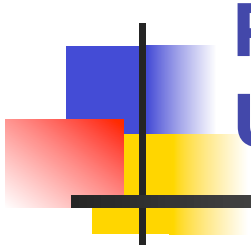

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

Robert CHEHAB
IPNL/IN2P3/CNRS & University of Lyon 1
On behalf of POSIPOL collaboration

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **FRAMEWORK**
- **1- Introduction**
- **2- Historical survey**
- **3- Last developments brought by POSIPOL**
- **4- Summary & Conclusions**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **1-INTRODUCTION**
- **POSIPOL represents a series of workshops started in 2006 with a dedication to polarized positrons for linear colliders. The acronym means in french: POSItons POLarises. Such sources are essentially based on *Compton Backscattering for ILC and CLIC and POSIPOL coordinates the efforts towards a complete Compton source design.* Since that time, the items presented have been extended to other ones concerning polarized sources (undulator schemes) and unpolarized sources (channeling and conventional) . Technical aspects which are essential to positron beams (targets, capture, stacking in DR,..) have progressively been introduced. After a short historical survey of the 5 Workshops, we present the last developments in the fields concerned by POSIPOL**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **2-POSIPOL: A SHORT HISTORICAL SURVEY**
- **The first meeting, in 2006 at CERN, concerned, mainly, the Compton scheme with an electron ring and a laser which has been proposed, first, at Snowmass in 2005 by K.Moenig et al. Other Compton schemes involving linacs, as was first proposed by T.Omori at the 1997 positron workshop at SLAC and later by V.Yakimenko (BNL), were also discussed. Important technical aspects related to the Compton scheme (focusing lattices for the ring, laser systems, optical cavities, polarimetry,...) or more generally to any kind of positron source like the conversion target or the optical matching device (OMD) were also analyzed. The method using a magnetic undulator considered as a baseline for ILC was presented with the E-166 SLAC experiment results**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **HISTORICAL SURVEY (following)**
- **The second workshop, held at LAL-Orsay, extended the nature of the electron machines, for the Compton scheme, to ERL (Energy Recovery Linacs). The importance of polarized positrons was emphasized and the associated polarimetry was described. Progresses in laser techniques for high power lasers, like for the fiber technology, were studied in some details. Capture and emittance preservation of the positron beams were also considered with some details. Applications of the Compton scheme, in low energy regime, for the production of X-rays for medicine and biology appeared, meeting a strong interest.**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **HISTORICAL SURVEY (following)**
- **The 2008 workshop, held at Hiroshima, extended the items to the unpolarized positron source using channeling. Such a scheme being studied since many years by Franco-Russian and Japanese teams. The main interest of such device was, by separating the crystal-radiator from the amorphous converter, to lower significantly the amount of PEDD (Peak energy Deposition Density). For such reason, mainly, it has been selected for the CLIC baseline. The applications of Compton schemes (in γ domain) were also extended to the analysis of radioactive wastes.**
- **Some synergy on the R&D on positron sources for ILC and CLIC appeared also clearly.**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **HISTORICAL SURVEY (following)**
- **The Compton scheme and the related techniques (optical cavities, lasers, accelerator type –ring, linac, ERL- ,…) stand as the main parts of the POSIPOL program for 2009 (IPNL-Lyon) and 2010 (KEK). The R&D on the ILC baseline solution (Undulator) are presented with interesting aspects on the targetry. Progresses in the simulation of the hybrid source using channeling allow a better understanding of all the aspects, specially for the thermal effects. Important contributions from theoreticians (Novosibirsk, Lyon) provide a more rigorous description of the physical phenomena for the polarized positrons specially in the target where depolarization may occur.**
- **If ILC and CLIC are the main projects discussed in POSIPOL, other colliders (SuperKEKB, SuperB and LHeC) are also considered.**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- 3-LAST DEVELOPMENTS IN POSITRON SOURCES FROM POSIPOL
- 1- THE COMPTON SCHEMES
- 2- THE UNDULATOR SCHEME
- 3- POLARIZED BREMSSTRAHLUNG
- 4- THEORETICAL INVESTIGATIONS ON POLARIZED POSITRONS
- 5- THE HYBRID SOURCE USING CHANNELING
- 6- THE MATCHING SYSTEMS

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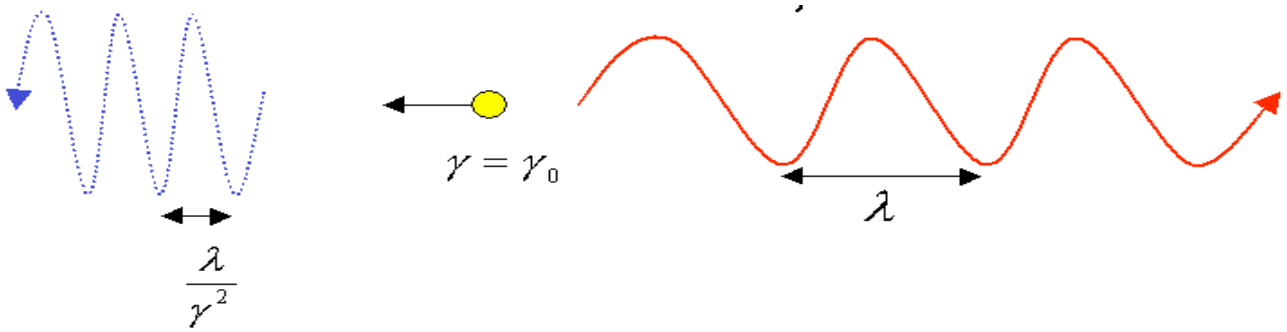
- **1-THE COMPTON SCHEMES**
- **The principle:**



The electrons with relative energy γ are colliding with a circularly polarized laser (λ) The Compton photons may have 30 to 60 MeV as average energy if the e-beam has 1.3 to 1.8 GeV. This beam is provided by: a ring, a linac or an ERL. As the Compton cross section is low, to increase the positron intensity we may:

- **use a multi-cavity optical system (5 to 10)**
- **improve the stacking of e+ bunches in the DR by reducing the longitudinal emittance prior to the injection in the DR**

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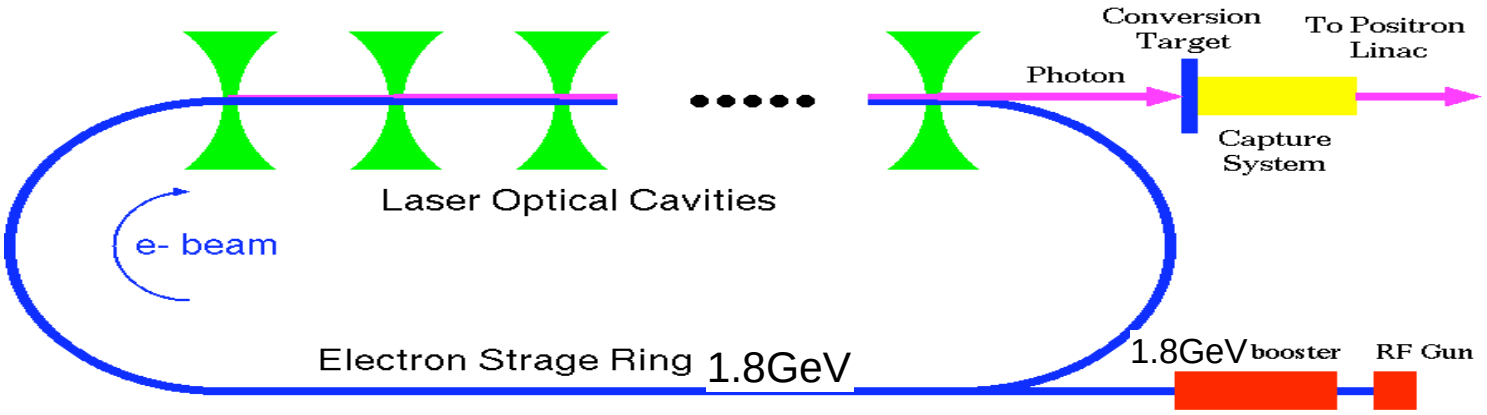
Compton Ring (2)

- Electron driver:5.3nC, 6.2ns, 1ps, 1.8GeV
- Laser : 0.6Jx5 CP (optical cavities). The number of optical cavities must be limited due to increase of energy spread of e- beam with consequences on its dimensions in the optical quadrupole channel.
- By one collision, positron bunch with Ne+:2.0E+8 is generated.
- 10 bunches are stacked on a same bucket. This process is repeated 10 times with 10ms interval .
- Finally, Ne+:2E+10 is obtained.



M. Kuriki/POSIPOL2010

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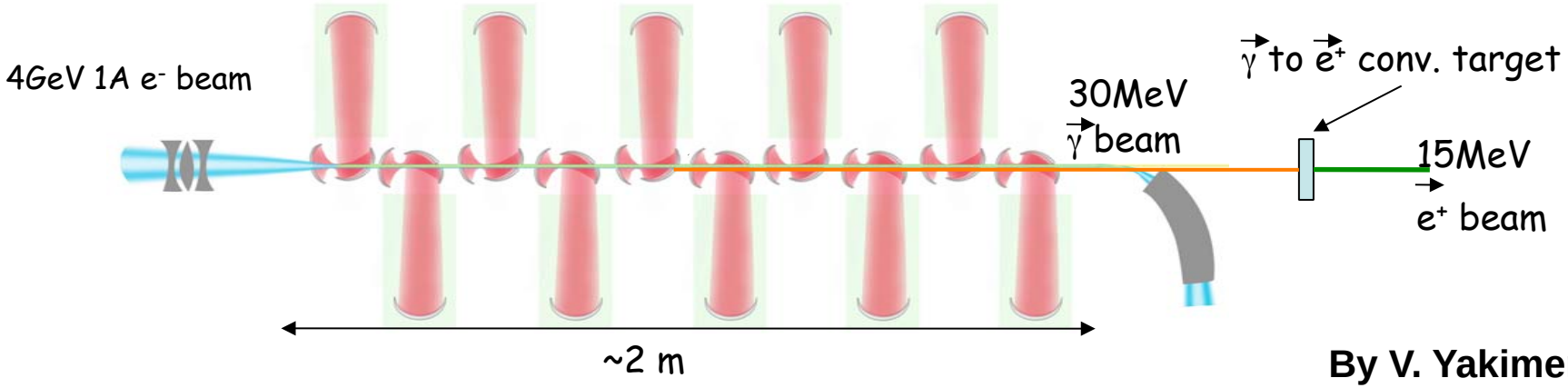
Linac Scheme (1): BNL scheme

- CO_2 laser beam and 4 GeV e-beam produced by linac.
  - **4GeV 15nC e- beam with 12 ns spacing.**
  - **10 CPs, which stores 10 J CO_2 laser pulse repeated by 83 Mhz cycle.**
- 5E+11 γ-ray -> 2E+10 e+ (2% conversion)
- 1.2μs pulse, which contains 100 bunches, are repeated by 150 Hz to generated 3000 bunches within 200ms.
  - Laser system relies on the commercially available lasers but need R&D for high repetition operation.
  - Ring cavity with laser amplifier realizes the C02 laser pulse train.



By V. Yakimenko

M. Kuriki/POSIPOL 2010

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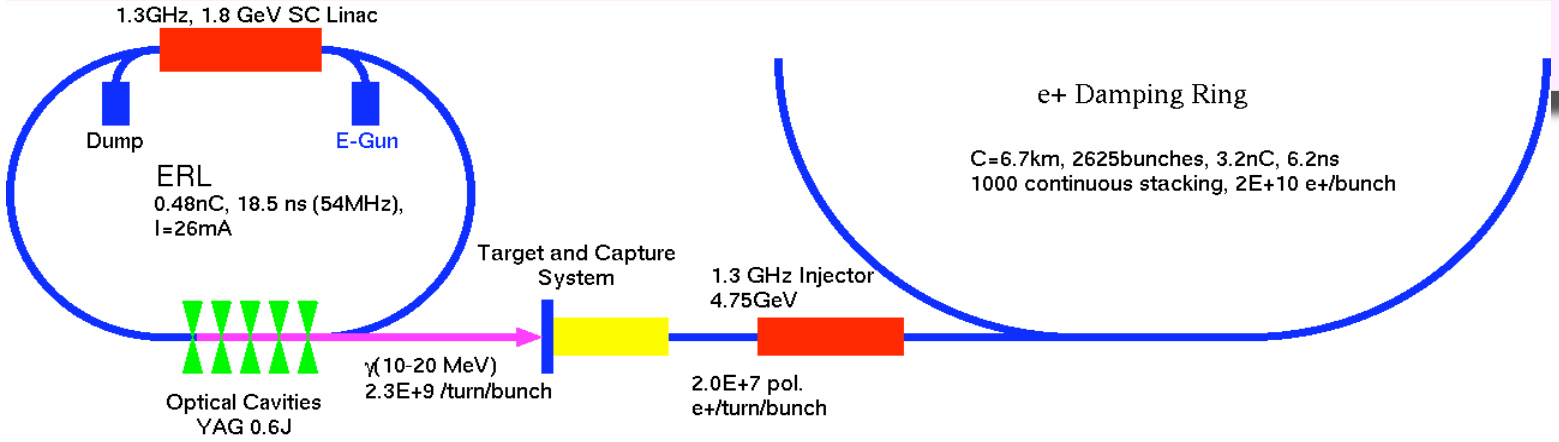
ERL scheme (1)

- Electron is provided by ERL (Energy Recovery Linac).
- Both advantages (high yield at Linac and high repetition at CR) are compatible in the ERL solution.
- Continuous stacking the e+ bunches on a same bucket in DR during 100ms, the final intensity is 2E+10 e^+.
- Another 100ms is used for damping.



M. Kuriki / POSIPOL 2010

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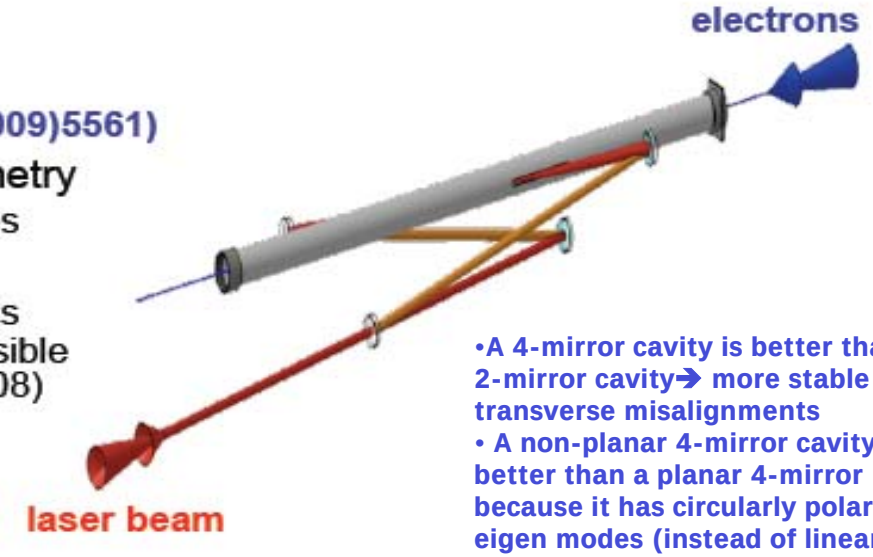
Associated technologies for Compton schemes: optical cavity
High finesse optical cavity (~3000) with 4 mirrors has been realized at LAL-Orsay and is now, installed on ATF/KEK for the tests. It has been locked. By the end of the year, Compton γ

- The cavity (➔Appl. Opt 48(2009)5561)
  - Non planar tetraedron geometry
    - Circ. Polarised eigen modes
    - Highly stable
    - Exp. Test & locking technics with topological phase possible (Opt. Comm. 282(2009)3108)



•A 4-mirror cavity is better than a 2-mirror cavity➔ more stable wrt transverse misalignments
• A non-planar 4-mirror cavity is better than a planar 4-mirror because it has circularly polarized eigen modes (instead of linearly polarized) and it is more stable.

F. Zomer/POSIPOL 2010

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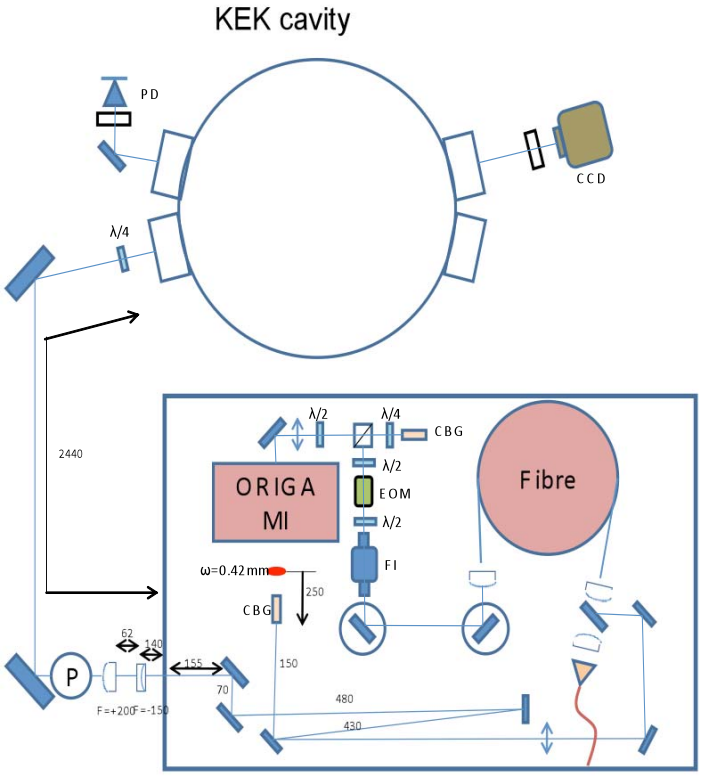
- **THE FOUR-MIRROR CAVITY OF LAL FOR ATF/KEK**
- **An Ytterbium laser (λ=103 nm) with an average powe of 250 mW is feeding the FP cavities with 4 mirrors. The laser scheme is represented on the right.**
- **[Victor Soskov]**



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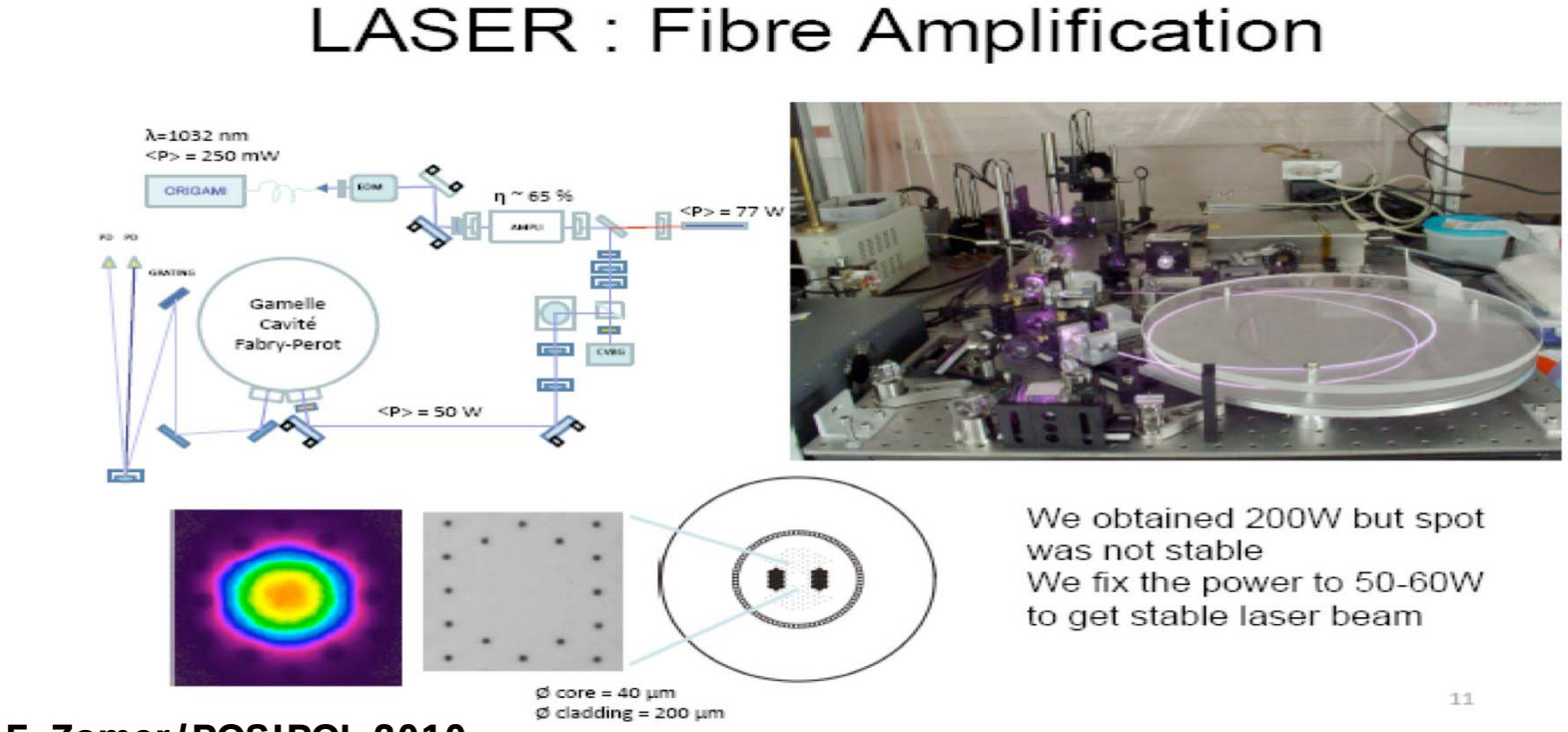
- **Associated technologies for Compton scheme: the laser**



F. Zomer / POSIPOL 2010

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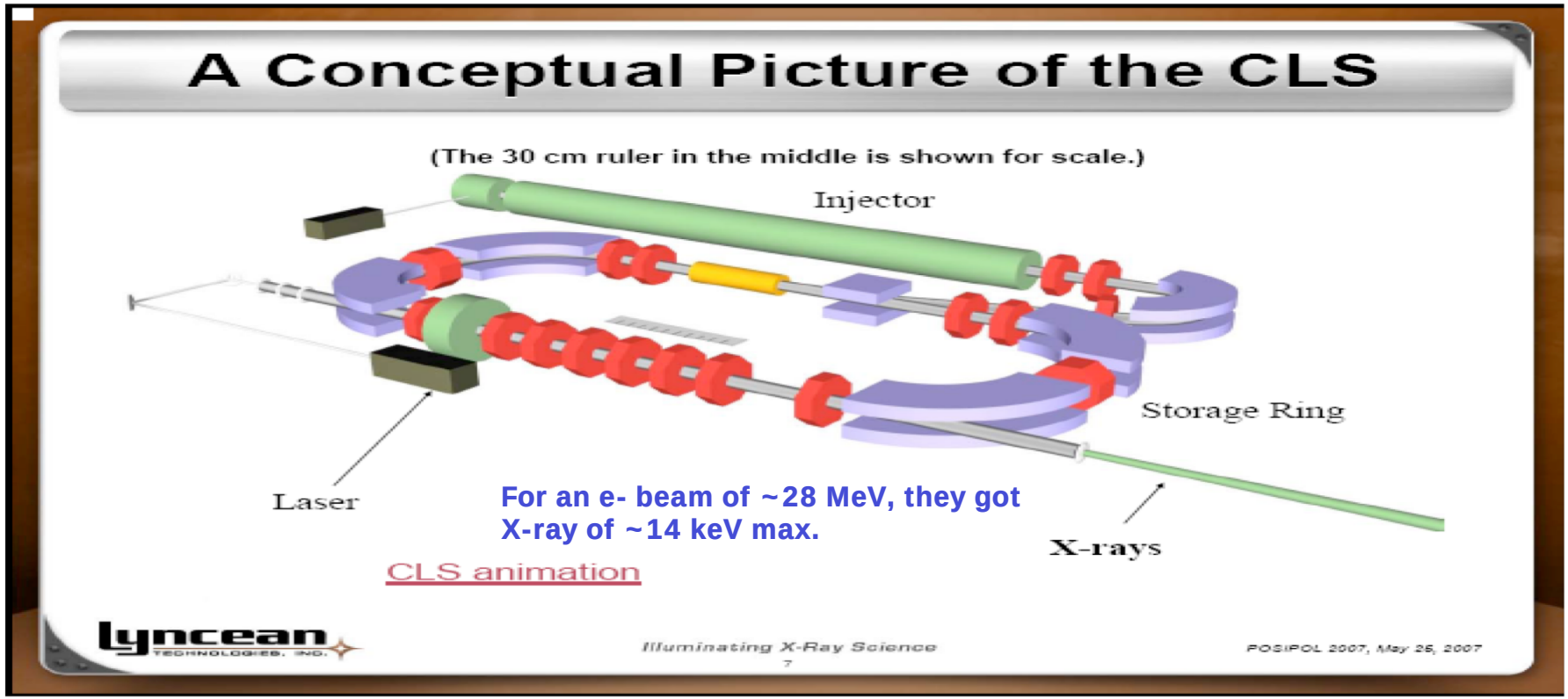
- **Applications for Compton schemes: medical**



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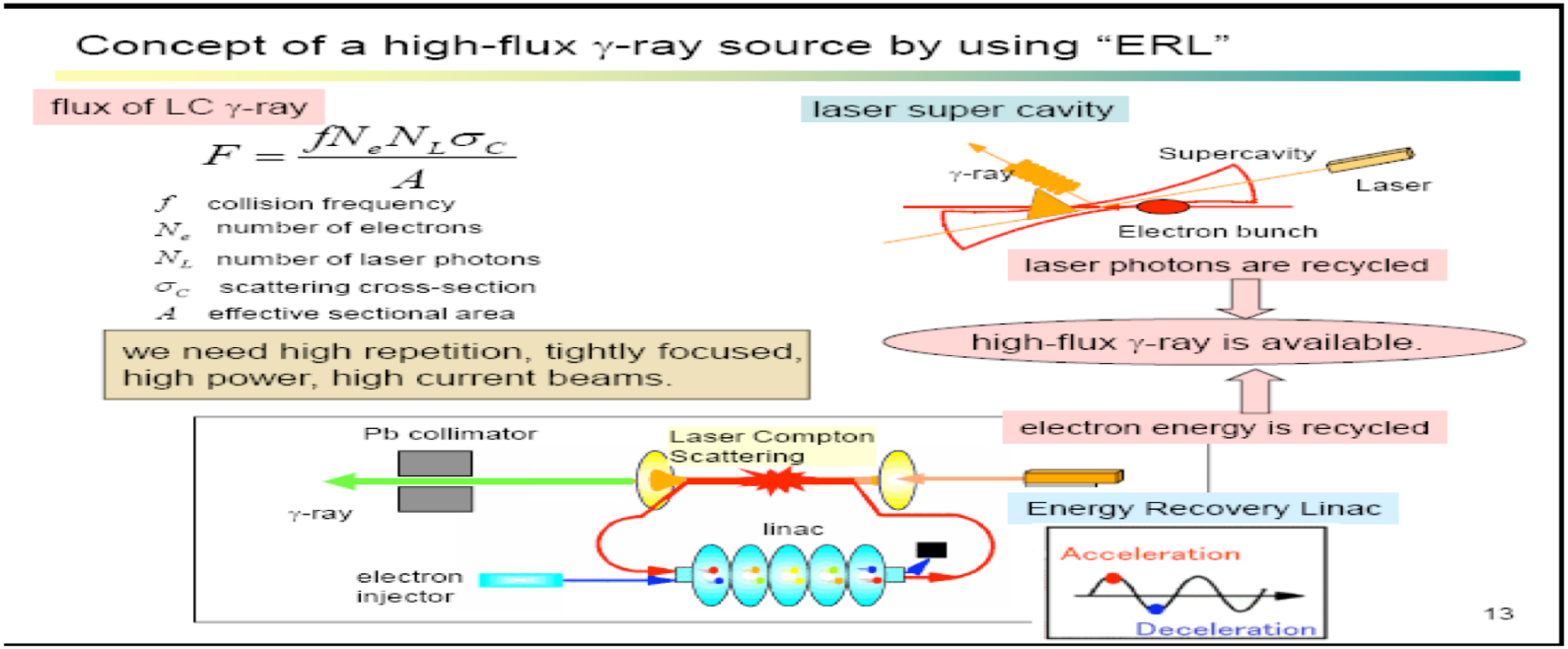
- **Applications for the Compton scheme: industrial**
- **Nuclear resonance Fluorescence (NRF) is used to detect the isotopic contents of a material. Photon energy is of some MeV (for instance 2-8 MeV) and these γ are penetrating probes to determine the chemical components of the material. Used to analyze nuclear wastes and also to detect explosives.**



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- **2- THE UNDULATOR SCHEME**
- **2-a Basic scheme**

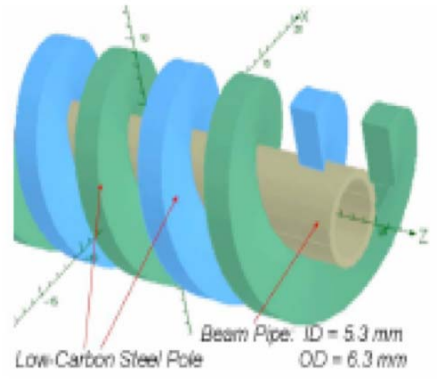

Fig. 1. A model of a double-helix coil for the low-carbon steel poles and beam chamber. A double-helix SC coil with equal currents in opposite directions in each helix is to be inserted between the steel coils.

The circularly polarized photons are emitted in an angle ~ $1/\gamma$ The photon λ is given by:

$$\lambda = (\lambda_u/2\gamma^2)(1 + K^2)$$

Where $K = eB\lambda_u/2\pi mc$; B, magnetic field. For $\lambda_u \sim 1$ cm we need an e-beam energy of 150 GeV to get 30 MeV photons useful to create e +e- pairs in a conversion target

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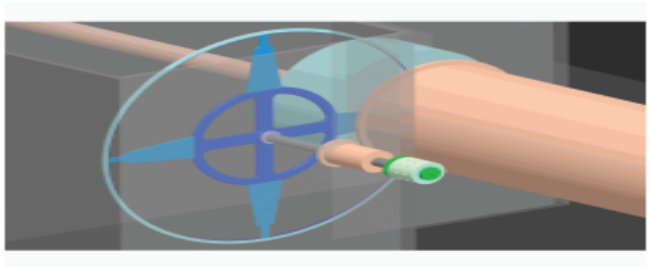
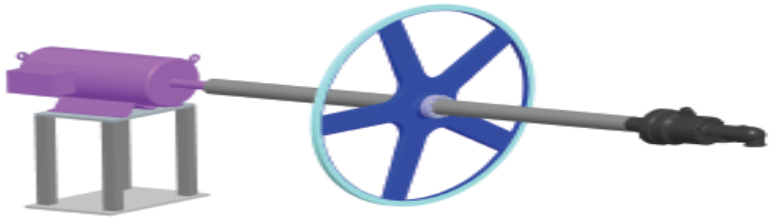
- **Technological developments for the undulator scheme**

Rotating Vacuum Seal Tests





Evaluating: Effectiveness, Survivability, Leakage (internal fluid), Magnetic Interference

Lawrence Livermore National Laboratory

comment

The ILC bunch is carrying 10J with 10^{13} γ ; 8% of this energy is deposited in the Ti target. For a wheel rotating at 100 m/s, the energy density is 40 J/g. The high velocity of the wheel induces constraints on the vacuum seal.➔ Tests

T.Piggott/POSIPOL 2010

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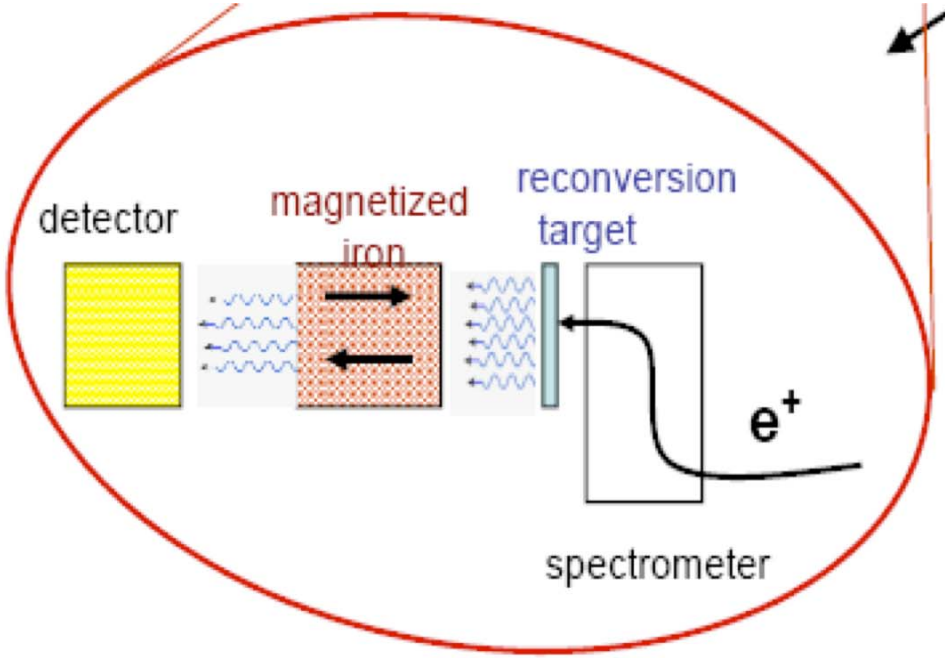
- **POLARIMETRY**



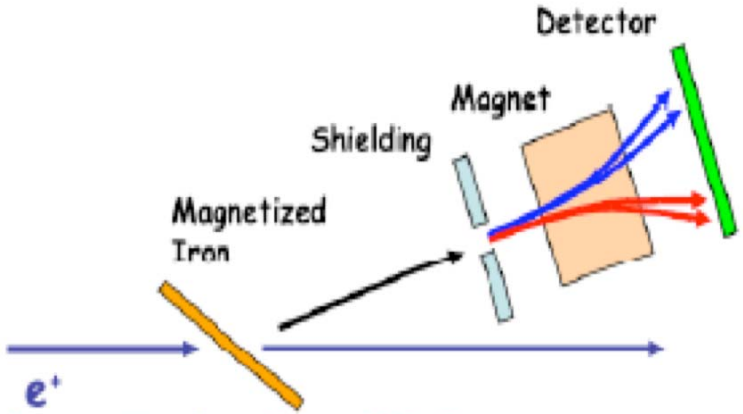
– Reconversion of polarized e+ to polarized photons
– transmission of photons through iron depends on its magnetization
– Measurement of transmission asymmetry for opposite (→ and ←) iron magnetization

Method was also used at ATF

S.Riemann/POSIPOL 2009

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

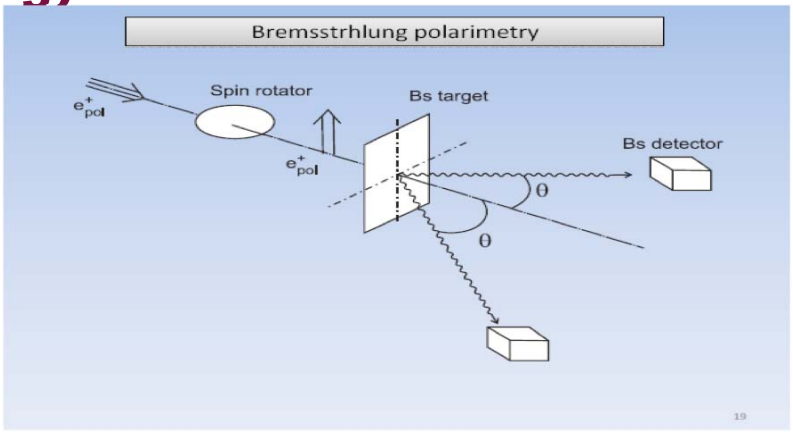
- **POLARIMETRY (following)**



Bhabha scattering @ ~ 400 Mev

Both e+ and e- (target) are polarized. The angular distribution of scattered e-, depending on polarization, is measured for two magnetization states of the target; asymetry is of some % For $P^+ = 0.6$ and $P^- = 0.07$, maximumasymetry is 0.03. The needed angular aperture is <10° for $E^+ = 400$ MeV

S. Riemann (LEPOL) /POSIPOL 2009



This method uses the dependence of bremsstrahlung on polarization; the spin is perpendicular to (k, p) plane

- **Energies considered: 5 to 10 Mev**
- **Analyzing power increases with Z**
- **Photon yield; 5.10^{-8} γ/e+**
- **target thickness: 10^{-3}Xo (Fe)**
- **Asymmetry $[(N_L - N_R)/(N_L + N_R)] \sim Z\alpha$ may reach 10 %**

A. Potylitsin/POSIPOL 2010

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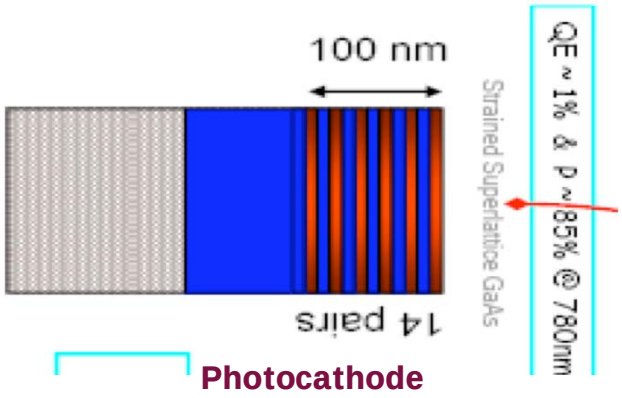
- **3- POLARIZED BREMSSTRAHLUNG**

Polarized Bremsstrahlung

E.G. Bessonov, A.A. Mikhailichenko, EPAC (1996) A.P. Potylitsin, NIM A398 (1997) 395

- Within a high Z target, longitudinally polarized e^-'s radiate circularly polarized γ's.
- Within the same/different target, circularly polarized γ's create longitudinally polarized e^+'s.

This method for producing polarized positrons is considered for CEBAF. The strained AsGa photocathode is illuminated by a a polarized laser (red). The e- (120 MeV) impinge on a W target (3 mm).



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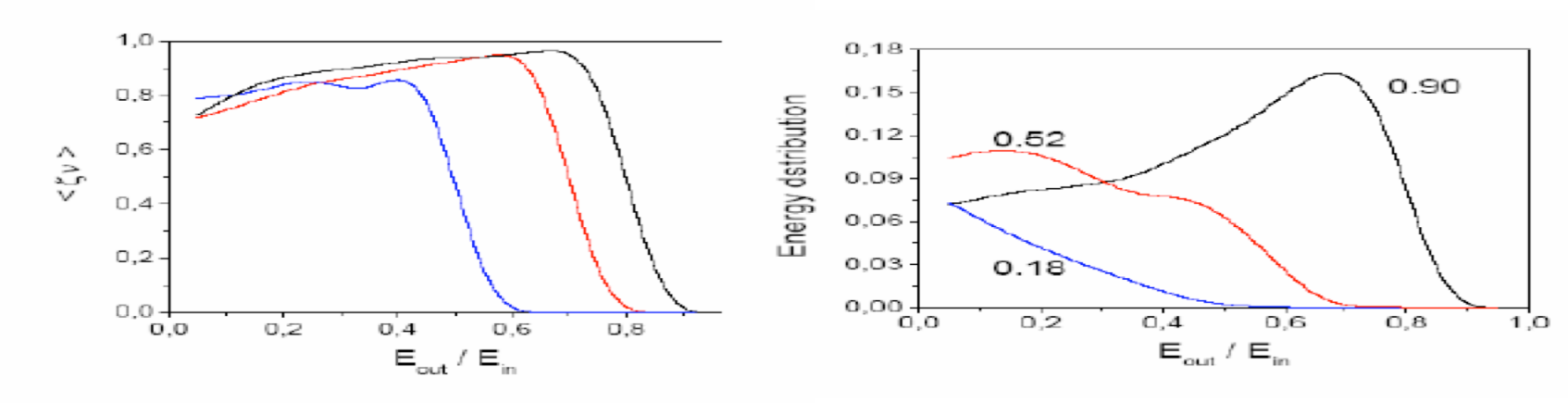
- **4- THEORETICAL INVESTIGATIONS ON POLARIZED e+**

Depolarization of positrons in bremsstrahlung



X=0.175 cm(black) X=0.35cm (red) X=0.525 cm (blue)

Numbers give the ratio N(out) / N(in) E(in) =30 MeV

$[N_{in}, E_{in}]^+ \rightarrow [N_{out}, E_{out}]^+$ on the right curve

V.Strakhovenko (BINP) studied the depolarization of e+e- pairs in the target / POSIPOL 2009

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **5- THE HYBRID SOURCE USING CHANNELING**
- **The conventional way, using high intensity electron beams impinging on thick targets with high Z, presents some inconvenients due to the worse emittance and the high rate of power deposition. Some improvements are undergoing, mainly at KEK and Hiroshima.**
- **An alternative and promising way is to replace the magnetic undulator by an atomic undulator (oriented crystal) in order to get a large amount of soft photons with channeling radiation. Such a method has been proposed more than 20 years ago by a French team and has been developed since by strong collaborations with Russian and Japanese teams.**
- **In order to lower the amount of deposited power in the targets, an *hybrid scheme* associating a crystal-radiator and an amorphous-converter has been proposed in the POSIPOL sessions**

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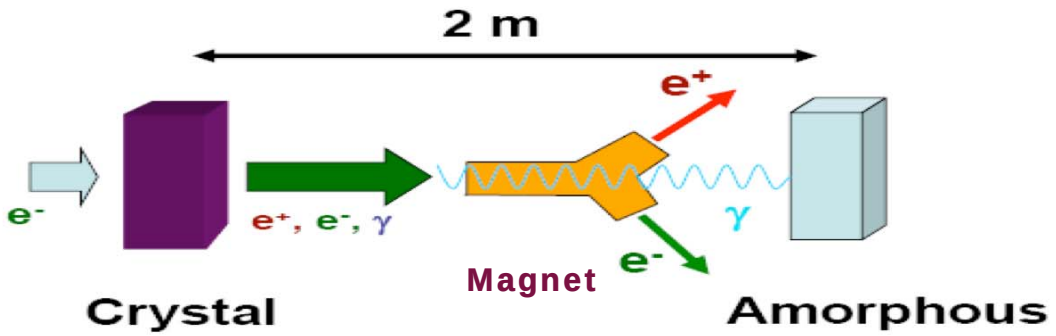
- **THE HYBRID SCHEME FOR FUTURE LINEAR COLLIDERS**
- **Assuming thin crystal target and, hence, moderate heating in it and in order to lower the amount of energy deposited in the amorphous target and also the PEDD, the following scheme has been proposed**
- **[R.Chehab, V.M.Strakhovenko, A.Variola]**



Putting a drift between the 2 targets allows sweeping off the charged particles coming from the crystal; only the γ impinge on the amorphous target

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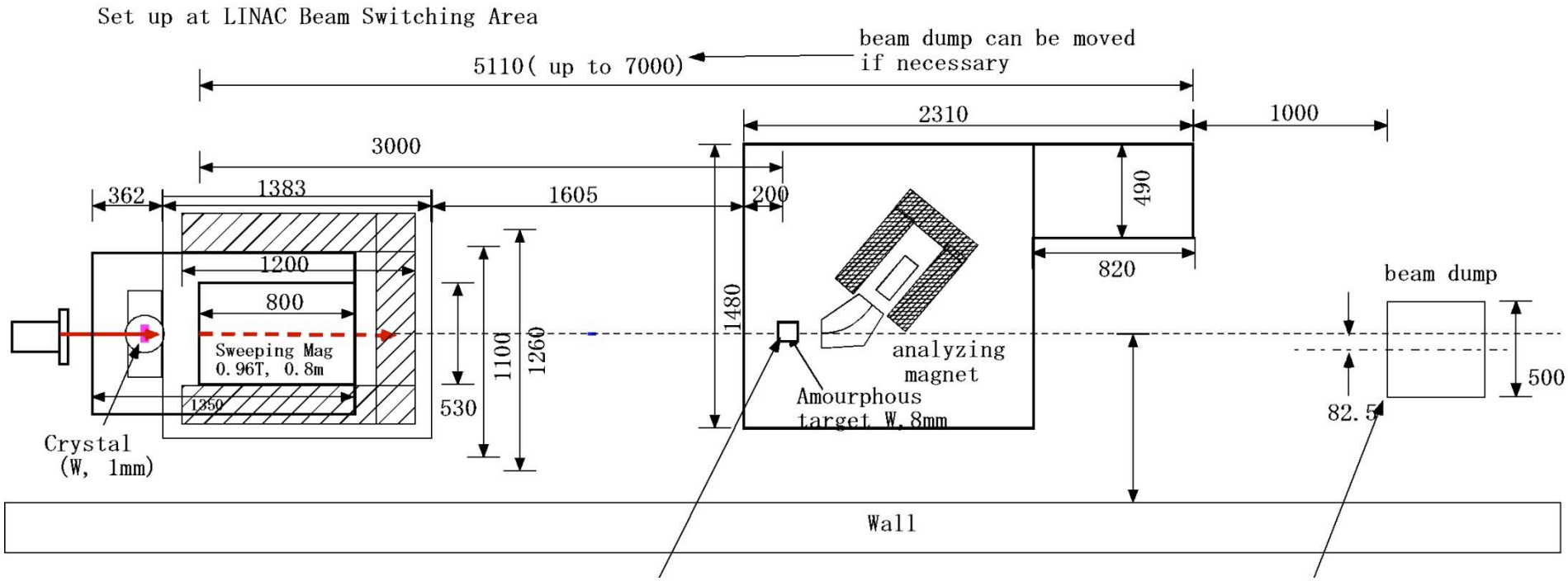
Experimental test of the hybrid source at KEK



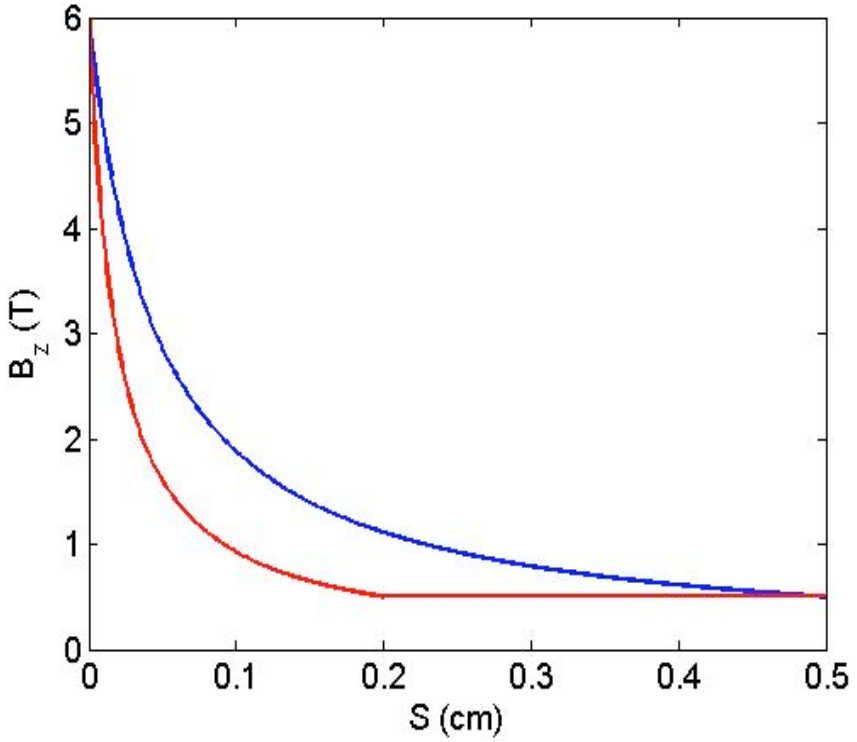
T.Takahashi et al. (KEK & Hiroshima U.)

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

6- MATCHING SYSTEMS: THE AMD

- Magnetic Length: L = 20-50 cm
- field at the target : B_0 = 6 T
- Magnetic field at the end : B(L) = 0.5 T
- Magnetic Field Behaviour :

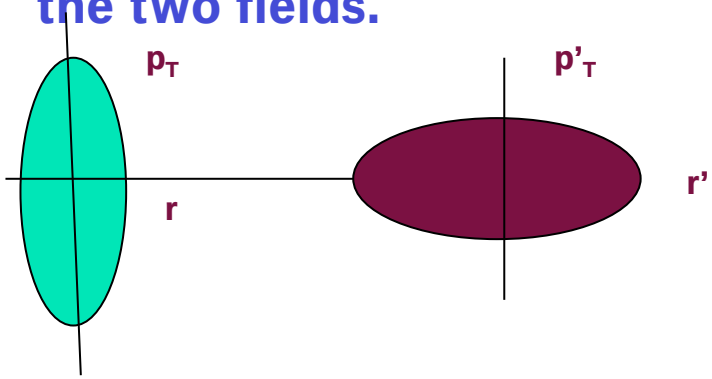
$$B(z) = \frac{B_0}{1 + \mu z}$$



The AMD may use a pulsed Flux Concentrator or a SC magnet

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **QWT**
- **The quarter wavelength**
- **transformer (QWT) is**
- **made of a strong field**
- **coil followed by a low**
- **field solenoid with an**
- **abrupt change between**
- **the two fields.**



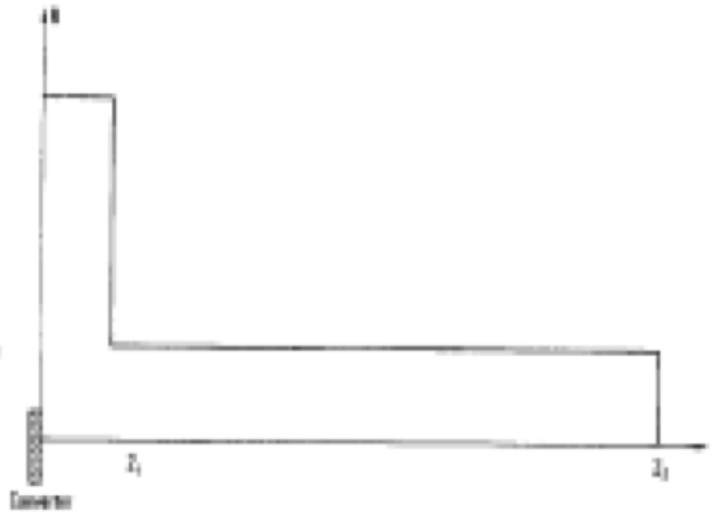


Fig. 14 Field profile of the quarter-wave transformer

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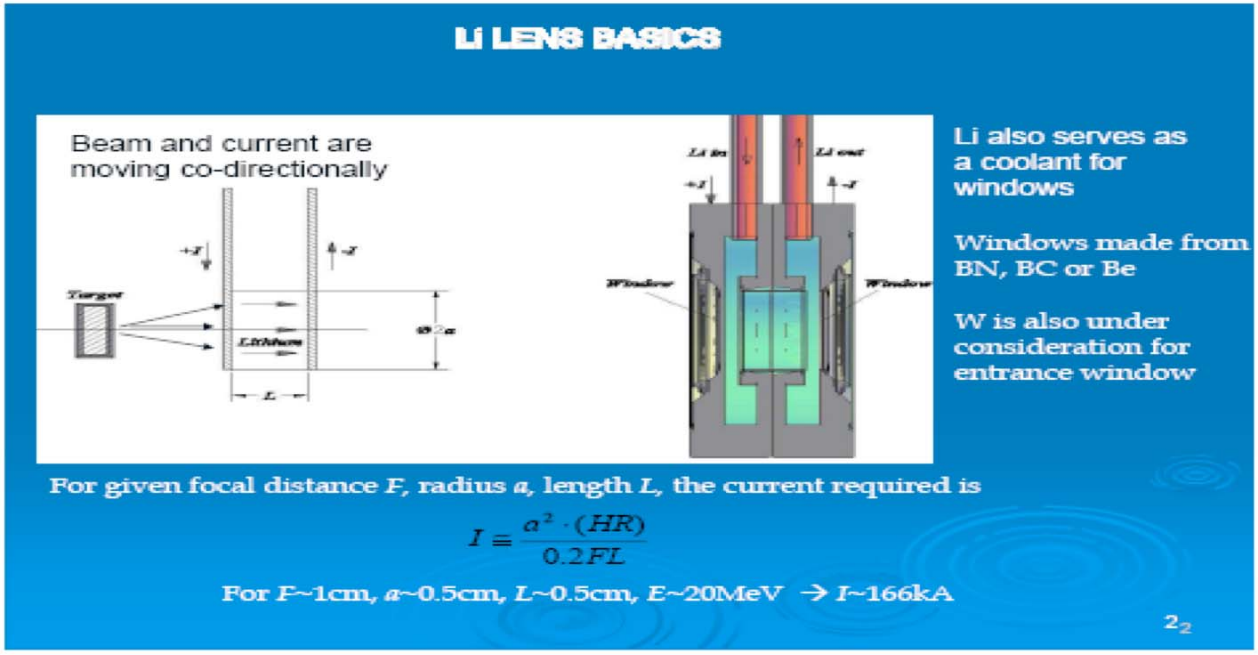
- **MATCHING SYSTEMS: LITHIUM LENS : Azimuthal field**



Such device focuses one particle (e+) and defocuses the other (e-)

A.Mikhailichenko

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **SUMMARY & CONCLUSIONS**
- **Since the starting of POSIPOL meetings many perspectives have been open thanks to such meetings:**
- *** Closer collaborations on the starting subject (Compton scheme) between the different partners (France & Japan)**
- *** Extension of the meeting contents to:**
- **- other kinds of e+ sources (Polarized, like undulator**
- **and polarized bremsstrahlung, or unpolarized like**
- **channeling and conventional)**
- **- technical developments needed (Optical Matching,**
- **Target Cooling, stacking in DR,...)**
- *** As was shown by the last POSIPOL's , the positron community is, now, largely represented in such meetings.**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- **SUMMARY & CONCLUSIONS**
- **Next POSIPOLs are already considered:**
- **2011, at Beijing (China) organized by IHEP → J. Gao**
- **2012, in Germany (Hamburg, Berlin???) organized by DESY → S. Riemann, G. Moortgat-Pick**

POSIPOL: FROM POLARIZED AND UNPOLARIZED PHOTONS TO POSITRONS

- ACKNOWLEDGEMENTS
- I am particularly indebted to Xavier Artru, Michel Chevallier (IPNL), Vladimir Strakhovenko (BINP), Tsunehiko Omori, Takuya Kamitani, Tsuyoshi Suwada, Junji Urakawa (KEK), Tohru Takahashi, Masao Kuriki (Hiroshima), Alessandro Variola, Olivier Dadoun, Freddy Poirier (LAL), Louis Rinolfi, Alessandro Vivoli (CERN), Alexandre Potylitsin (TPU), Sabine Riemann (DESY) and many other contributors to POSIPOL.