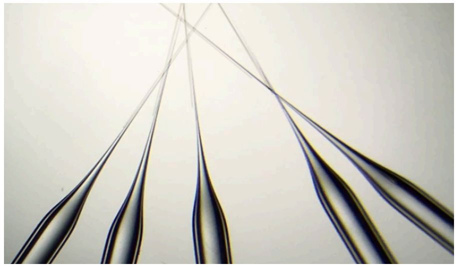


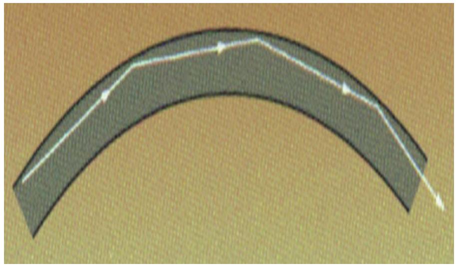
- **Laser & Plasma Channels**
  - Beam profiling for high current/luminosity;
  - Dynamics for wake field acceleration;





- **Capillary MicroChannels**
  - Electron beam deflection;
  - Compact storage (?)



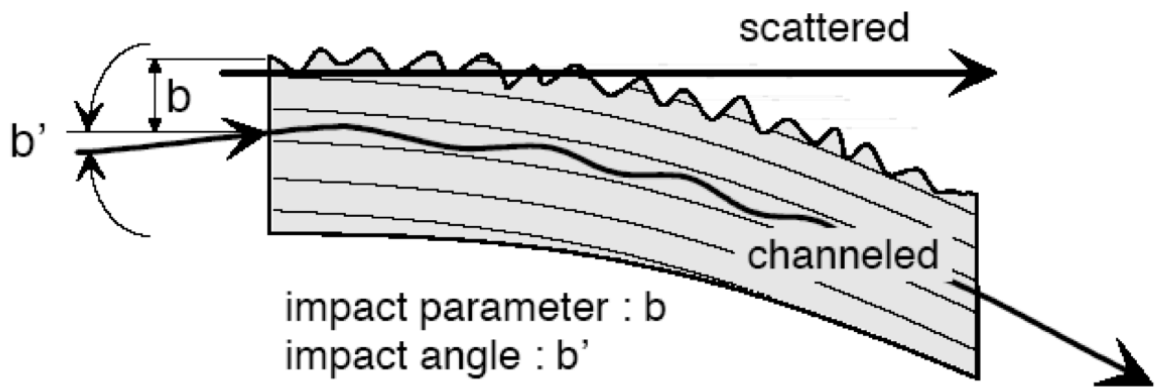


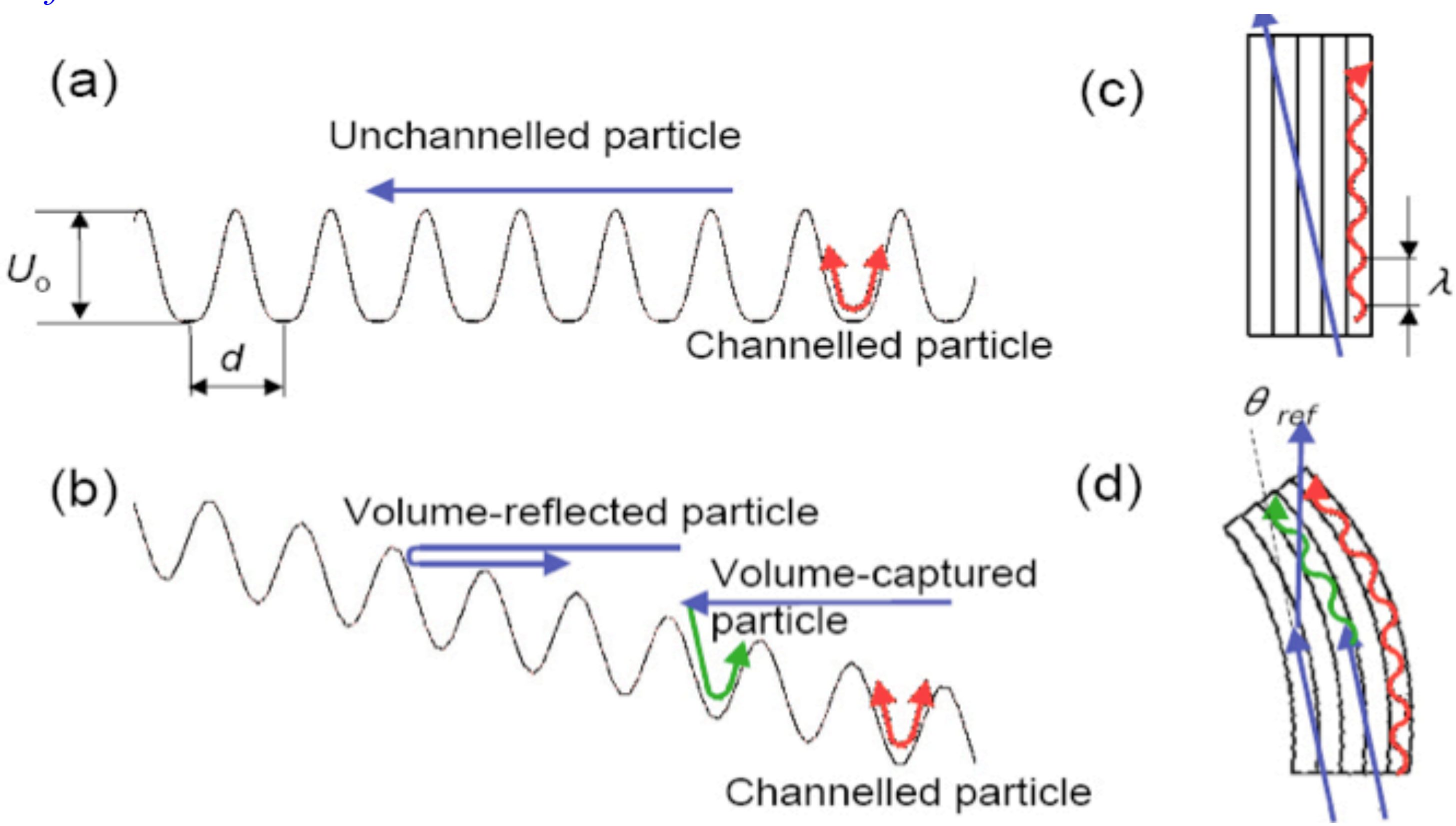
@ Beam Steering & Coherent Radiation

@ beam steering by crystal

Possible processes:

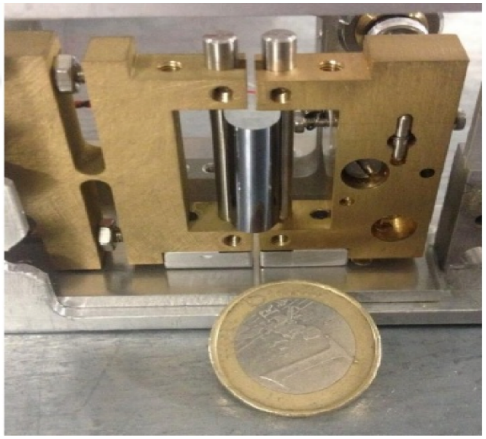
- multiple scattering
- channeling
- volume capture
- de-channeling
- *volume reflection*

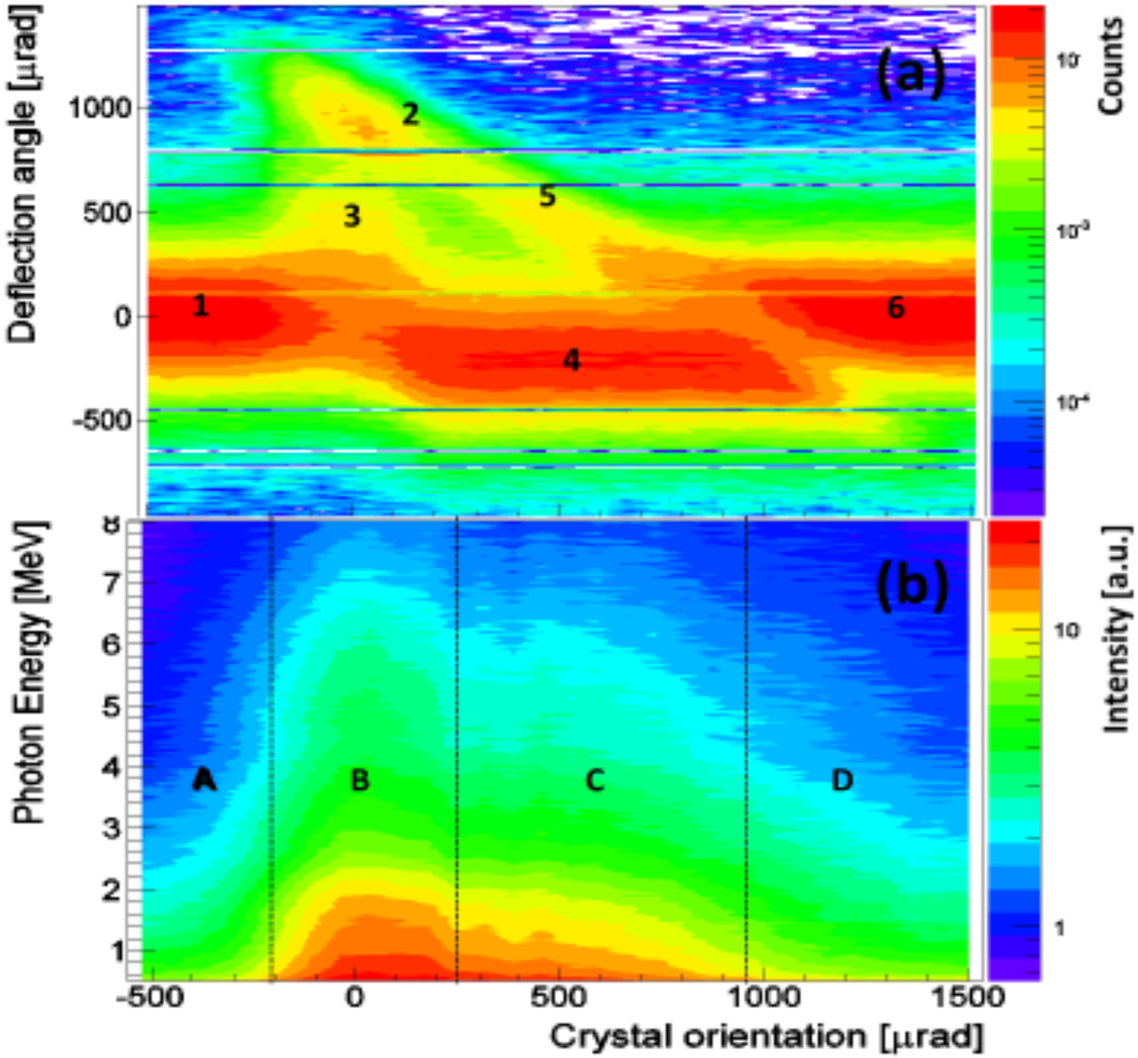




@ deflection & radiation: 855 MeV e^- MAMI

30 µm Si (111)





A:: Beam deflection by bent crystal

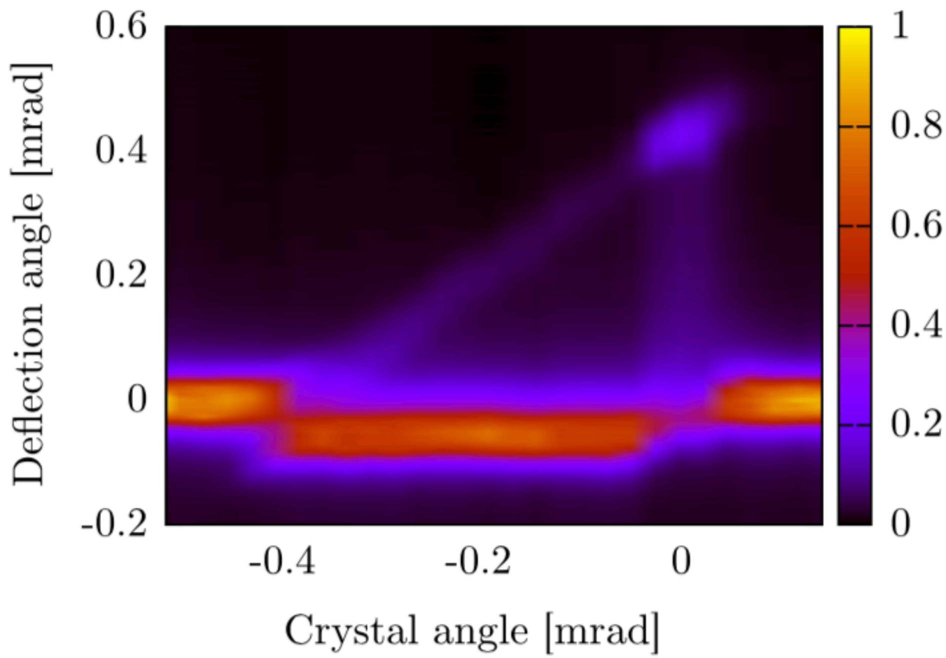
1 & 6 – nonaligned;
2 – channeling;
3 – dechanneling;
4 – volume reflection;
5 – volume capture

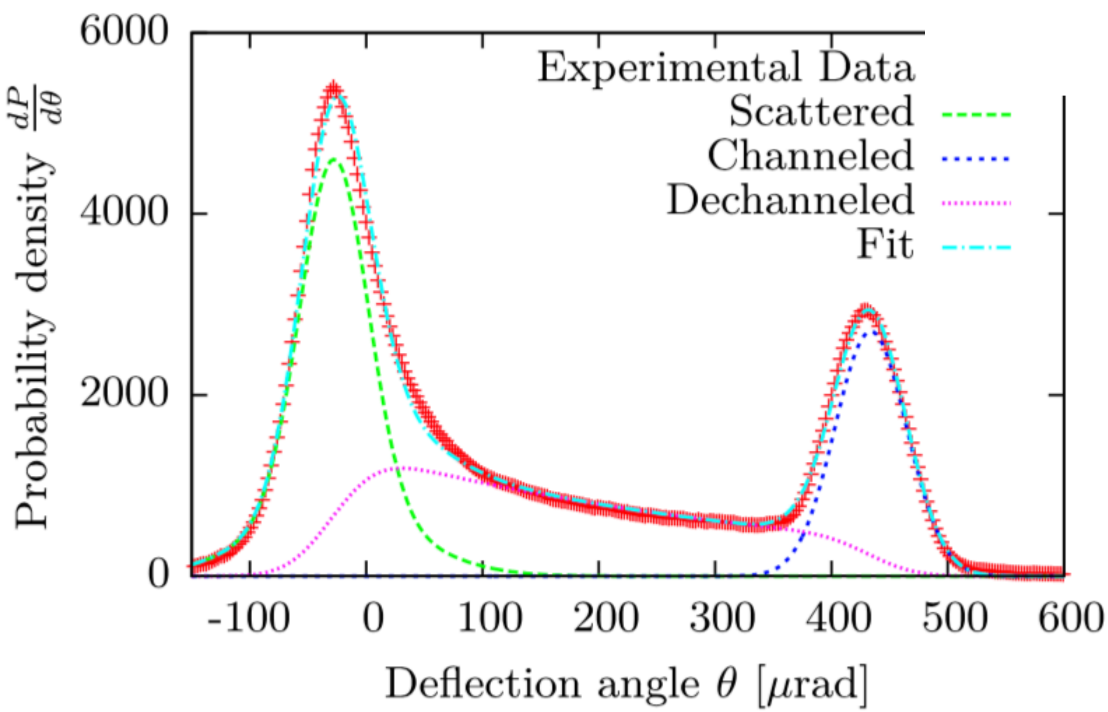
B:: EM Radiation in bent crystal

A & D – nonchanneling;
B – channeling;
C – volume reflection

@ ultra-high γ beam steering: 10.5 GeV e⁻ SLAC

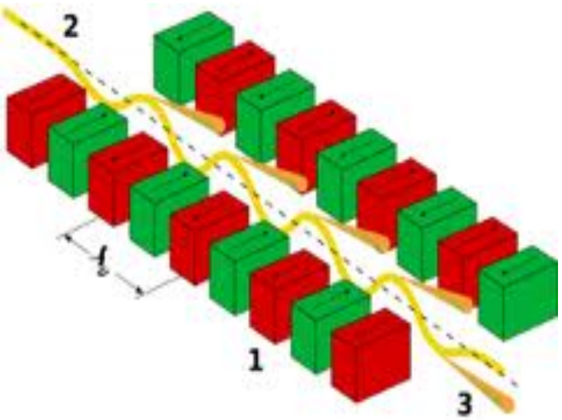
Deflected beam angular distribution

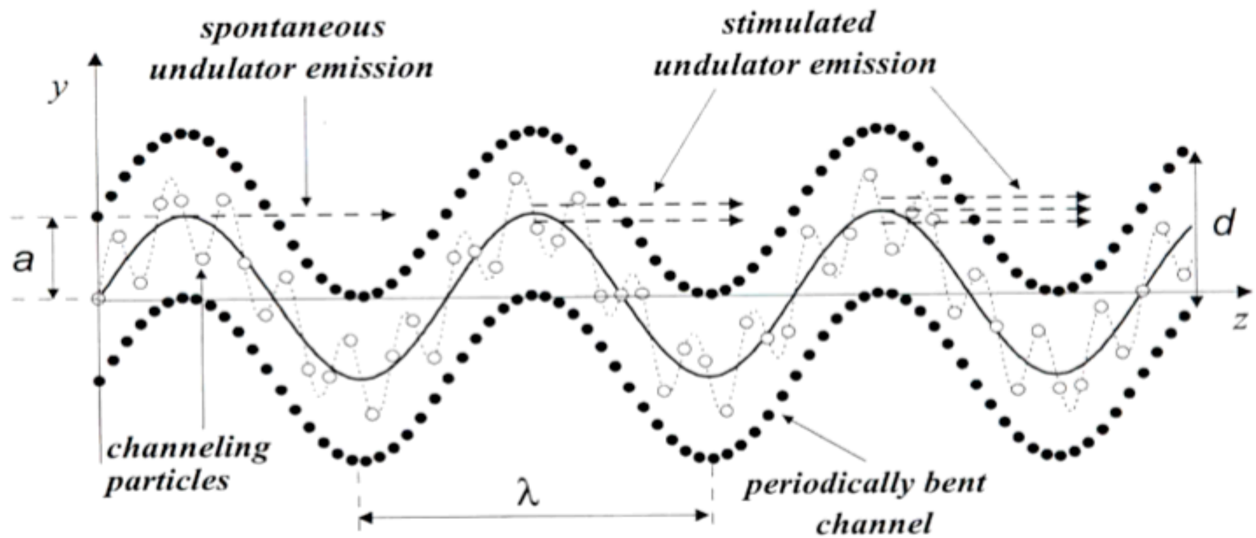




Distribution at channeling orientation

@ crystal/crystalline undulator - i



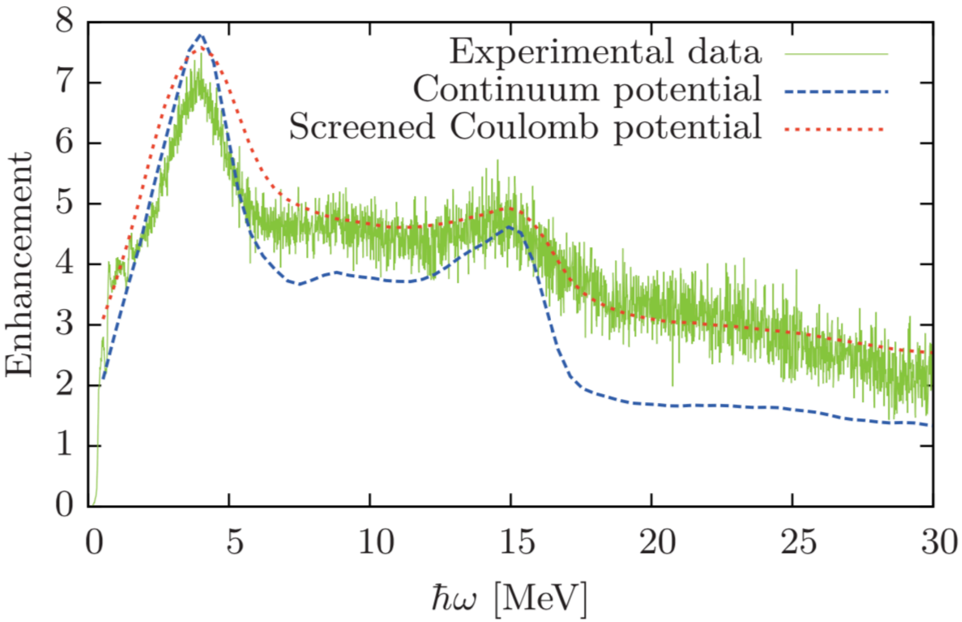


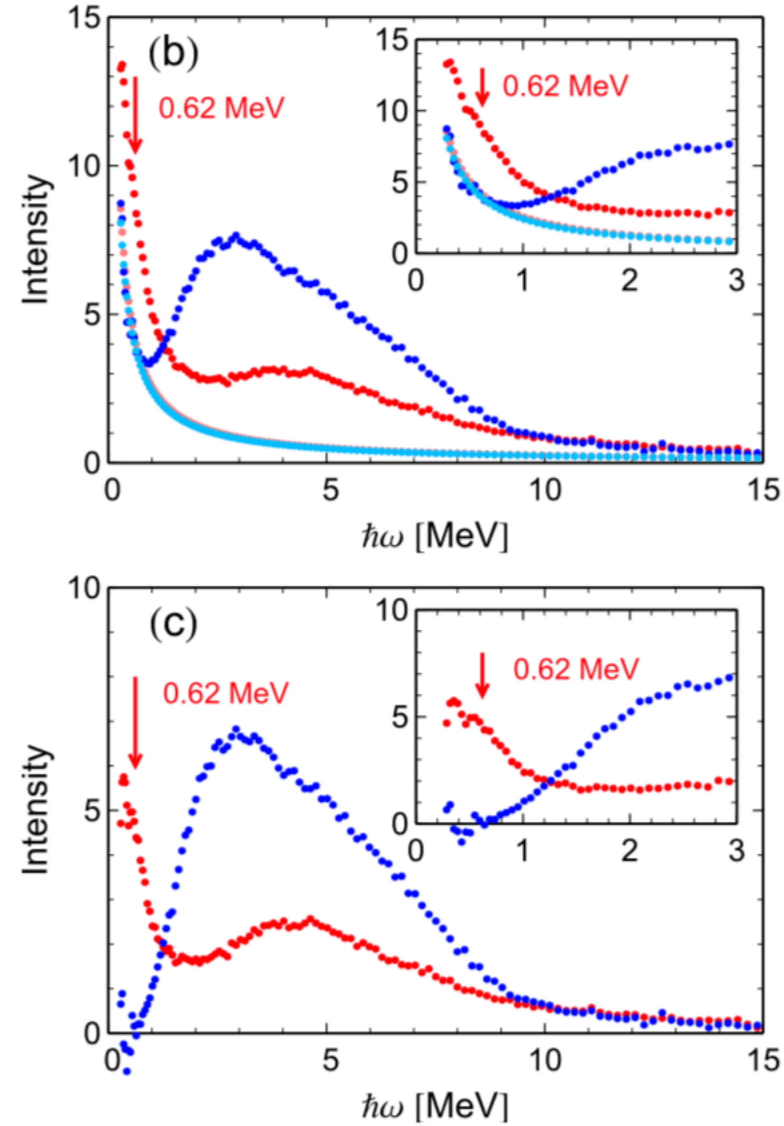
SCALE FACTOR – several orders more compact!

- A Crystalline Undulator may play the same role as a conventional magnetic undulator.
- It can be built with millimetric-submillimetric period, increasing the energy of radiated photons than in a magnetic undulator with the same beam energy.
- An operating CU could produce highly monochromatic X- and γ-ray beam, with energies up to 1 MeV or higher.

H2020-RISE PEARL (2016-2020)
(consortium with several institute that work in the subject of radiation in oriented crystals such as ESRF, MAMI, INP MINSK, AARHUS, INFN & UNIFE)

@ crystal/crystalline undulator - ii

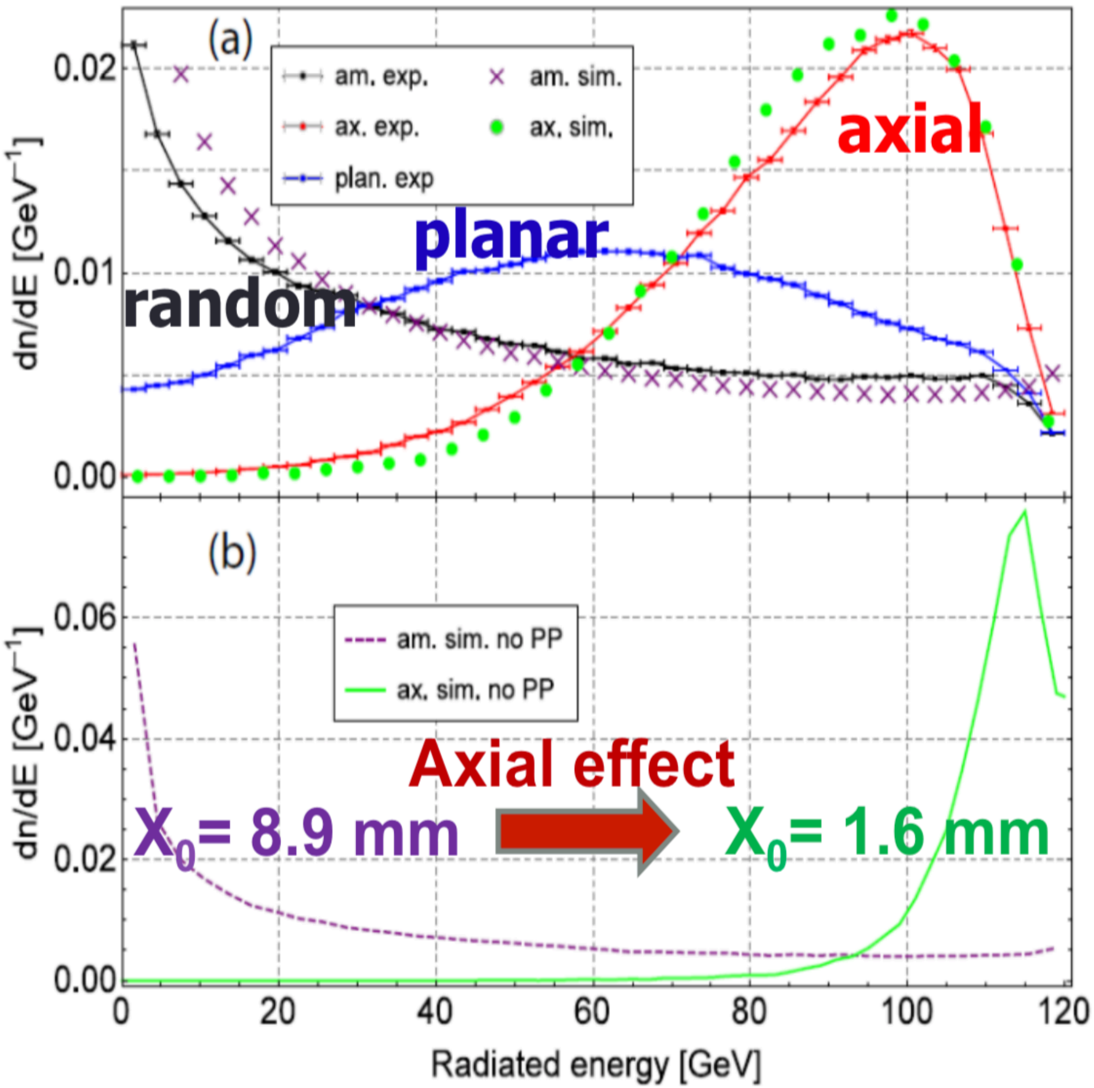




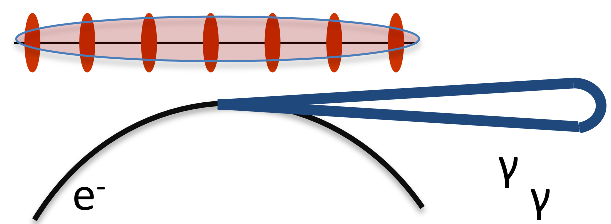
A comparison of the theoretical and experimental results for 855 MeV electrons penetrating a 10-period crystalline undulator with period 0.4 μm and planar oscillation amplitude 0.12 Å.

$Si_{1-x}Ge_x$ undulator //
4-period with a period length 9.9 μm

@ strong radiation regime at channeling: 120 GeV e^- CERN



PWO –
lead tungstate $PbWO_4$ crystal
4 mm



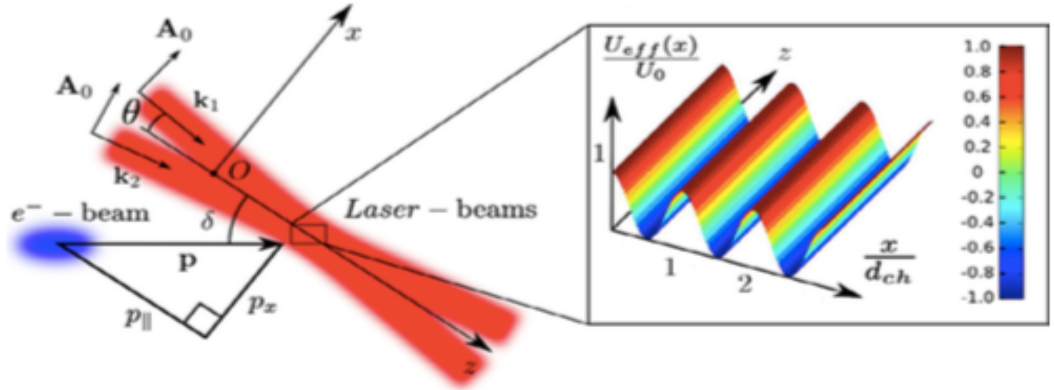
- Synchrotron-like radiation at channeling

$\gamma >>1 \rightarrow \Sigma N \rightarrow N_{eff} >> N$
scattering by "single atom"

- Strong reduction of radiation length

@ Laser Channels → Optical Lattice

@ channeling in OL



Equation for slow motion particle wave function

$$i\hbar\frac{\partial\bar{\psi}}{\partial t}=\left(-\frac{\hbar^2}{2\gamma_\parallel m}\nabla^2+U_{eff}\right)\bar{\psi}$$

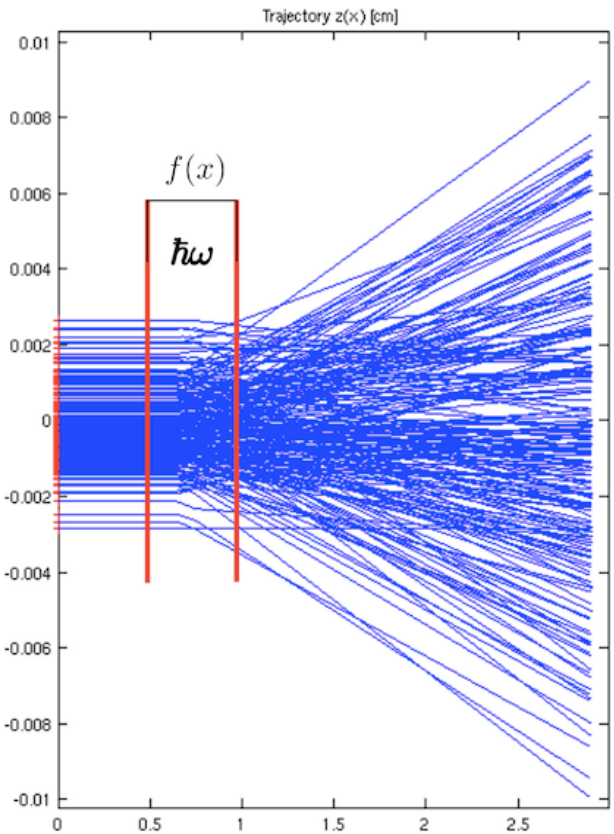
Effective potential[1]

$$U_{eff}=\frac{e^2A_2^2}{4\gamma_\parallel mc^2}-\frac{\hbar^2}{2\gamma_\parallel m}\overline{(\nabla\ln\chi)^2}-\frac{i\hbar e}{\gamma_\parallel mc}\overline{(\mathbf{A},\nabla\ln\chi)}+$$

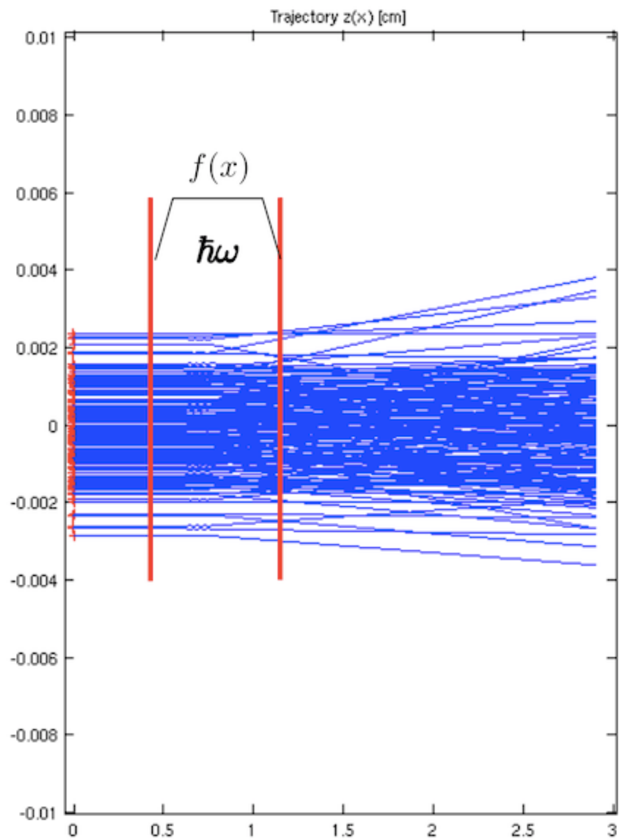
$$+\frac{\hbar^2}{2\gamma_\parallel mc^2}\left[\overline{\left(\frac{\partial}{\partial t}\ln\chi\right)^2}-2\beta_\parallel c\overline{\frac{\partial}{\partial t}\ln\chi\frac{\partial}{\partial\zeta}\ln\chi}+\beta_\parallel^2c^2\overline{\left(\frac{\partial}{\partial\zeta}\ln\chi\right)^2}\right]$$

here $\zeta=z-\beta_\parallel ct$, $\omega=\omega_0-\beta_\parallel k_z$ - oscillation frequency of χ, A_2 - slowly changing term of the field $\mathbf{A}$, U_{eff} - complex function, $\mathrm{Im}U_{eff}\sim\frac{e^2A^2}{(\gamma_\parallel mc^2)^2}\left(\nabla\bar{\psi}\right)^2$

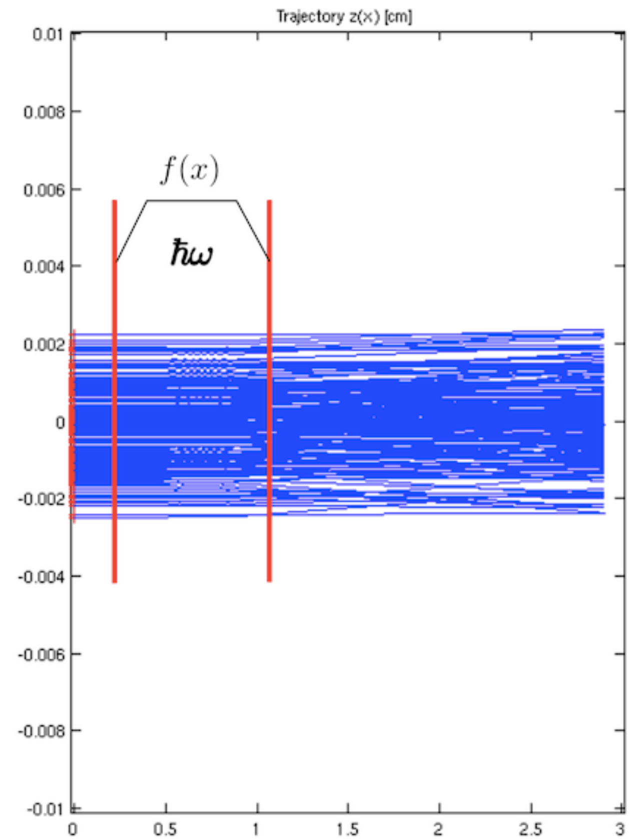
@ optical lattice time structure for beam profiling



Scattering - defocusing

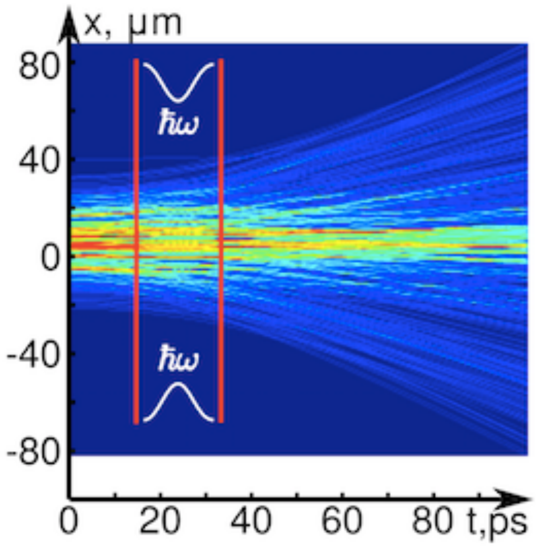


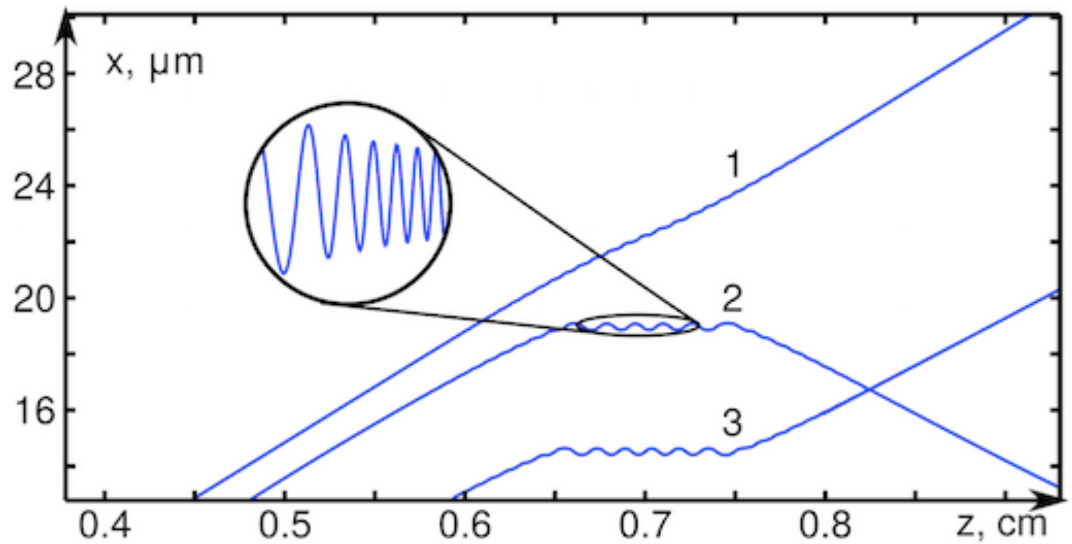
Focusing



Condensing

@ beam flux-peaking vs space charge

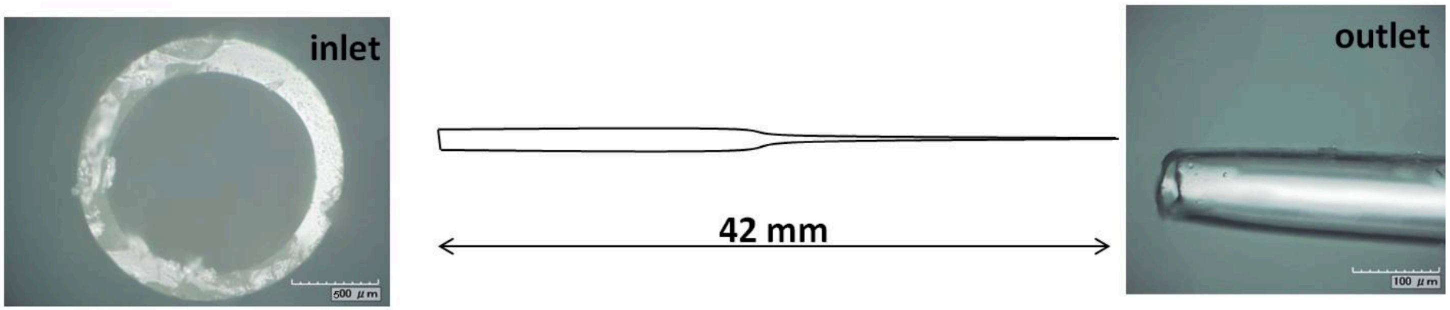




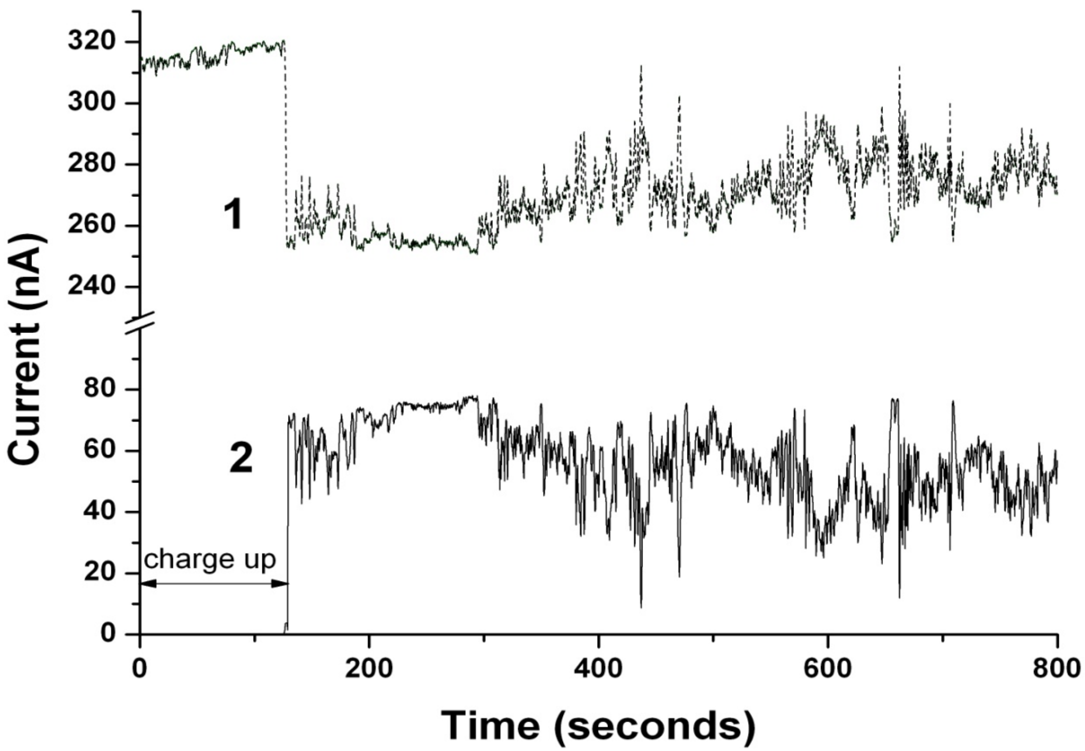
Numerical simulations (presented above) show that 0.8 pC 1.9 MeV Gaussian electron beam with zero initial divergence might be partially trapped by optical lattice, formed by two counter propagating laser beams with electrical field intensity 10^5 CGS units each. The laser beams have Gaussian transverse profile with σ_z=1mm and are positioned at 23 ps from initial beam position. Density color plot of the beam passing through optical lattice (left) depicts particle distribution over time. While the majority of electrons was trapped by optical lattice potential channel, there were some with transverse energy big enough to escape from it

@ Capillary MicroChannels

@ effective low-energy e⁻ guiding by tapered capillary

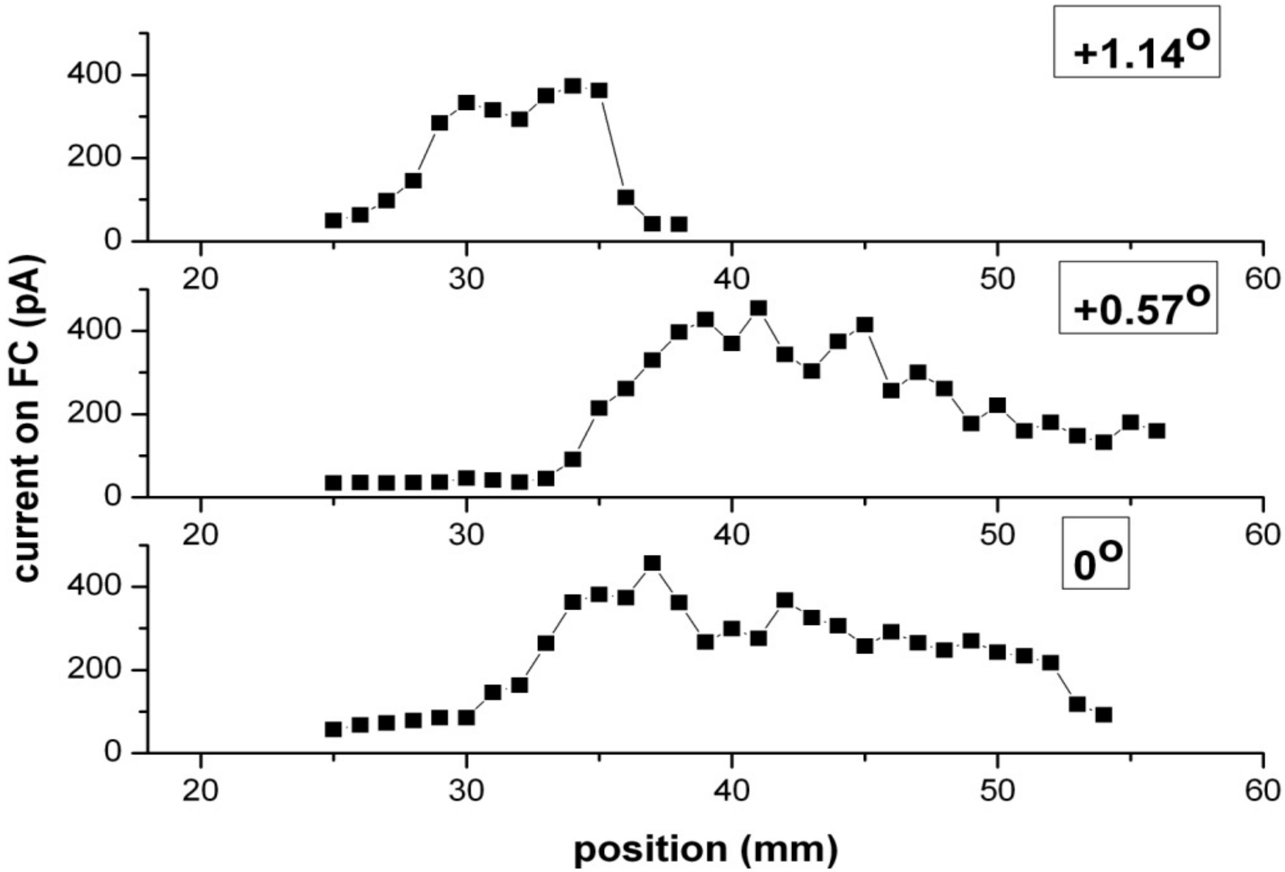


The draft image of the capillary and the photos of its inlet and outlet (inner diameters: inlet - 1.11±0.02 mm, outlet - 57±5 μm)



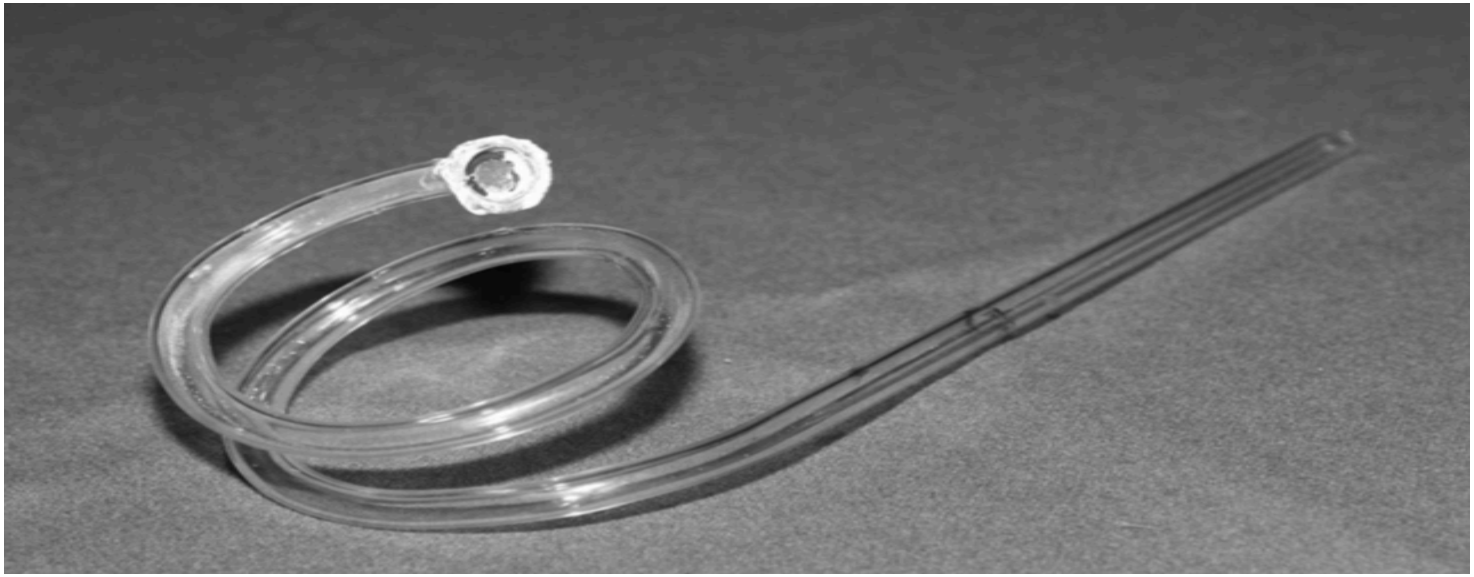
Time dependence of the current on mask (1) and the current transmitted through the capillary of 42 mm length and the inlet/outlet ratio – 1.11/0.057 (2)

@ beam profiling by tapered capillary



The profiles of transmitted current (average) for three tilt angles of the capillary relative to the beam axis (inlet/outlet – 1mm/15µm, length – 30 mm)

@ high I channeling of electrons in strongly bent capillaries



E = 10-20 keV –> 10 MeV e^-
R = 15-20 cm

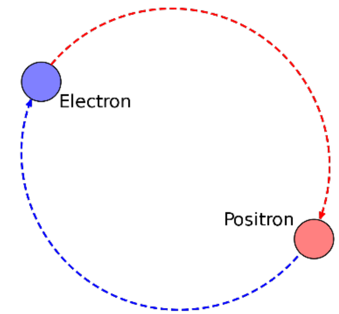
Glass capillary → ~ 100 kV/mm
d ~ 3mm // r ~ 3 mm

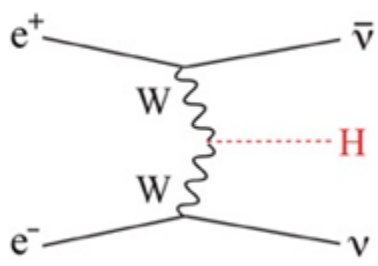
Declaration for ~100% channeling by strongly bent capillary (several complete turns)

@ Positron Source: Hybrid Scheme

@ positron source: motivation

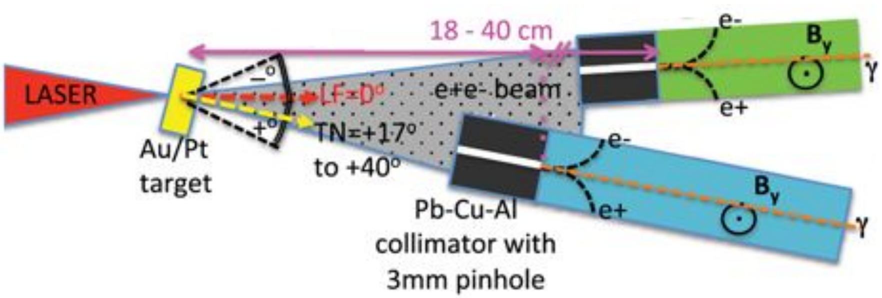
- Positronium atom [K. Michishio, T. Tachibana, R. H. Suzuki et al., Appl. Phys. Lett. 100 (2012) 254102]
- Low energy positron beams [C.M. Surko, G.F. Gribakin and S.J. Buckman, J. Phys. B: At. Mol. Opt. Phys. 38 6 (2005) 57]
- Positron Annihilation Spectroscopy [Horodek, P., Bugdol, M., Kobets, A.G. et al. Phys. Part. Nuclei Lett. 11 (2014) 708]
- Gravitational properties of antimatter [The ALPHA Collaboration and A.E. Charman, Nat. Commun. 4 (2013) 1785]
- Study of astrophysical leptonic jets [G. Sarri, W. Schumaker, A. Di Piazza et al., Phys. Rev. Lett. 110 (2013) 255002]
- Electron-positron colliders [M. Inoue et al, Nucl. Instrum. Meth. B 173 (2001) 104]



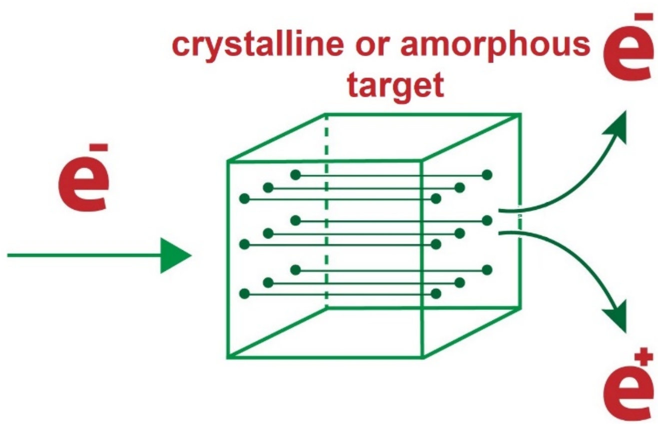


@ low energy positron beam production

@ $$^{22}_{11}\text{Na} \rightarrow {}^{0}_{1}\text{e} + {}^{22}_{10}\text{Ne}$$

@ 

[E. Liang, T. Clarke, A. Henderson, et al., Sci. Rep. 5 (2015) 13968]

@ 

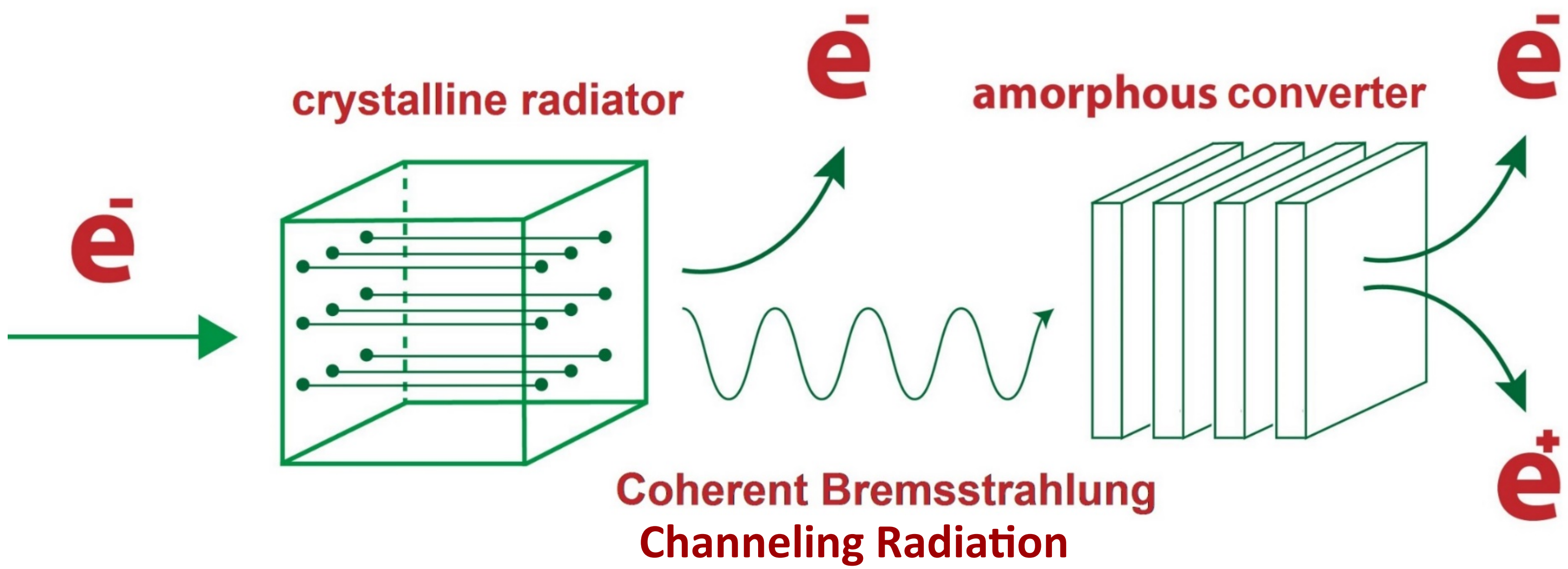
[J.-M. Rey, G. Coulloux, P. Debu, et al., J. Phys.: Conf. Ser. 443 (2013) 012077]

@ hybrid scheme for crystal based positron source

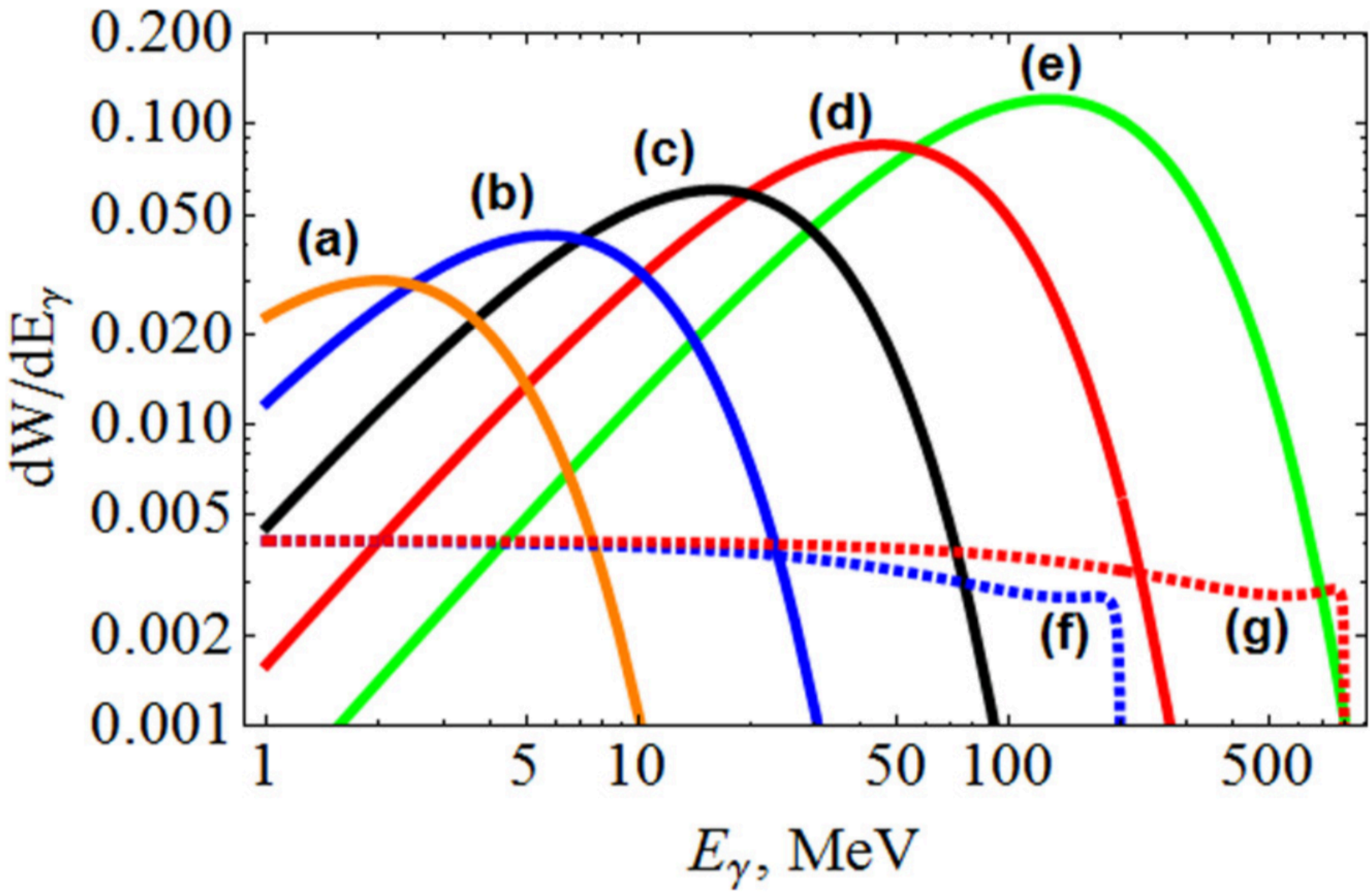
- **Undulator+converter**
- **The scheme of hybrid positron source using CR or CB from primary electron beam**

Channeling Radiation – efficient for sub GeV – essential increase for higher electron energy **200 MeV – and higher**

Coherent Bremsstrahlung – efficient even for MeV energies **10 – 100 MeV**



@ channeling radiation vs bremsstrahlung



<1 0 0> axial channeling radiation energy spectra (dW/dEc) from (a) 0.1 GeV, (b) 0.2 GeV, (c) 0.4 GeV, (d) 0.8 GeV and (e) 1.6 GeV electrons and energy spectra of bremsstrahlung from (f) 0.2 GeV and (g) 0.8 GeV electrons in L = 10 mm W.

@ comparison of CB based positron source with other sources

Facility	e^- energy, MeV	Current	e^+ yield, 1/sec	Reference
This simulation	**10**	**0.02 mA**	**4.6 10^9**	**1.5 mm W converter**
Giessen LINAC (Germany)	37	0.1 mA	10^8	[F. Ebel et al. Hyperfine Interact 44 (1989) 179]
MAMI microtron (Germany)	14 170	0.015 mA 0.075 mA	2 10^5 10^8	[M. Begemann et al. NIM 201 (1982) 287] [G. Graff et al. Appl. Phys. A33 (1984) 59]
Tsukuba AIST LINAC (Japan)	70	0.5 μA	10^6	[N. Oshima et al. Materials Science Forum 607 (2009) 238]
Argonne Nat. Lab. LINAC (USA)	15	0.2 mA	10^10	[H.M. Chen et al. Applied Surface Science 252 (2006) 3159]

@ higher beam intensity problem

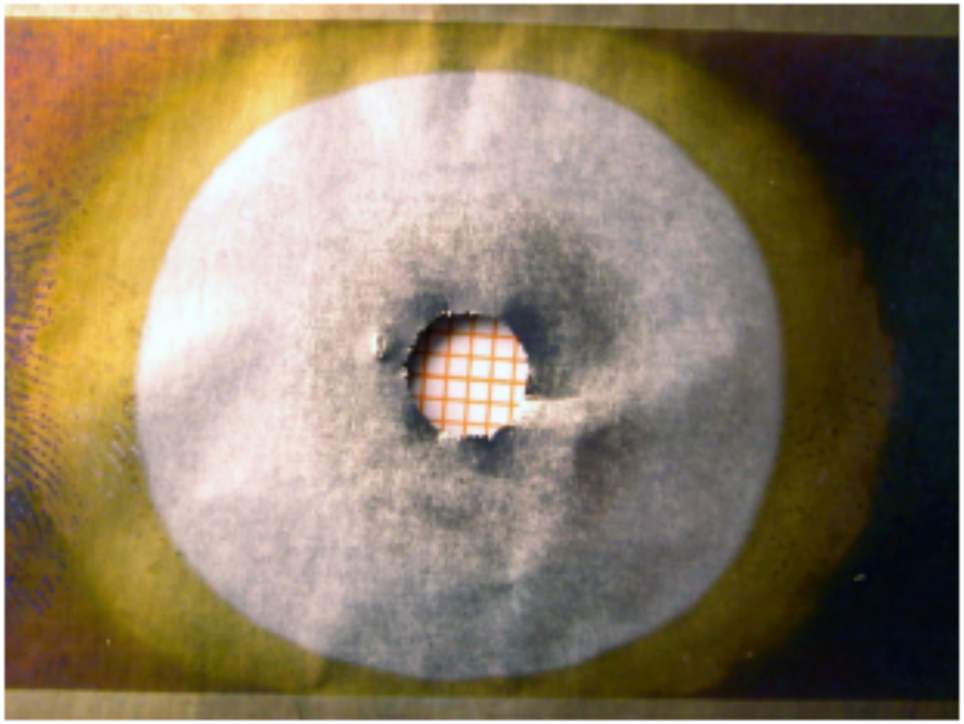
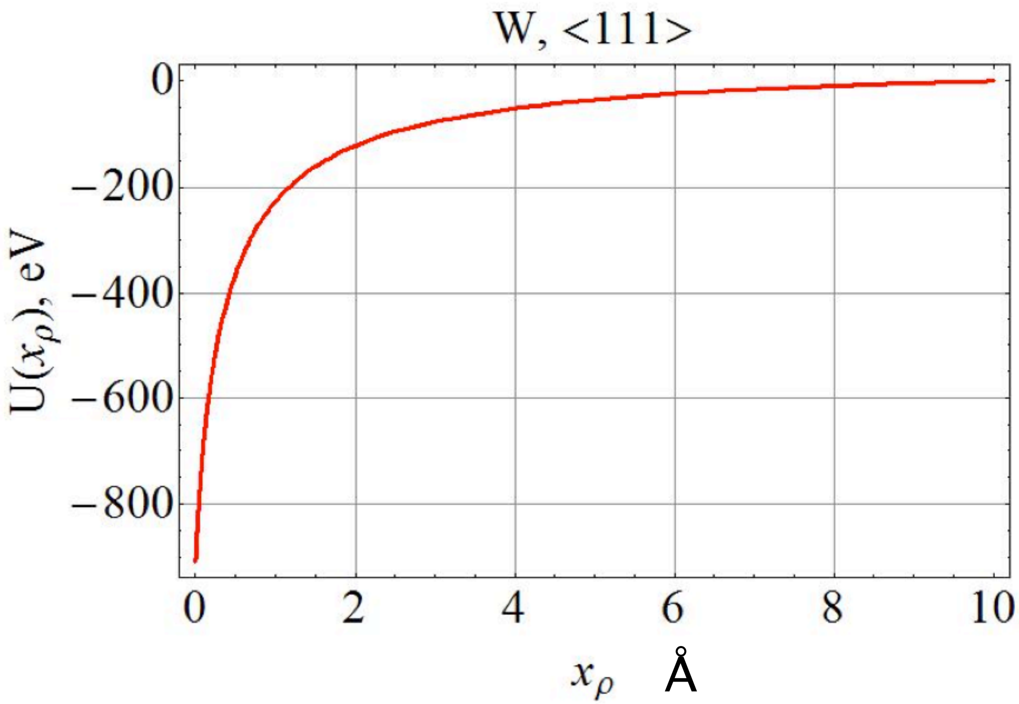


Figure 2: Perforation of a 50 μm tungsten sample under the electron soldering gun. The scale is given by the millimeter paper underneath.

[P .Perez, A. Rosowsky SLAC LOI-2003-3 Intense Source of Slow Positrons]

@ channeling radiation at axial e- channeling in W: simulations



continuous axial potential for e- in W:

extremely high field gradient **~10-10^3 GeV/m**

ε, GeV	$(I_{\max} \times \Delta L)$, MeV		L=20 μm $<111>$
0.5			179.3
0.6			258.2
0.7			351.5
0.8			459.1
0.9			581.0
1.0			717.3

axial <111> W ChR intensity in comparison with amorphous target

Intensity becomes higher with e- beam energy increase

However, it remains extremely crucial to have enough experience to perform the measurements on channeling phenomena:

--> the beam preparation;

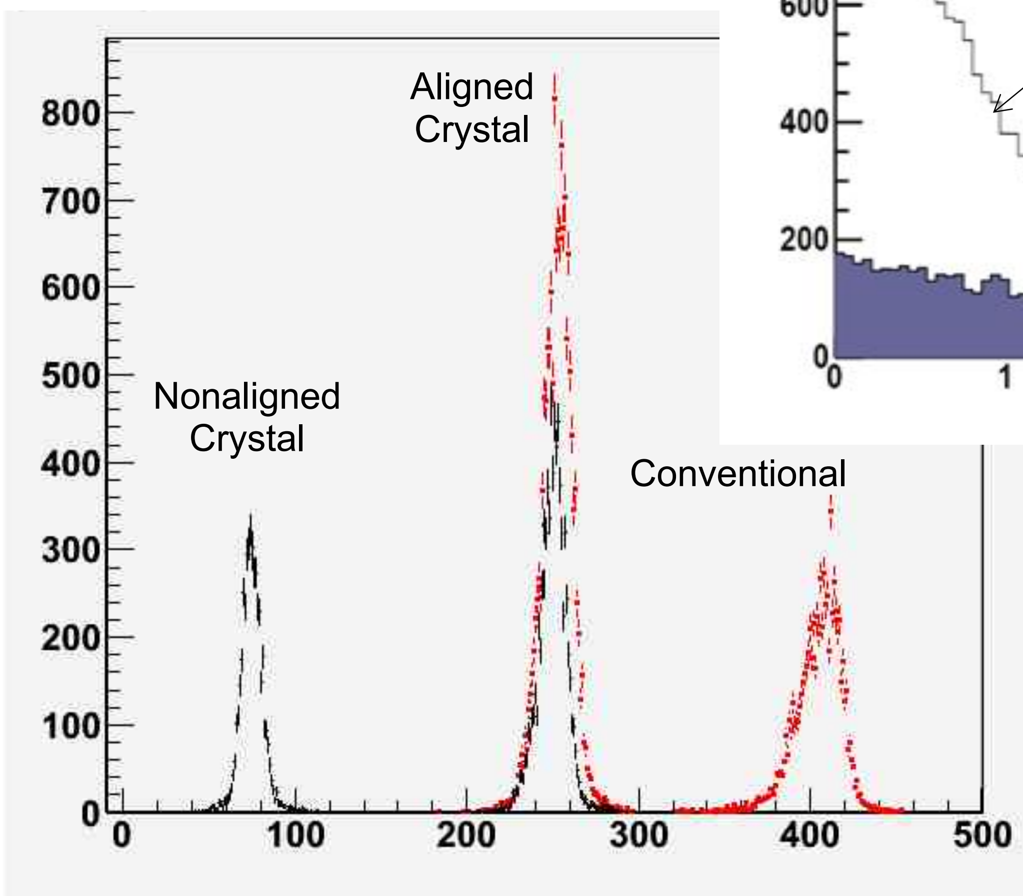
--> crystal-beam alignment procedure;

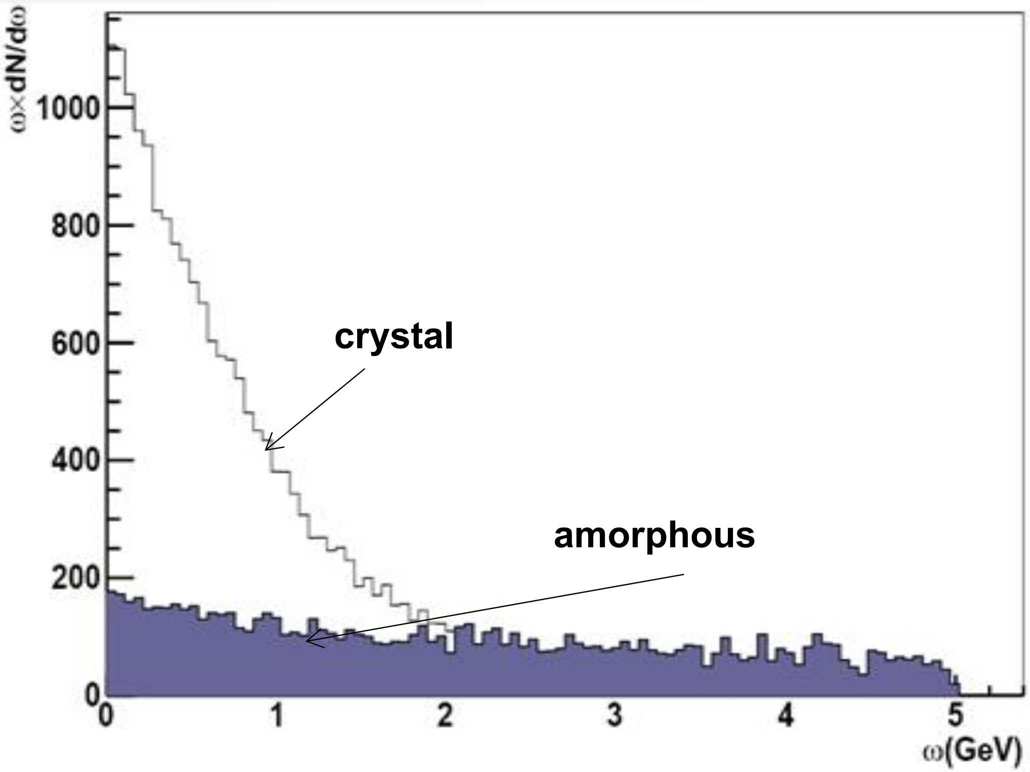
--> the best detector optimization…

POSSO @ channeling radiation at axial e- channeling in W

(CLIC+POSIPOL at Channeling 2010)

e+ yield for aligned
and misaligned crystals





intensity of γ-ChR becomes much higher over B with primary e^- energy increase

@ total yield of positrons produced by <100> CR by 0.1 ÷ 1.6 GeV e^- in 10 μm W radiator

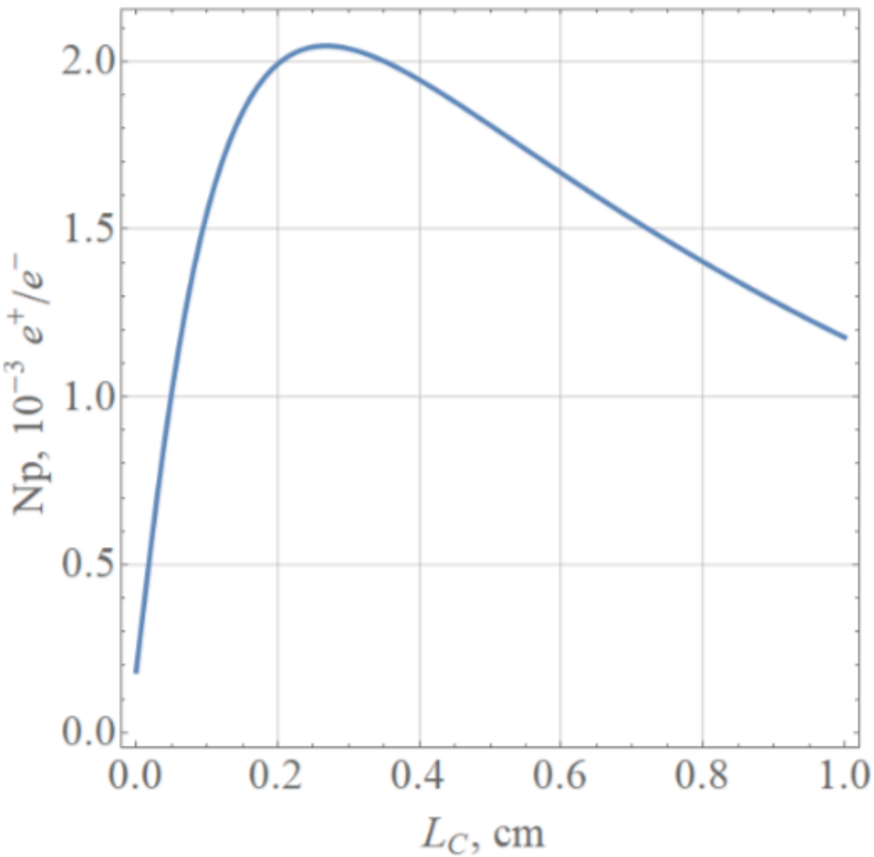
e^- energy, GeV	Photon energy of maximum intensity, MeV	Total yield of e^+ / e^- in 0.1 mm W converter, 10^{-3}	The thickness L_{max} of W converter correspond to the maximum of the e^+ total yield, cm	Total yield of e^+ / e^- in W converter of thickness L_{max}, 10^{-3}	The maximum of the energy spectra of positrons, 1/MeV
0.1 CR	2.0	0.056	0.19	0.46	$0.19\ 10^{-3}$
0.2 CR	5.7	0.35	0.35	4.88	$1.01\ 10^{-3}$
0.2 B	4.1	0.16	0.71	3.28	$0.72\ 10^{-3}$
0.4 CR	16.1	1.10	0.56	25.14	$2.32\ 10^{-3}$
0.8 CR	45.6	2.49	0.82	79.78	$3.15\ 10^{-3}$
0.8 B	4.1	0.27	0.85	6.74	$0.53\ 10^{-3}$
1.6 CR	128.9	4.65	1.00*	156.29	$2.88\ 10^{-3}$

@ simulations for SPARC_LAB – EuPRAXIA :: 0.15–0.60–1.0 GeV

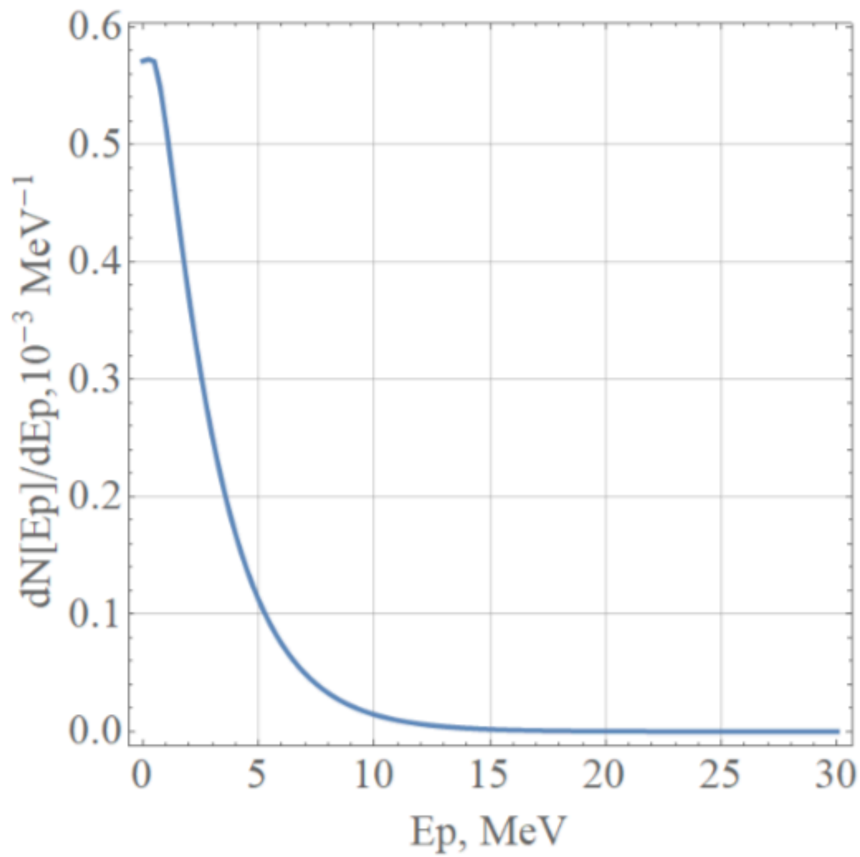
The initial electrons of energies from 150 MeV, 600 MeV and 1.0 GeV under <100> axial channeling condition in a **10 μm W crystalline radiator** serves as a photon source.	**150 MeV**		**600 MeV**		**1000 MeV**	
	Per electron	Per bunch of 10^9 electrons	Per electron	Per bunch of 10^9 electrons	Per electron	Per bunch of 10^9 electrons
The total yield of positrons produced in **0.1 mm W converter** by Channeling Radiation	0.00018	1.8 10^4	0.0018	1.8 10^6	0.0031	3.1 10^6
The thickness L_{max} of W converter correspond to the maximum of the e+ total yield, cm	0.28		0.71		0.89	
Total yield of e^+ / e^- in **W converter of thickness** L_{max}	0.00205	2.0 10^6	0.0519	5.2 10^7	0.1054	1.1 10^8

The maximum of the energy spectra of positrons is in the range 1÷3 MeV.

@ simulations for SPARC_LAB – EuPRAXIA :: 0.15 GeV

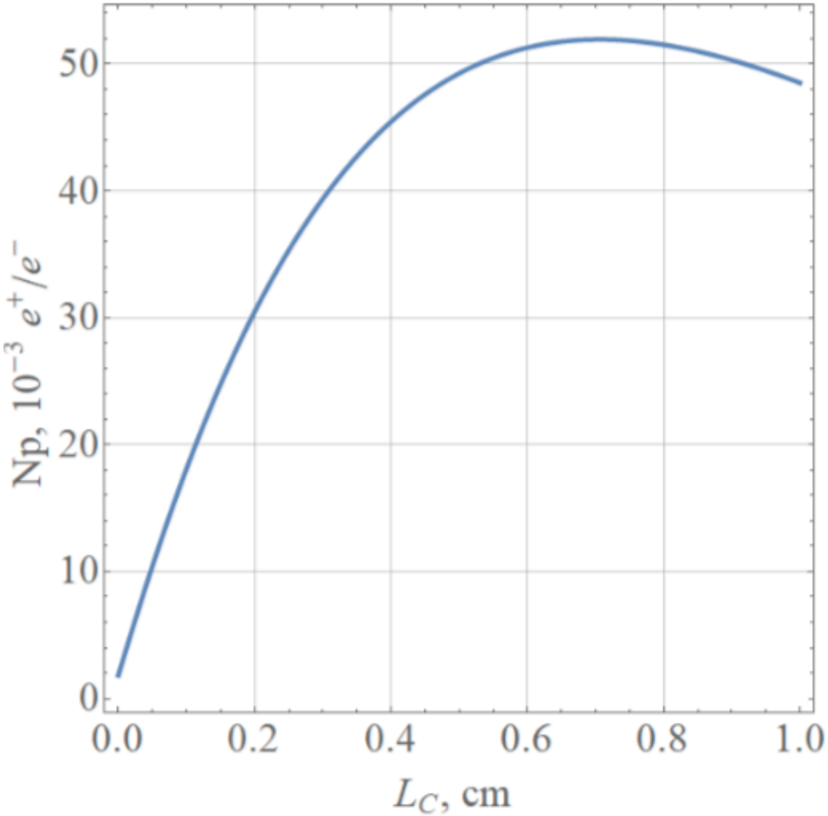


Total yield of positrons Yp (e^+ per e^-) produced by the <100> CR from 150 MeV electrons in L=10 μm W radiator as the function of L_c - the W converter thickness (cm).

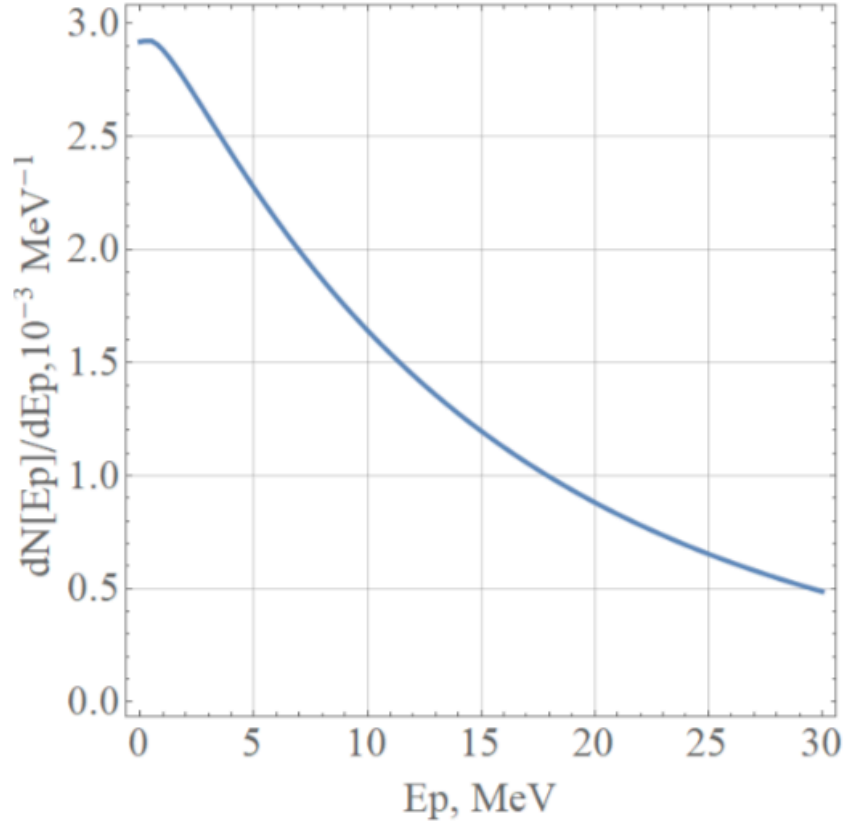


The energy spectra of positrons $d\sigma/dE_p$ (1/MeV) produced by the <100> CR from 150 MeV electrons in L=10 μm W radiator. Thickness of W converter is chosen at total yields maximum L_{max} (0.28 cm).

@ simulations for SPARC_LAB – EuPRAXIA :: 0.6 GeV

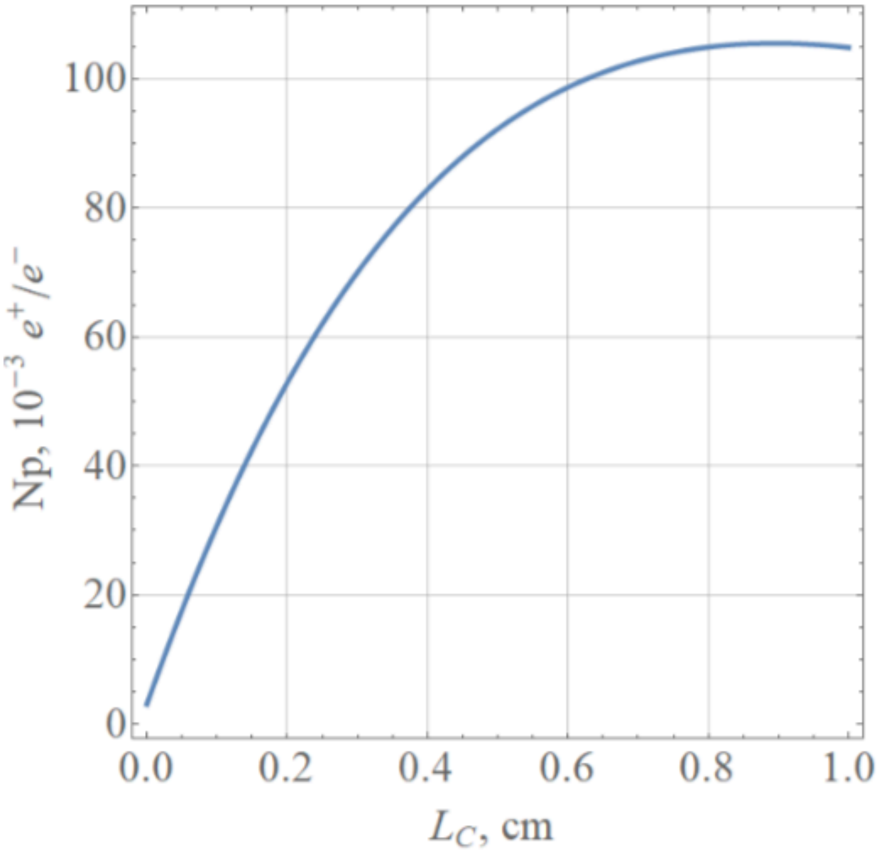


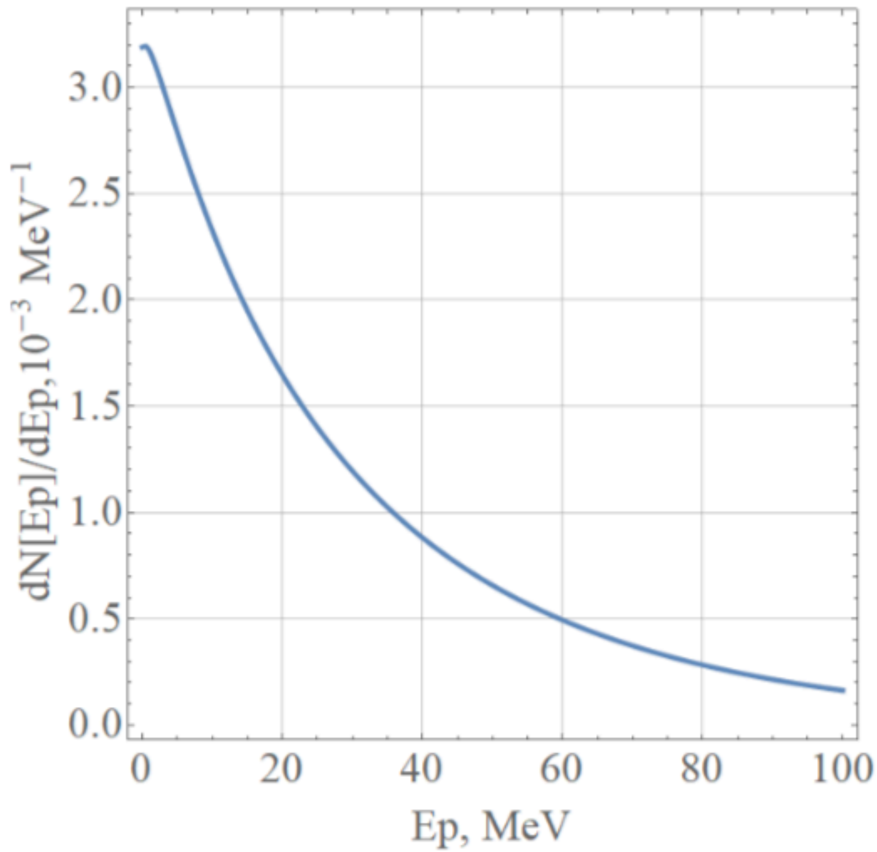
Total yield of positrons Yp (e^+ per e^-) produced by the <100> CR from 600 MeV electrons in L=10 μm W radiator as function of W converter thickness L_c (cm).



The energy spectra of positrons $d\sigma/dE_p$ (1/MeV) produced by the <100> CR from 600 MeV electrons in L=10 μm W radiator. Thickness of W converter is chosen at total yields maximum L_{max} (0.71 cm).

@ simulations for SPARC_LAB - EuPRAXIA :: 1 GeV

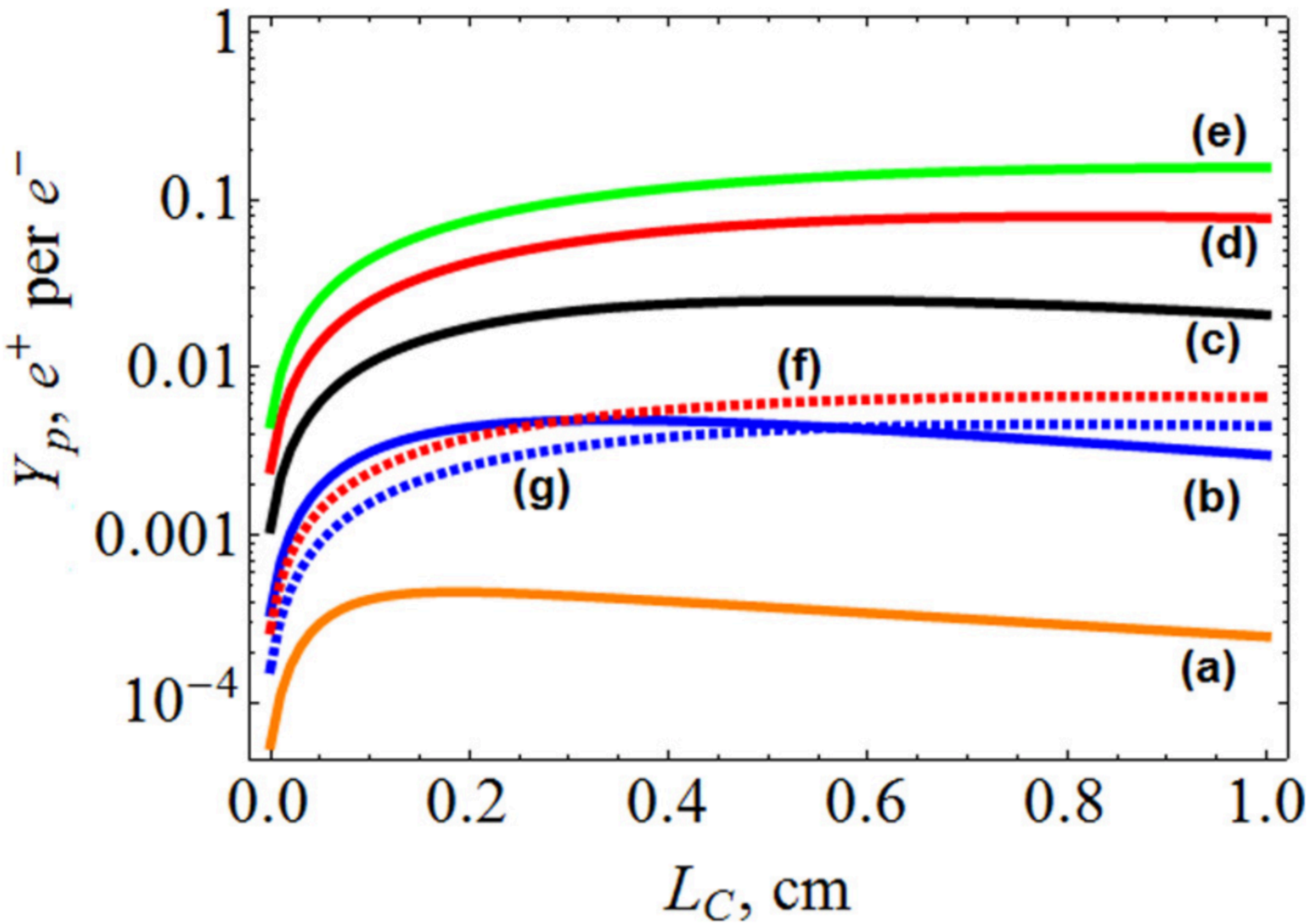




Total yield of positrons Yp (e^+ per e^-) produced by the <100> CR from 1.0 GeV electrons in L=10 μm W radiator as function of W converter thickness L_c (cm).

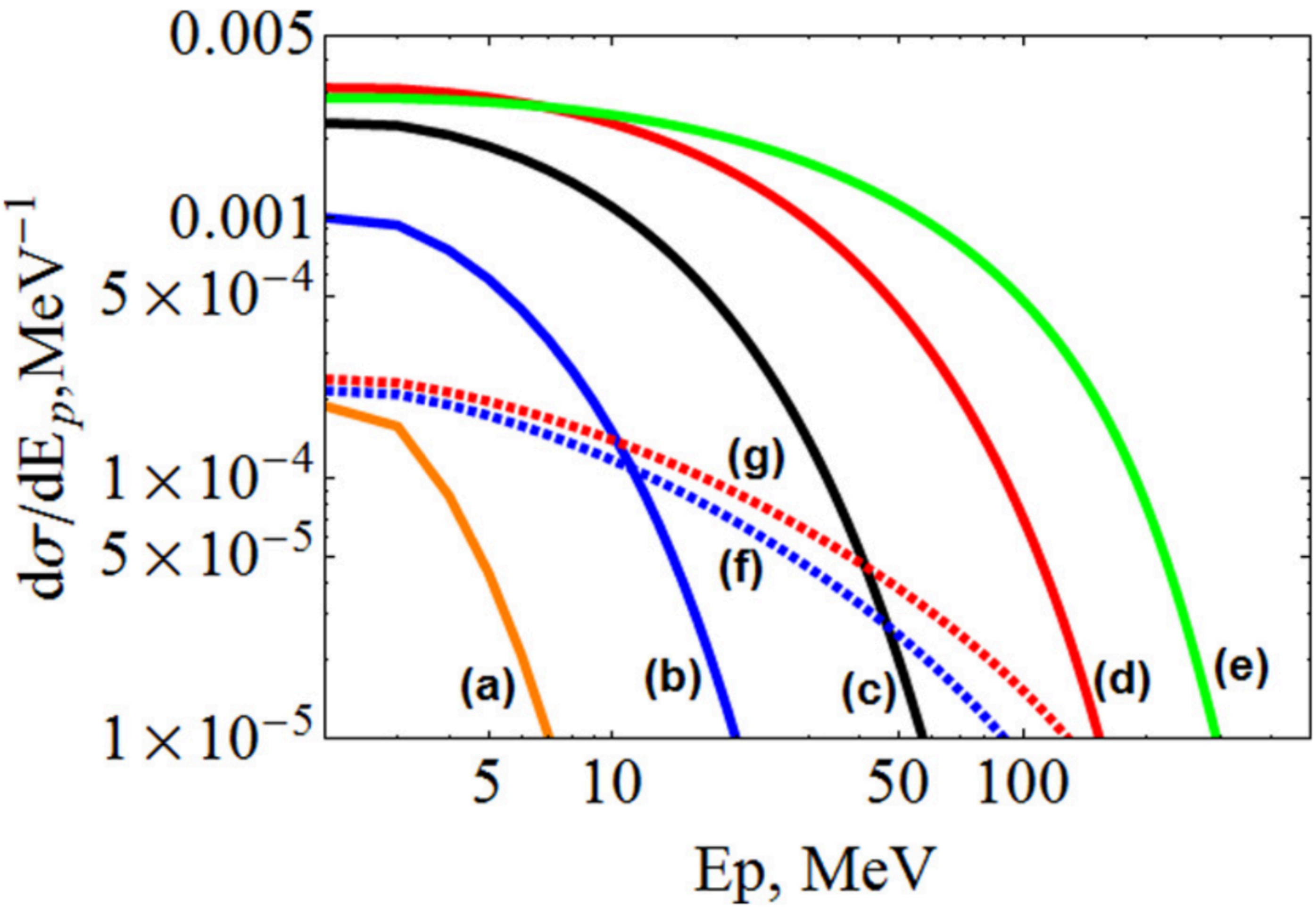
The energy spectra of positrons $d\sigma/dE_p$ (1/MeV) produced by the <100> CR from 1.0 GeV electrons in L=10 μm W radiator. Thickness of W converter is chosen at total yields maximum L_{max} (0.89 cm).

@ total yield of e^+ per e^-



Total yield of positrons Yp (e+ per e%) produced by the <100> CR from (a) 0.1GeV, (b) 0.2GeV, (c) 0.4GeV, (d) 0.8GeV and (e) 1.6GeV electrons and bremsstrahlung from (f) 0.2 GeV and (g) 0.8 GeV electrons in L = 10 mm W as the function of Lc – the W converter thickness (cm).

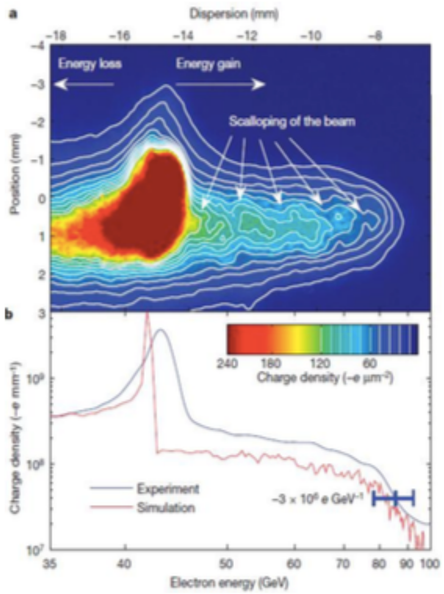
@ e^+ energy spectra



The energy spectra of positrons dr/dEp (1/MeV) produced by the <100> CR from (a) 0.1 GeV, (b) 0.2 GeV, (c) 0.4 GeV, (d) 0.8 GeV and (e) 1.6 GeV electrons and bremsstrahlung from (f) 0.2 GeV and (g) 0.8 GeV electrons in L = 10 mm W. Thickness of W converter is chosen at total yields maximum Lmax

@ micro/nano-channeling

Gas-State Plasma

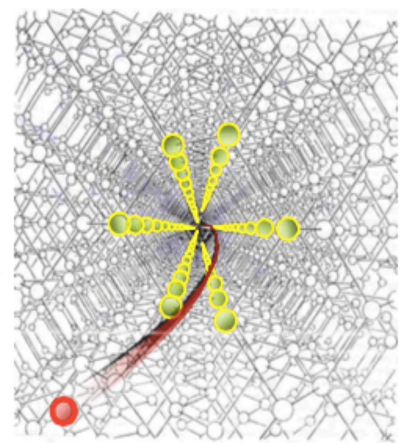


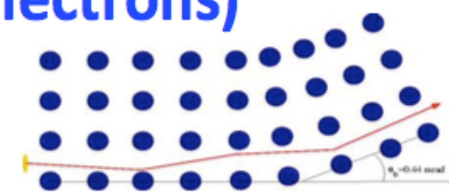
$10^{16} - 10^{18} cm^{-3} \rightarrow 10 \sim 100$ GeV/m

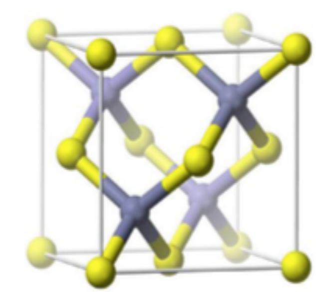
Nature 445, 741-744 (2007)

Energy Doubling: ~ 52 GV/m (@ 42 GeV)

Solid-State Plasma (Conduction Electrons)







$$E_0 = \frac{m_e c \omega_p}{e} \approx 100[\frac{GeV}{m}] \cdot \sqrt{n_0[10^{18} cm^{-3}]}$$

$10^{20} - 10^{23} cm^{-3} \rightarrow 1 \sim 30$ TeV/m

@ channeling for acceleration: i

$$\Delta E_{max} = \left(\frac{M_b}{M_p}\right)^2 (\Lambda G)^{1/2} \left(\sqrt{\frac{G}{z^3 \times 100[GV/cm]}}\right) \cdot 10^5 [TeV]^*$$

(M_b *and* M_p are the mass of the beam particle and mass of the proton respectively, Λ is the de-channeling length per unit of energy, G is the accelerating gradient, and z is the charge of the beam particle)

- 0.3 TeV for electrons/positrons,

- 10^4 TeV for muons,

- 10^6 TeV for protons

*P. Chen and R.J. Noble, in: Relativistic Channeling, eds. R.A. Carrigan, Jr and J.A. Ellison (Plenum, New York, 1987) p. 517.

@ channeling for acceleration: ii

	Dielectric based	Plasma based	Crystal channeling
Accelerating media	micro-structures	ionized plasma	solid crystals
Energy source: option 1 option 2	optical laser e^- bunch	e^- bunch optical laser	x-ray laser particle beam
Preferred particles	any stable	e^-, μ	μ^+, p^+ ($e+$, $e-$)
Max acc gradient	1-3 GV/m	30-100 GV/m	0.1-10 TV/m
c.m. energy in 10 km	3-10 TeV	3-50 TeV	10^3-10^5 TeV
# stages/10 km: option 1 option 2	10^5 - 10^6 10^4 – 10^5	~100 10^3 - 10^4	~ 1

- V. Shiltsev, Physics-Uspekhi (2012)
- F. Zimmermann, "The future of highest energy accelerators", CERN, Geneva, Switzerland

@ Channeling of electrons… future …

- Electron Beam Shaping (deflection, collimation)
- Crystal Channeling & Channeling related Radiation Phenomena
- Channeling in Combined Laser fields
- Channeling of Electrons in Capillary Structures

(compact storage rings)

Activities at SLAC, MAMI, DESY, DAFNE…

channeling …

… nice for imaging and useful in applications …

@ Channeling: main recent papers - i

Recent papers related to the presentation at EAAC 2019:

- D. De Salvador et al. JINST 13, C04006 (2018)
- L. Bandiera et al., Phys. Rev. Lett. 121 (2018) 021603
- S.V. Abdrashitov, et al., Nucl. Instr. Meth. B402 (2017) 54-57.
- A.I. Sytov, L. Bandiera et al. Eur. Phys. J. C 77, 901 (2017)
- S.V. Abdrashitov, et al. Journal of Physics: Conf Ser. 732 (2016) 012021.
- S.B. Dabagov, et al. Synchrotron and Neutron Techniques 10 (1) (2016) 254 -260.
- L. Bandiera et al. Phys. Rev. Lett. 115 (2015) 025504.
- S.V. Abdrashitov, et al. Nucl. Instr. Meth. B355 (2015) 65-68.
- D.Lietti et al. Rev. Sci. Instrum. 86 (2015) 045102.
- A. Mazzolari et al., Phys. Rev. Lett. 112 (2014) 135503.
- S.V. Abdrashitov, et al. Nucl. Instr. Meth. B309 (2013) 59-62.

Review papers (for general basic principles):

- S.B. Dabagov, and Yu.P. Gladkikh, Advanced Channeling Technologies for X-ray Applications (invited review), Radiation Physics and Chemistry 154 (2019) 3-16.
- S.B. Dabagov, Advanced Channeling Technologies in Plasma and Laser Fields (invited review), European Physical Journal Web Conferences 167 (2018) 01002.
- S.B. Dabagov, and N.K. Zhevago, “On radiation by relativistic electrons and positrons channeled in crystals” (invited review), La Rivista del Nuovo Cimento 31 (9) (2008) 491-529.
- S.B. Dabagov, “Channeling of Neutral Particles in Micro- and Nanocapillaries” (Reviews of Topical Problems), Physics Uspekhi 46 (10) (2003) 1053-1075.

@ Channeling: main recent papers - ii

Proceedings of Channeling meetings (for complete activity list):

- S.B. Dabagov, Ed., “Channeling 2018”, Proc. of the 8th International Conference "Charged and Neutral Particles Channeling Phenomena" (Ischia (Napoli), September 23-28, 2018), Physical Review: Accelerators and Beams (2019) - in processing.
- S.B. Dabagov, Ed., “Channeling 2016”, Proc. of the 7th International Conference "Charged and Neutral Particles Channeling Phenomena" (Sirmione-Desenzano del Garda, September 25-30, 2016), Nuclear Instruments and Methods in Physics Research B402 (2017) 392 pp.
- S.B. Dabagov, Ed., “Channeling 2014”, Proc. of the 6th International Conference "Charged and Neutral Particles Channeling Phenomena" (Capri, October 5-10, 2014), Nuclear Instruments and Methods in Physics Research B355 (2015) 402 pp.
- S.B. Dabagov, Ed., “Channeling 2012”, Proc. of the 5th International Conference "Charged and Neutral Particles Channeling Phenomena" (Alghero, September 23-28, 2012), Nuclear Instruments and Methods in Physics Research B309 (2013) 280 pp.
- S.B. Dabagov, L. Palumbo, and V. Guidi, Eds., “Channeling 2010”, Proc. of the 4th International Conference "Charged and Neutral Particles Channeling Phenomena" (Ferrara, October 3-8, 2010), Nuovo Cimento C 34 (4) (2011) 560 pp.
- S.B. Dabagov, and L. Palumbo, Eds., Charged and Neutral Particles Channeling Phenomena - “Channeling 2008”, Proc. of the 51st Workshop of the INFN Eloisatron Project, World Scientific, (2010) 823 pp.
- S.B. Dabagov, Ed., “Channeling 2006”, Proc. of the International Conference on Charged and Neutral Particles Channeling Phenomena (Frascati, July 3-7, 2006), Proc. of SPIE 6634 (2007) .
- S.B. Dabagov, Ed., “Channeling 2004”, Proc. of the International Conference on Charged and Neutral Particles Channeling Phenomena (Frascati, November 2-6, 2004), Proc. of SPIE 5974 (2005) 506 pp.

@ acknowledgements

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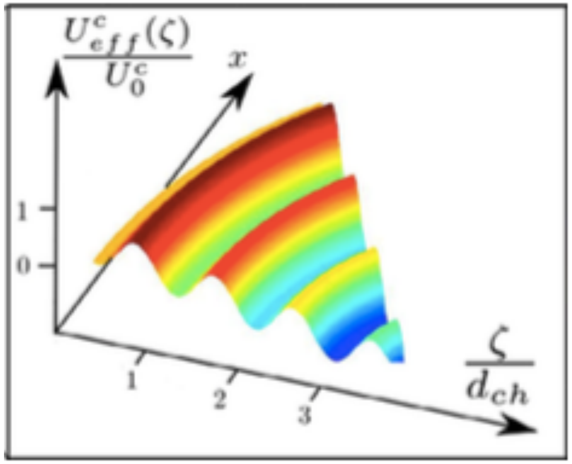
INFN (Italy), CERN (Switzerland), SLAC & Fermilab (USA),
LPI & MEPHI & TPU & BSU (Russia)
Projects

Special acknowledgements for their exciting results on channeling physics!

Thank you for attention

… additional …

@ effective potential of curved laser channels



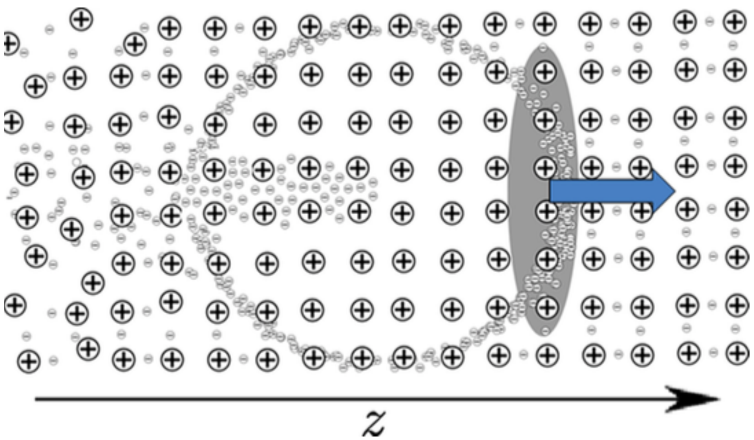
$$\rho_{cr} = \frac{4(m\bar{\gamma}c^2)^2}{e^2 A_0^2 k\psi} \approx 1.6 \cdot 10^{-8} \left(\frac{m\bar{\gamma}c^2}{e}\right)^2 \frac{\omega_0}{\psi I}$$

critical radius for e- steering in curved laser field

$$U^c_{eff}(\bar{\zeta}) = \frac{e^2 A_0^2}{8mc^2\bar{\gamma}} \cos\left(2k\psi\bar{\zeta}\right) - \frac{\bar{\gamma} m v_0^2 \bar{\zeta}}{\rho_0}$$

effective potential of curved laser channel

@ laser based plasma channel: i



buble propagates creating behind a positively charged channel

$$\frac{dp_z}{dt} \approx -2\pi e^2 n_0 (z - v_l t),$$
$$\frac{d\mathbf{p}_\perp}{dt} \approx -2\pi e^2 n_0 \mathbf{r}_\perp,$$

$$\begin{cases} \mathbf{A} \approx 0, \\ \varphi = -\pi n_0 e r_\perp^2 \end{cases}$$

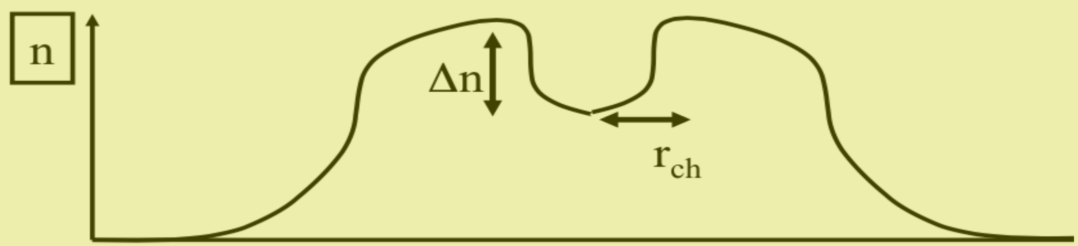
for an infinite cylindrical channel containing 'frozen' ions

relativistic electron motion

down to the ion channel

$$H = E_z + \frac{c^2 p_\perp^2}{2E_z} - e\varphi$$

$$E_z = c\sqrt{p_z^2 + m^2 c^2}$$



$$w_0 = \left[r_{ch}^2 / (\pi r_e \Delta n) \right]^{1/4}; \quad r_e = e^2 / mc^2$$

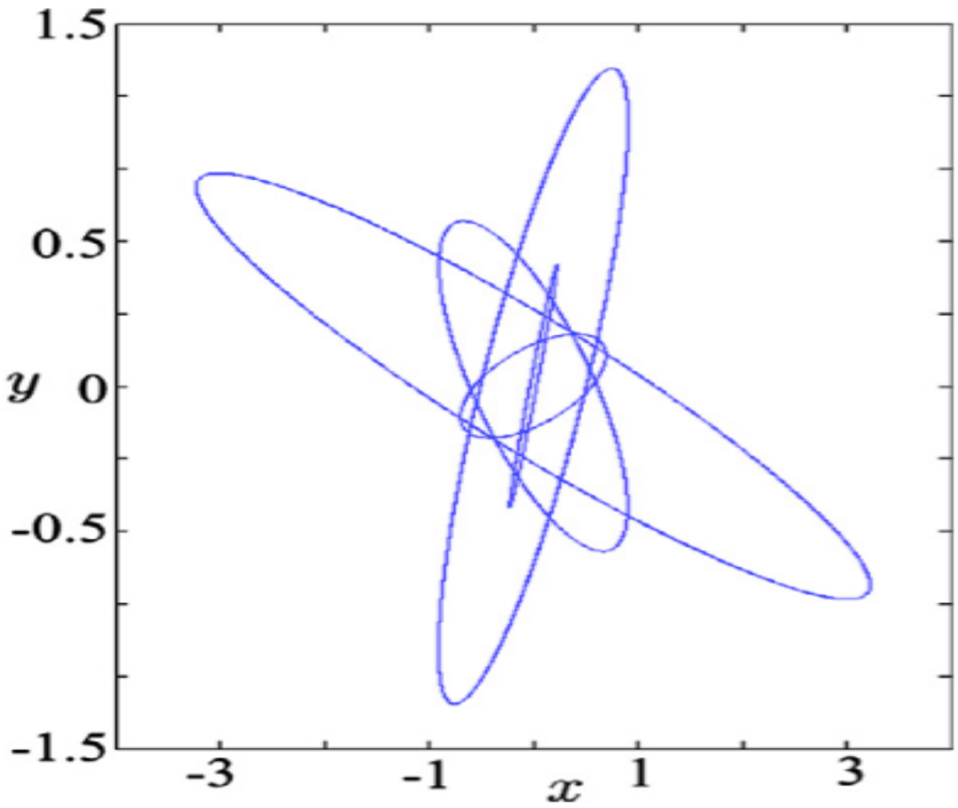
@ laser based plasma channel: ii

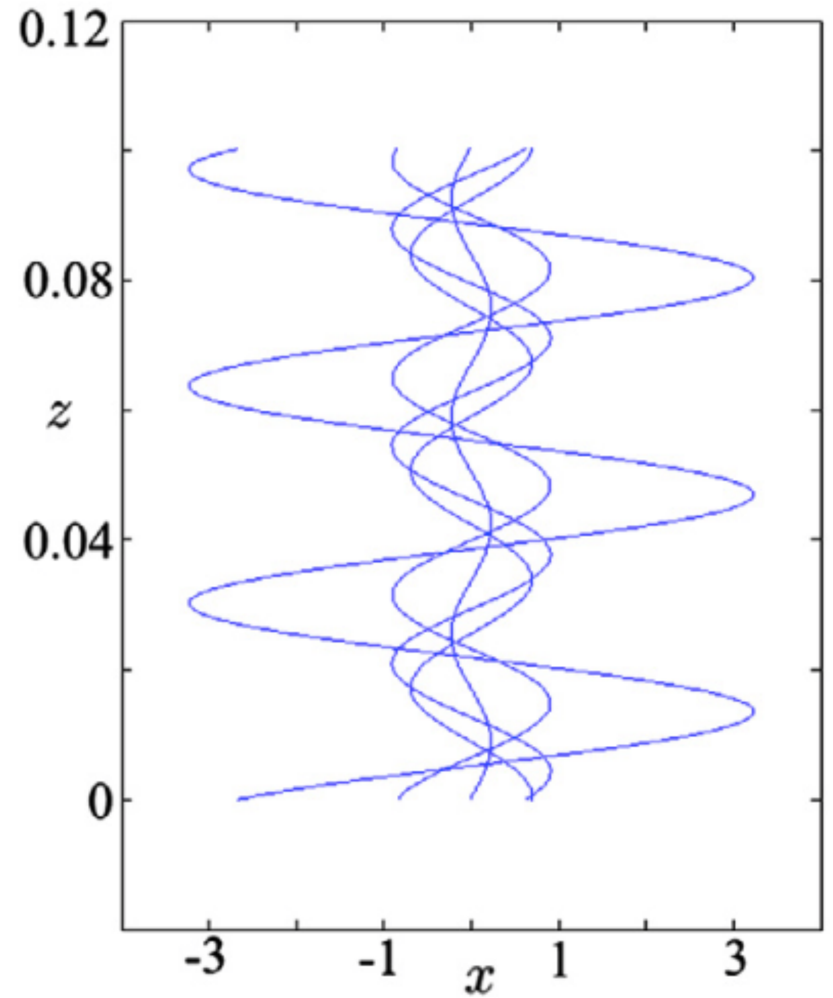
...channeling method simplifies calculations...

trajectory of a plasma channeled particle

$$z(t) = at + b\sin(2\omega_0 t + \alpha), \quad \mathbf{r}_\perp(t) = \mathbf{r}_0 \cos(\omega_0 t) + \mathbf{v}_0 \sin(\omega_0 t)/\omega_0$$

$$\omega_0^2 = \frac{2\pi e^2 n_0 c^2}{E_z}$$





… announcements …

the 1st Russian edition of IRRMA

IRRMA 2020

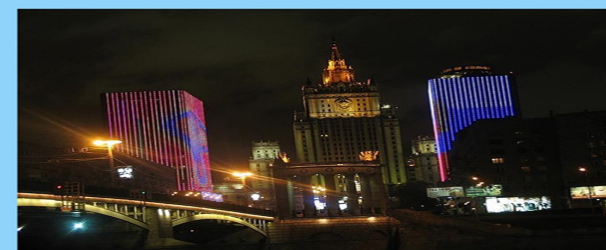
XIth INTERNATIONAL TOPICAL MEETING

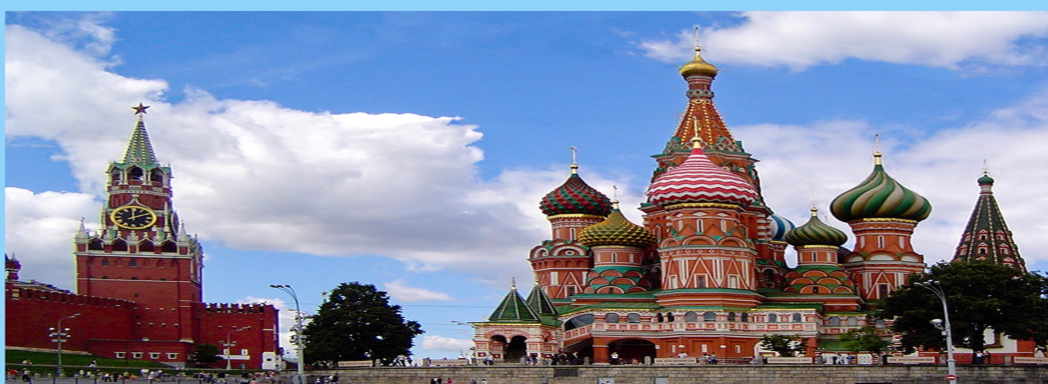
Industrial Radiation & Radioisotope Measurement Applications

MOSCOW … July 5 – 10, 2020 … RUSSIA

Golden Ring Hotel
Золотое Кольцо

MEPhI IRPS INFN Istituto Nazionale di Fisica Nucleare





Welcome to IRRMA 2020 - Moscow!

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Francesca Casarin & Daniela Napoleoni (secretaries) -
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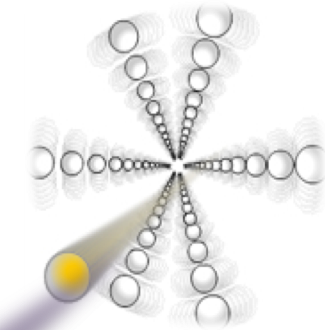
daniela.napoleoni@lnf.infn.it



The 9th International Conference

CHARGED & NEUTRAL PARTICLES

CHANNELING PHENOMENA

CHANNELING 2020

20-25 September 2020

Riccione (Rimini), Italy


CORALLO


ATTIBASSI
ESPRESSO
ITALIANO

You are welcome to take part in both meetings:

IRRMA 2020

&

Channeling 2020

-

in a time and a place

but much in advance

to contact us with your ideas and proposals

irrma2020@lists.lnf.infn.it

&

ch2020@lists.lnf.infn.it