CORNELL ACTIVITIES FOR ILC

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Abstract. We describe some activities/plans caring out at Cornell LEP in framework of ILC project.

It covers the general layout, damping ring and **positron production system.**

The last includes undulator, combining scheme, collimators, liquid Hg target, fast spin rotators and elements of fast feedback system.

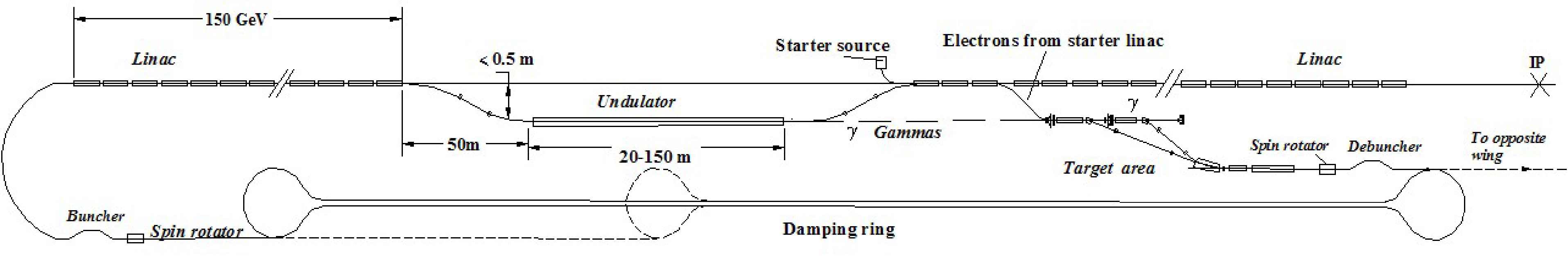
http://www.lns.cornell.edu/public/CBN/2005/CBN05-21/CBN05-21.pdf

GENERAL LAYOUT

The >150 GeV electron/positron beam is used for the production of (polarized) positrons/electrons. Electron/positron beam passes a ~200m helical undulator (50% surplus)

After conversion, the positrons are captured and accelerated, high energy beam gouing to IP

Spin handling system includes spin rotators etc. In baseline scheme electrons create positrons.



Positron wing of collider can operate independently from electron one, thanks to the presence of **fast feedback and starter source**.

The length of straight sections in this cooler can be adjusted depending on the fast kicker parameters and collective phenomena.

Saying ahead, a **Concept of fast kicker allowing rise time down to~0.1ns, no reflections, have been developed and will be introduced soon.**

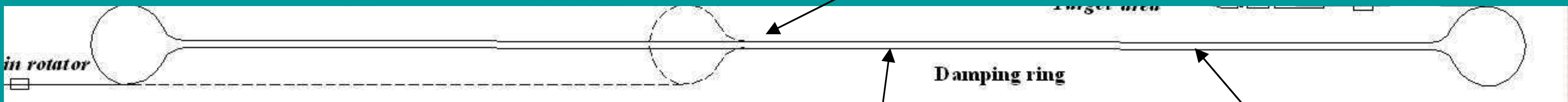
To work at lower energy, giga Z, the beam **decelerated** in the residual part of accelerator.

Debuncher before damping ring required as the bunch lengthening during collection might be not enough.

The shape of the ring was considered for VLEPP and was introduced at LC91 Workshop, 1991, Protvino, Moscow Region.

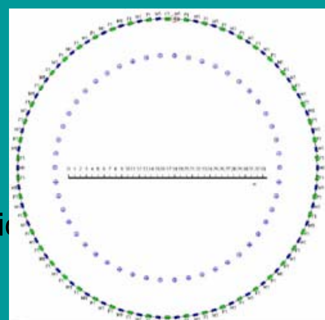
Right after the Workshop, DESY team implemented this type of cooler into TESLA project, ***referred*** that inspiration came at this Workshop.

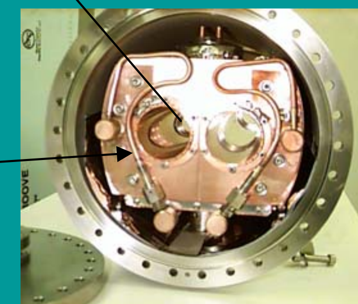
Trombone



Our design of DR for NLC type machine is probably the best: CBN 03-11

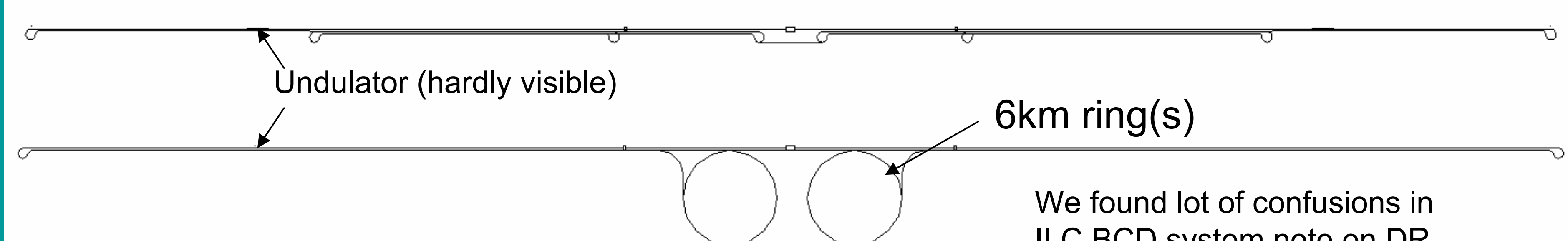
http://www.lns.cornell.edu/publi
/CBN/2003/CBN03-11/cbn03-11.pdf





Dual bore Quads, Sextupoles, **tested.** Octupoles, Dipoles developed

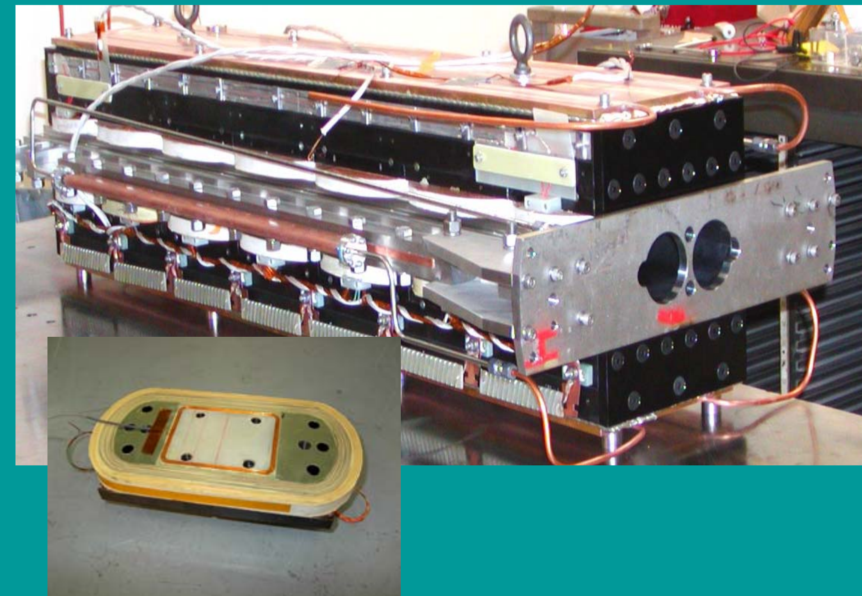
Now the work in progress on Layouts which include undulator for the base line and for TESLA-type Cooler. Scaled view of these two:



We found lot of confusions in ILC BCD system note on DR

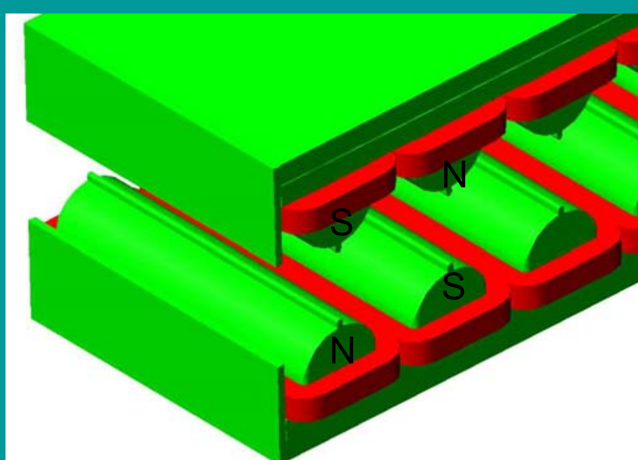
Wiggler for Damping Ring

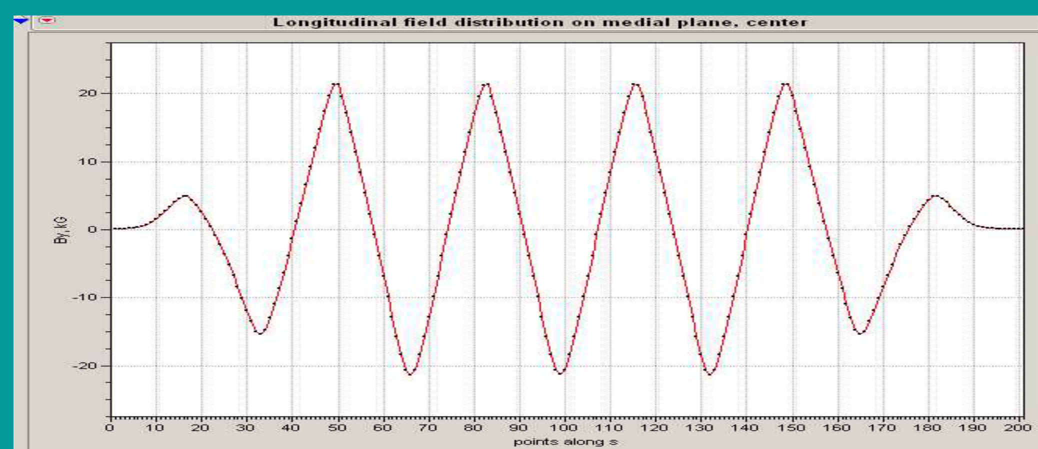
Wiggler for the damping ring was described in 2000, also at LC02 Feb.4-8 SLAC. The Cornell wiggler served as a prototype. Lot of ideas introduced for the first time



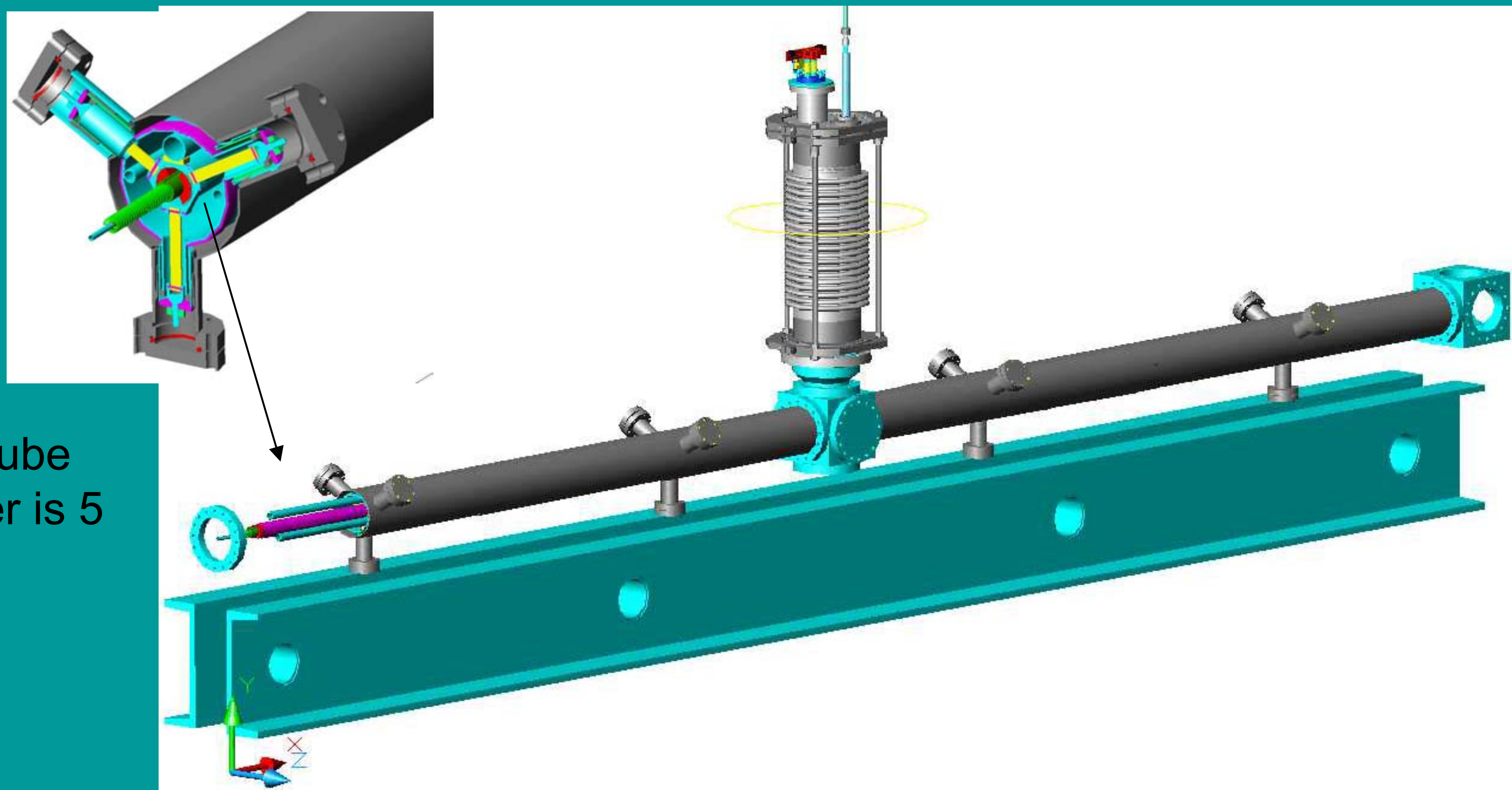
7-pole, **Wide** poles, Large aperture 90X50mm^2, Optimized coils shape, Recessed poles, Active field correction (end poles and central) for field adjustments, Tapering, Easy assembled cold mass...

Recently an **Ideal wiggler** was introduced. This wiggler has no nonlinearities. Field profile is ***piecewise-linear*** in this Wiggler. So the wiggler is not a problem anymore.





UNDULATOR



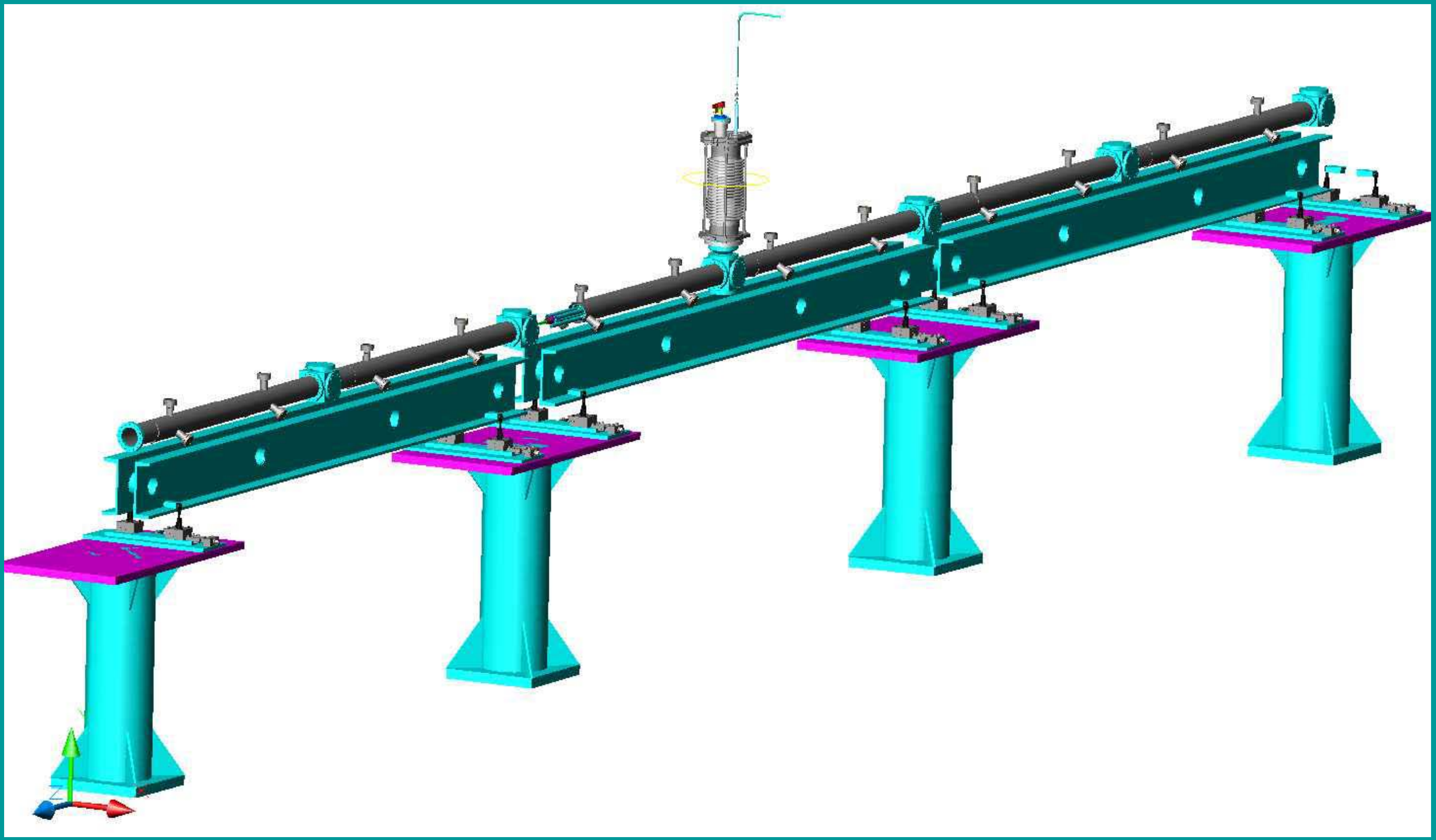
Outer tube diameter is 5 inch.

Cryomodule, 4 m—long. Cryostat contains two 2 m–long identical sections having opposite polarity. This delivers zero first integral along this module (was tested at VEPP-2M).

ACTIVE COLLABORATION WITH DARESBURY IN PROGRESS

Efficiency of conversion, Nonlinearities, Technology of fabrication, Cost, Vacuum,…

Test at DESY or Cornell



Sections installed in series. BPMs, pumps, quads etc installed between sections.

Total length of installation ~200 m

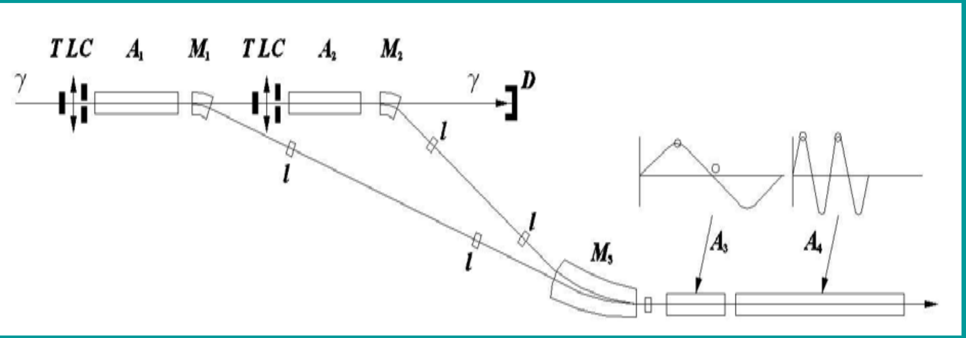
Beam dimensions

Angular spread in radiation	$\alpha \sim \sqrt{1+K^2}/\gamma$	$3\cdot 10^{-6}$ $(K=1)$
Angular spread in beam, vert.	$y' \cong \sqrt{\gamma\varepsilon_z/\beta\gamma}$	$2.6\cdot 10^{-8}$
Radius of helix	$a \cong \lambda_u K/\gamma$	$5\cdot 10^{-7}\,cm$ $(K=1)$
Beam size, vertical	$\sqrt{\langle y^2\rangle} \cong \sqrt{\gamma\varepsilon_y\beta/\gamma}$	$2.6\cdot 10^{-4}\,cm$
Beam size, radial	$\sqrt{\langle x^2\rangle} \cong \sqrt{\gamma\varepsilon_x\beta/\gamma}$	$2.6\cdot 10^{-3}\,cm$

In final, the undulator will have K~0.35

COMBINING SCHEME

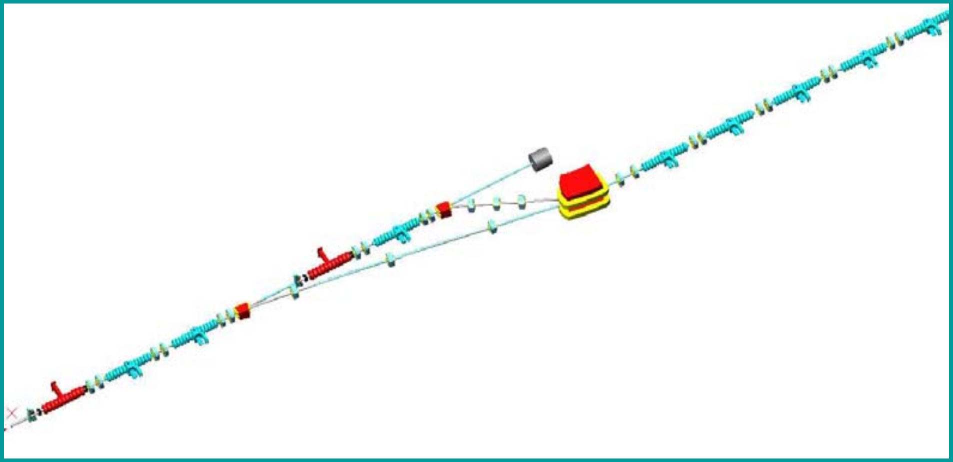
After the first target only 13% of photons are lost. So it is possible to install second target and collect positrons from this second target.



Combining could be arranged easily in the same RF separatrix in damping ring.

Energy provided by acceleration structures *A*1 and *A*2 are slightly different, *A*1>*A*2.

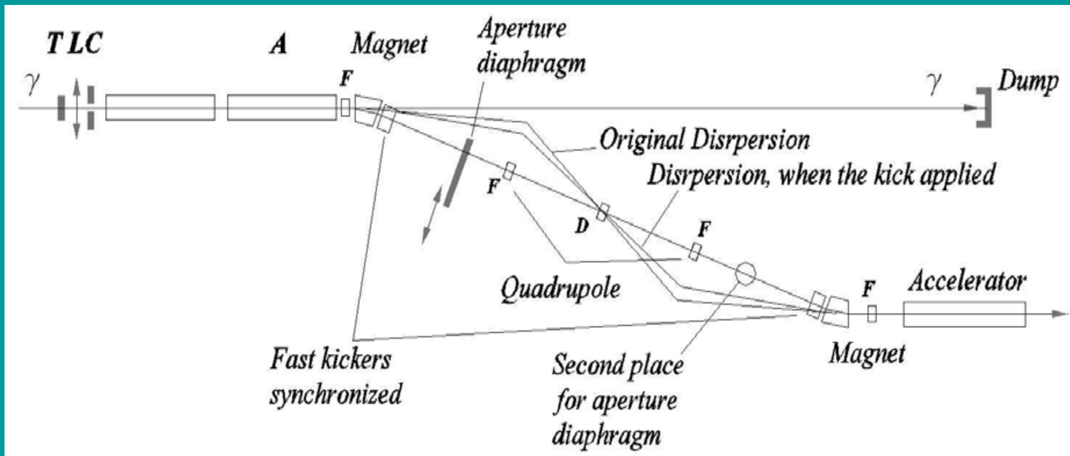
Additional feed back system will be required for fast dump of coherent motion.

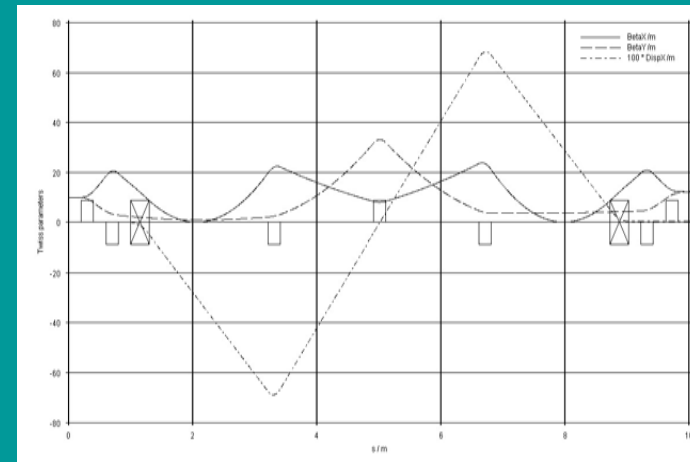


This combining can help in reduction of power deposition in target if each target made thinner, than optimal.

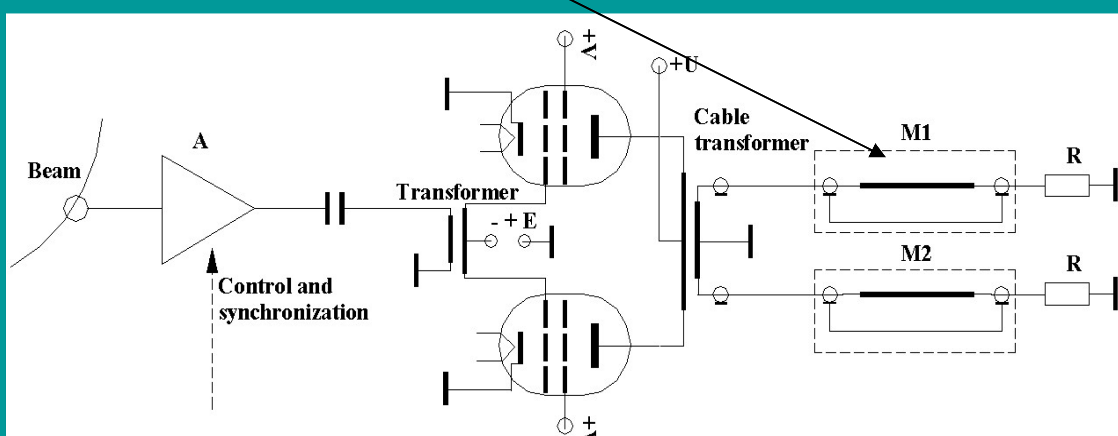
FAST FEEDBACK

Just cut extra particles



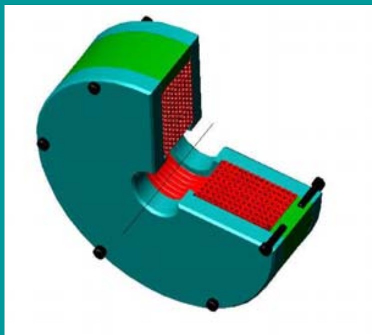


Tetrode amplifier. *M1* and *M2* stands for the kickers. *A* –controlled pre-amplifier. Voltages *E, V, U* applied for proper operation of tubes. *M1*, *M2* stand for the kicker magnets.

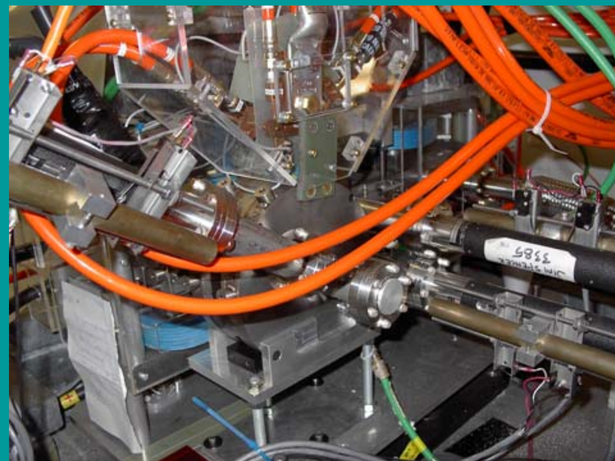


Principle of operation can be tested at CESR. In this case the amplifier can feed either fast quadrupole and change the betatron frequencies of each individual bunch in a train (useful for CESR), or fasr kickers can be arranged to make a bump to the aperture scraper.

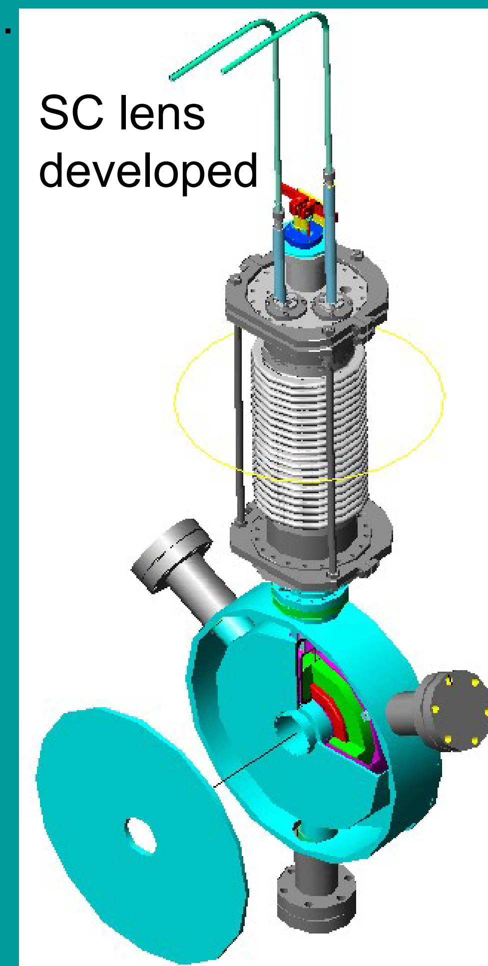
COLLECTION OPTICS



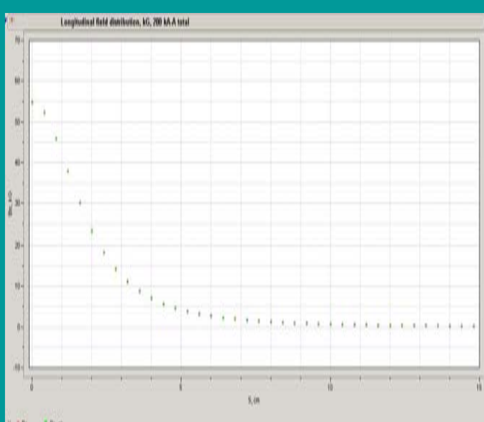
Current density in the coil ~45A/mm^2

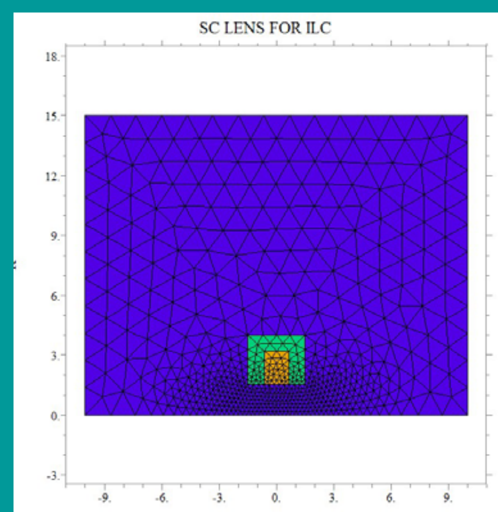


DC collection optics prototype was under the test at E-166, where the short focus-lens is a part of spectrometer (designed at Cornell, fabricated at Princeton).

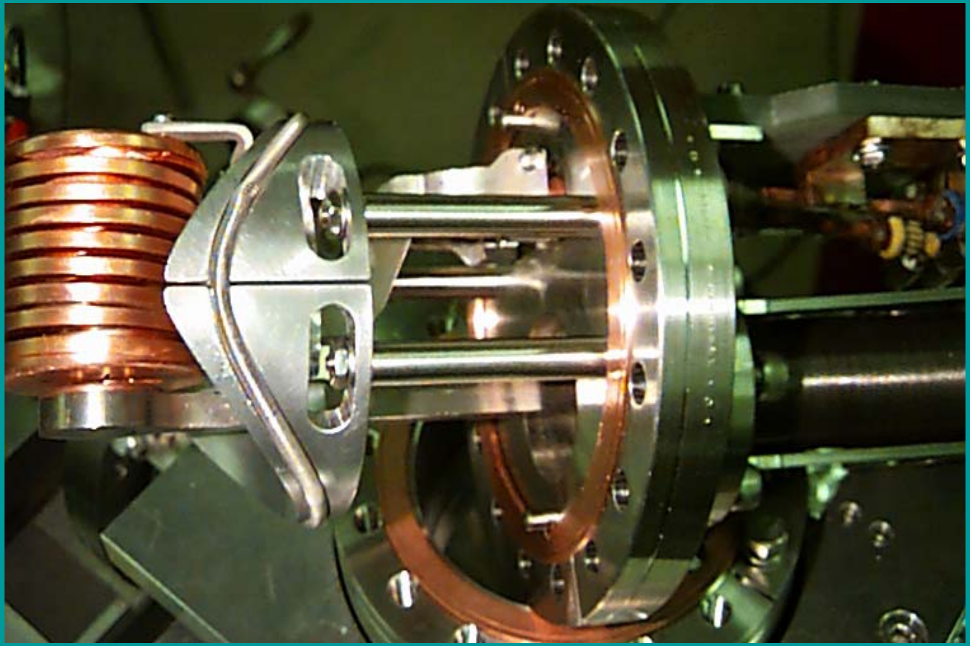


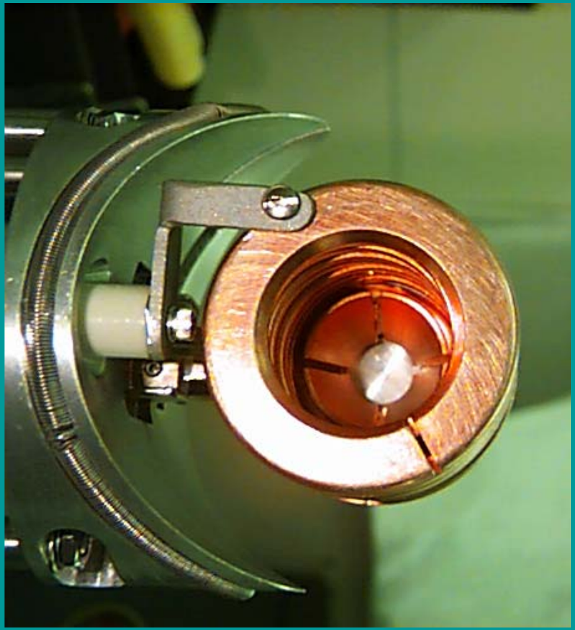
For ILC we considered a lens with SC windings. Irradiation is low. No Iron.





Positron collection system with partial flux concentrator, developed for CESR ~doubled positron ACCUMULATION



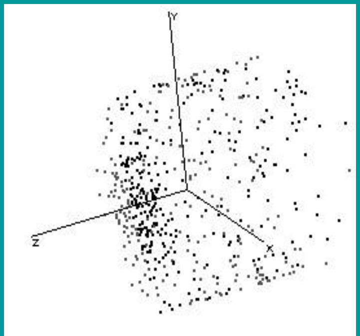


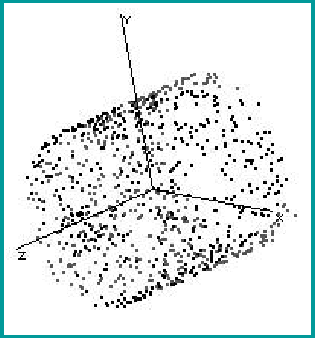
Experience is in hand

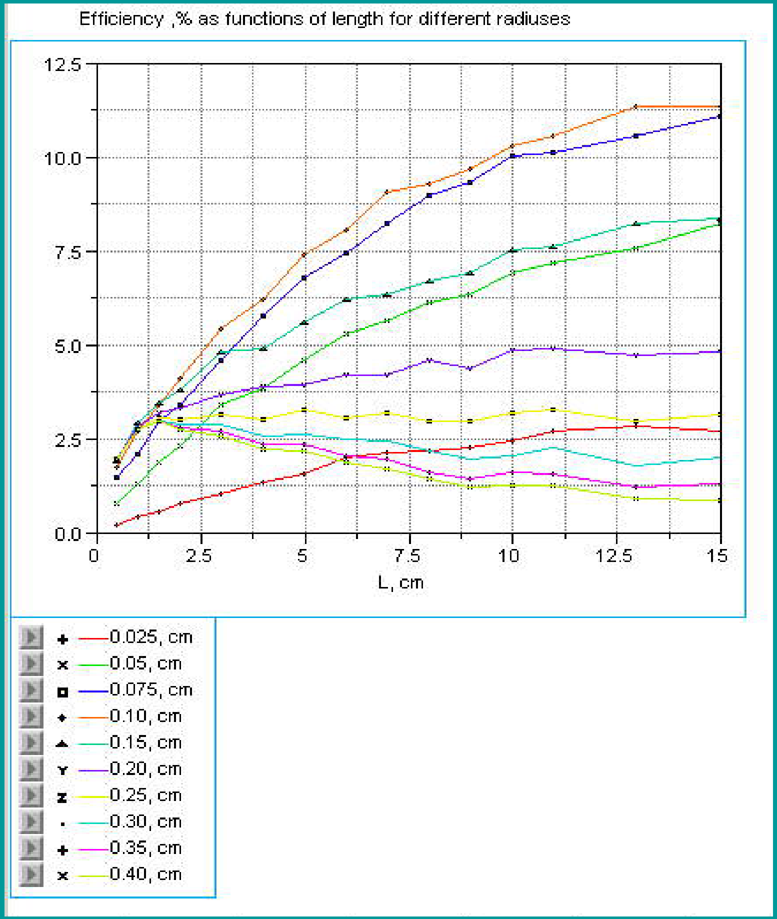
TARGET

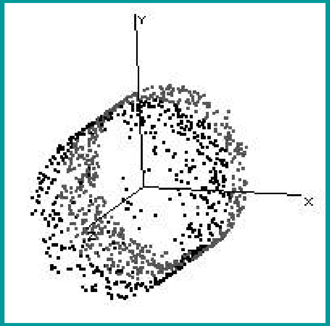
Although Ti rotating wheel target (Livermore, SLAC) is under development, we are looking for some more elegant solutions

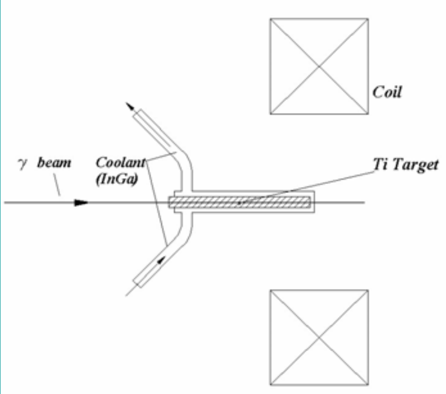
We are using numerical codes to evaluate efficiency. Cylindrical target example







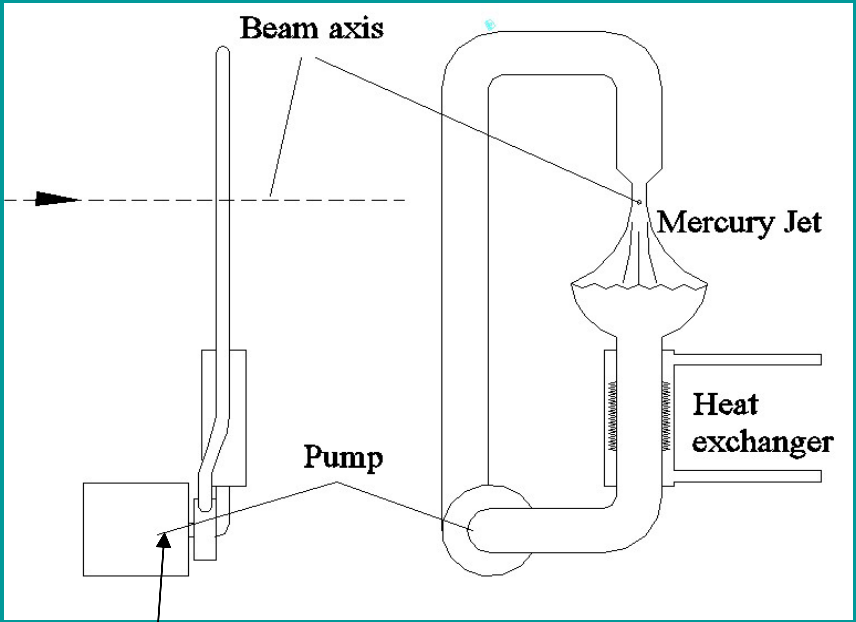


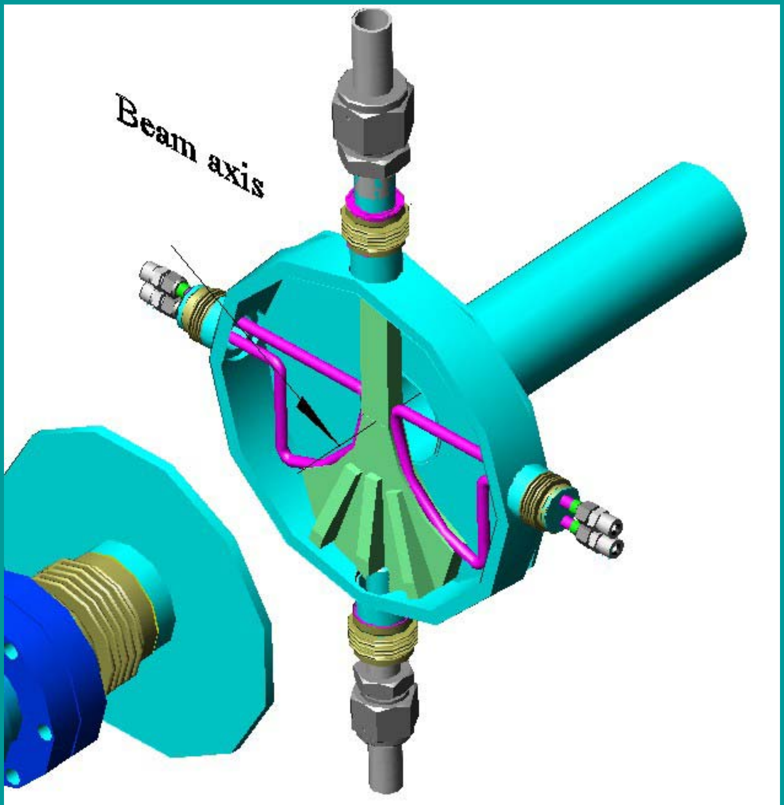


LIQUID METAL TARGET

High Z metals could be used here such as Lead, Mercury. InGa alloy also can be used here if filled with W powder.

We have chosen Hg



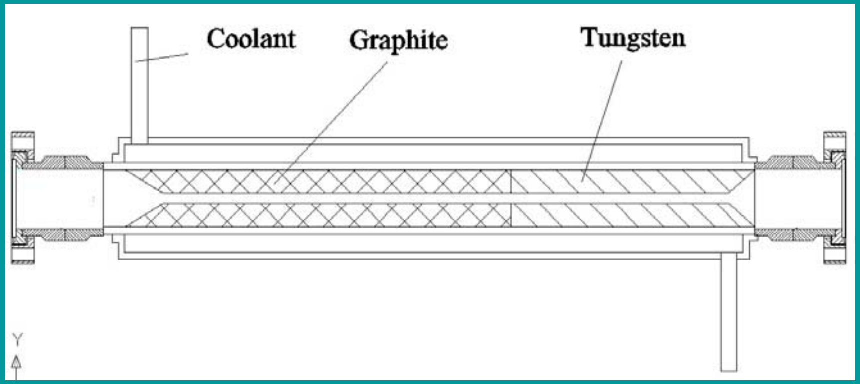


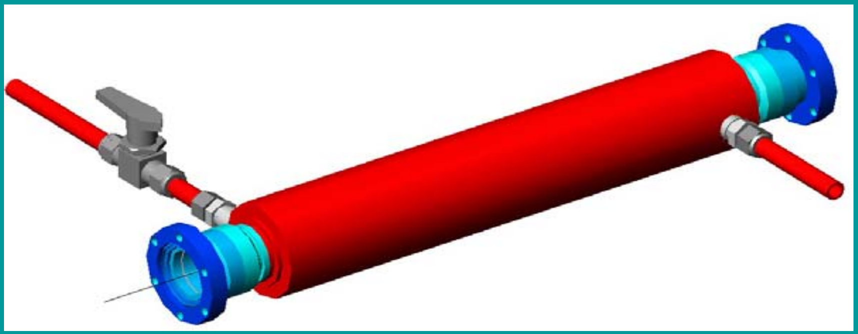
Gear pump. Hg Jet velocity~10m/s

Calculations show absolute feasibility of this approach

COLLIMATOR

Pyrolytic Graphite (PG) is used here. The purpose of it is to increase the beam diameter, before entering to the W part. Vacuum outgassing is negligible for this material. Heat conductivity ~300 W/m-oK is comparable with meals. *Beryllium* is also possible here, depending on task.

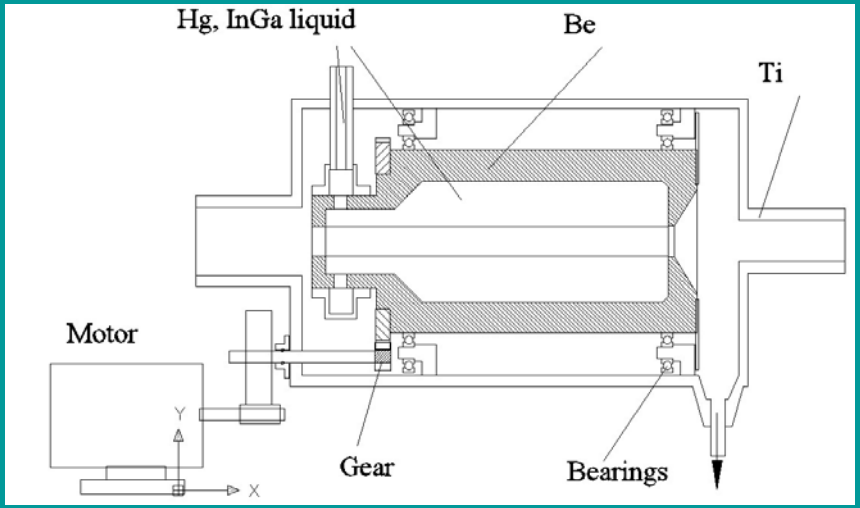


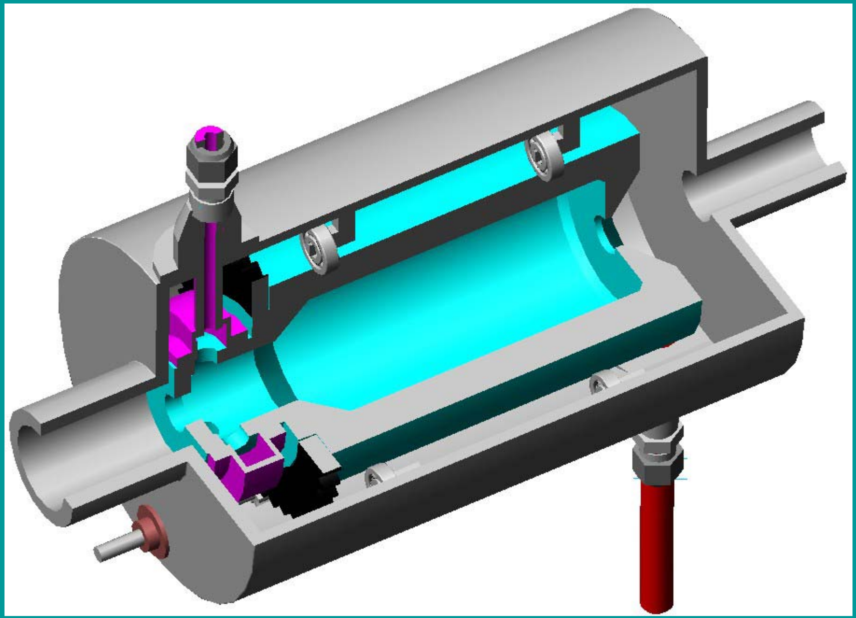


Transverse dimensions defined by Moliere radius

HIGH POWER COLLIMATOR

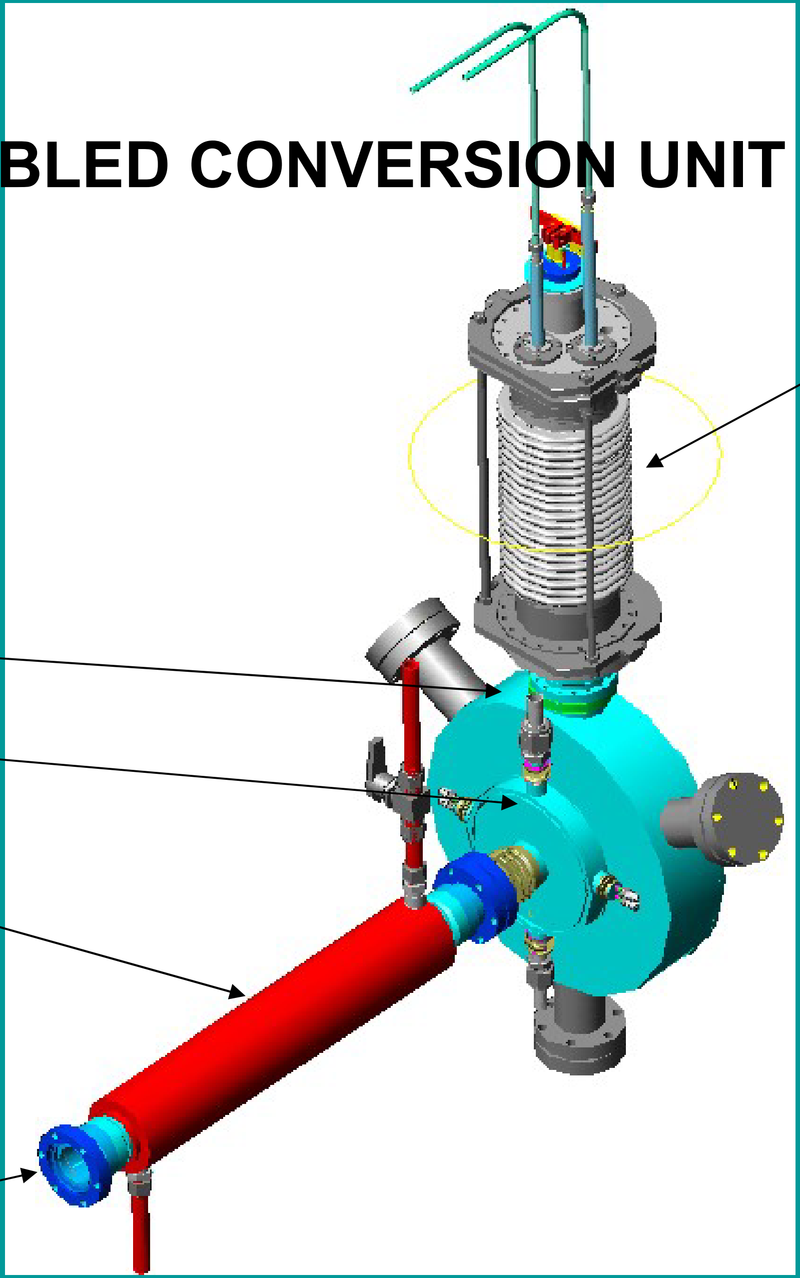
This a liquid metal one. Liquid formed a cylinder as result of rotation and centrifugal force





High average power collimator. Beam is coming from the right.

FULLY ASSEMBLED CONVERSION UNIT



This is much more compact, than the rotating (1 m in dia) wheel

UNDULATOR ACTIVITY AT CORNELL

SC undulator; period 10 mm, K=0.6

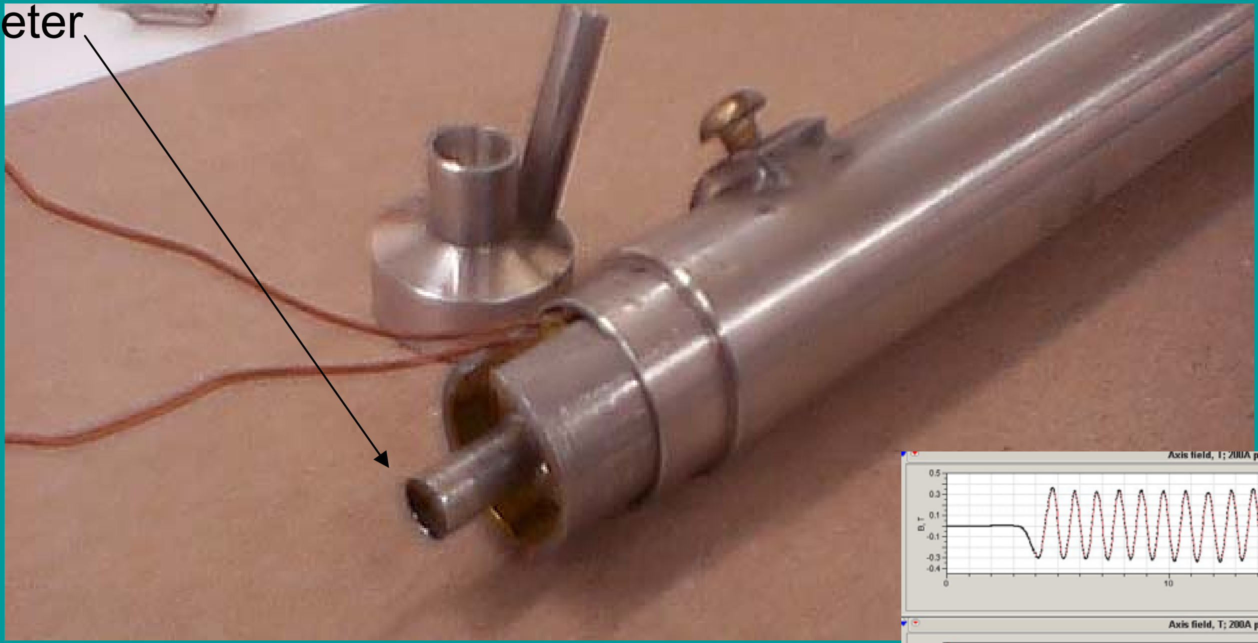
Aperture 6 mm in diameter tested

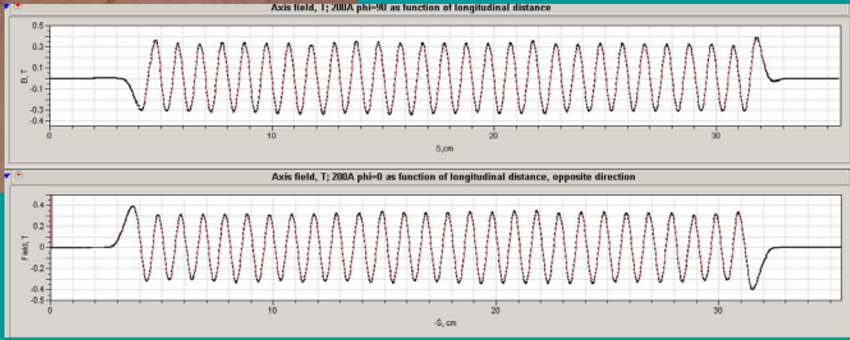
Plan is to fabricate and test an undulator with **8 mm aperture**, period 10mm, K=0.6, Length ~30 cm

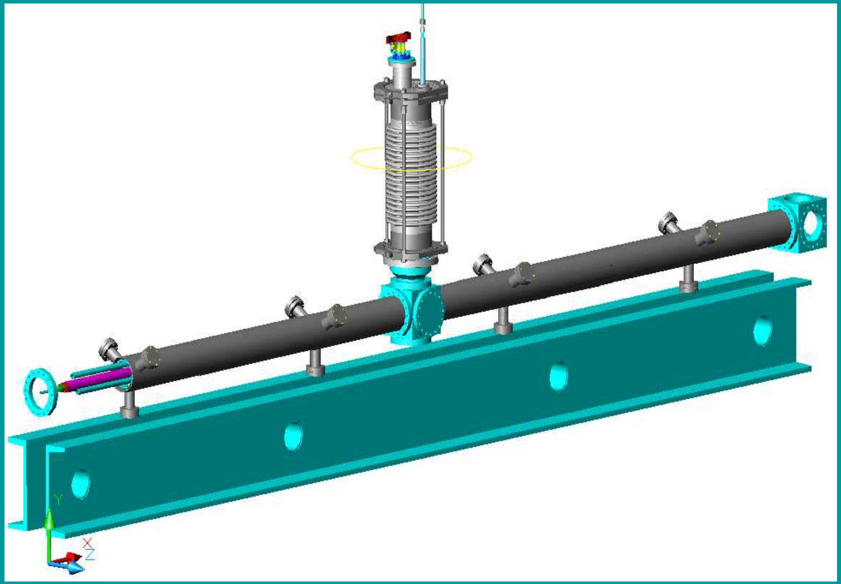
Equipment

MEASURED LONGITUDINAL FIELD DISTRIBUTION IN LHE

6 mm in diameter

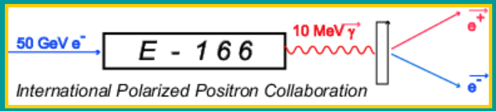






Goal: Assemble and test working 4-m long prototype module for ILC

E-166 EXPERIMENT



E-166 STATUS
Snowmass 2005

Few slides from my Talk at Snowmass 2005

Alexander Mikhailichenko
for E-166 collaboration:

G. Alexander, J.Barley, P. Anthony, V. Bharadwaj, Yu.K. Batygin, T.Behnke, S.Berridge, G.R. Bower, W. Bugg, R. Carr, H.Carsten, E.Chudakov, J.Clarke, J.E. Clendenin , F.J. Decker, Yu. Efremenko, T.Fieguth, K.Flottmann, M. Fukuda, V. Gharibyan, T.Hadler, T. Hirose, R.H.Iverson, Yu. A. Kamyshkov, H. Kolanoski, K.Laihem, T.Lohse, C.Lu, K.T.McDonald, N. Meyners, R.Michaels, A.A. Mikhailichenko, K.Moning, G. Moortgat-Pick, M. Olson, T. Omori, D. Onoprienko, N.Pavel, R.Pitthan, R.Poeschl, M. Purohit, L. Rinolfi, K.P. Schuler, D.Scott, T.Schweizer, J.C.Sheppard, S. Spanier, A. Stahl, Z.M.Szalata, J.Turner, D. Walz, A. Weidemann, J.Weisend

53 members from 17 institutions

ILC dedicated collaboration working in practice

Brunel U. & CERN & Cornell U., Phys. Dept. & DESY & Durham U. & Jefferson Lab & Humboldt U., Berlin & KEK, Tsukuba & Princeton U., Plasma Physics Lab. & South Carolina U. & SLAC & Tel Aviv U. & Tokyo Metropolitan U. & Tennessee U. & Waseda U SLAC-TN-04-018, SLAC-PROPOSAL-E-166, Jun 2003. 67pp.

E-166 Collaboration meeting at DESY/Zeuthen, November 7-9, 2005

(~4/10 of all personnel involved)

E-166 Experiment Motivations

E-166 is a demonstration of undulator-based production of (polarized) positrons for linear colliders:

- Photons are produced ~in the same energy range and polarization characteristics as for ILC;

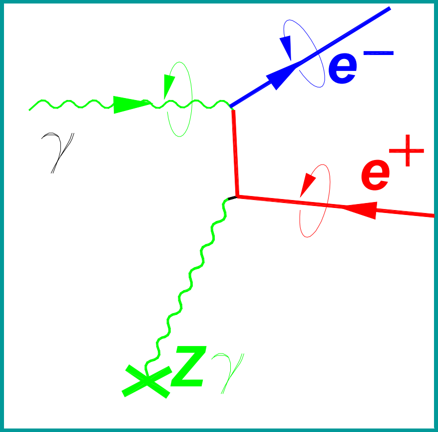
-The same target thickness and material are used as in the linear collider;

-The polarization of the produced positrons is the same as in a linear collider.

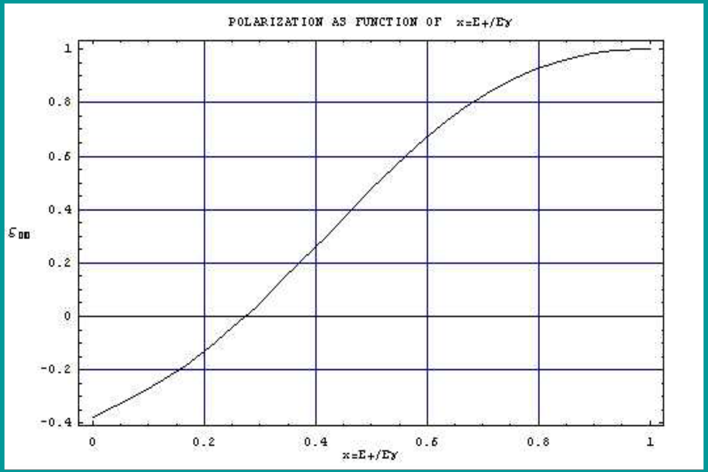
-The simulation tools are the same as those being used to design the polarized positron system for a linear collider.

- Number of gammas per electron is lower ~210 times, however: $(150/1)(2.54/10)(0.4/0.17)^2$.

Polarized $e^{\pm}$ production



The way to create circularly polarized positron, left. Cross-diagram is not shown. At the right-the graph of – longitudinal polarization – as function of particle's fractional energy

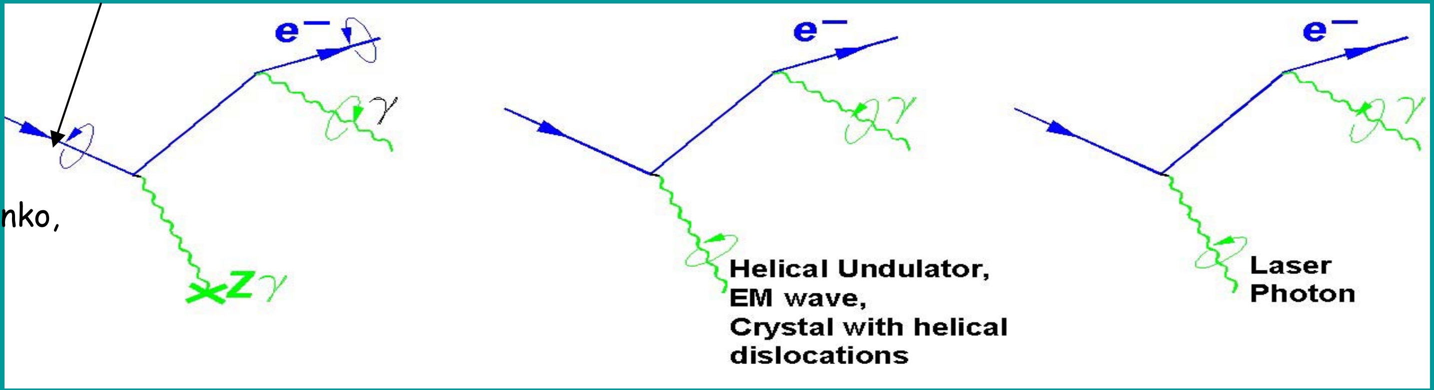


The way to create circularly polarized photon

V.Balakin, A. Mikhailichenko, 1979

Polarized electron

E.Bessonov, A.Mikhailichenko, 1996



E.Bessonov

1992

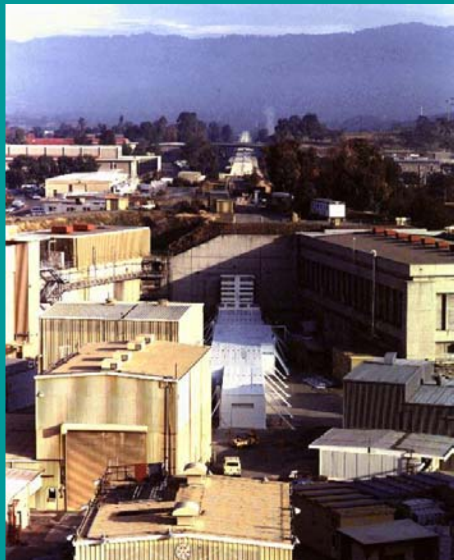
Strong motivation for **polarized** positrons.

1996 1979

THE ROLE OF POLARIZED POSITRONS AND ELECTRONS IN REVEALING FUNDAMENTAL INTERACTIONS AT THE LINEAR COLLIDER.

G. Moortgat-Pick *et al.*. SLAC-PUB-11087, CERN-PH-TH-2005-036, Jul 2005. 149pp.

SLAC, Stanford, California



FFTB

Novosibirsk team delivered Magnets for FFTB, 1991 (CERN Courier, #4,1991)

Ballistic alignment was introduced for FFTB (1993)

Scope of E-166

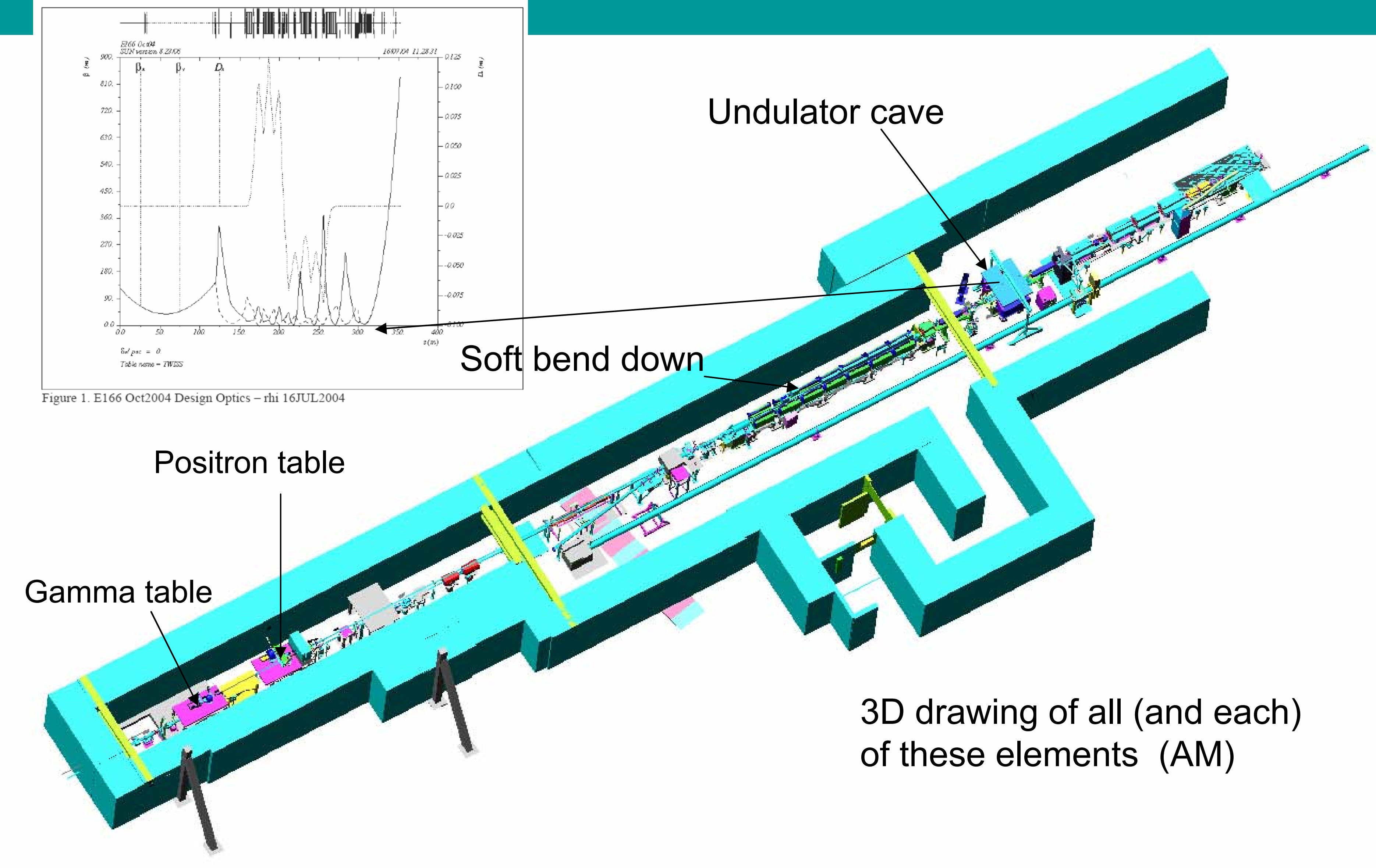


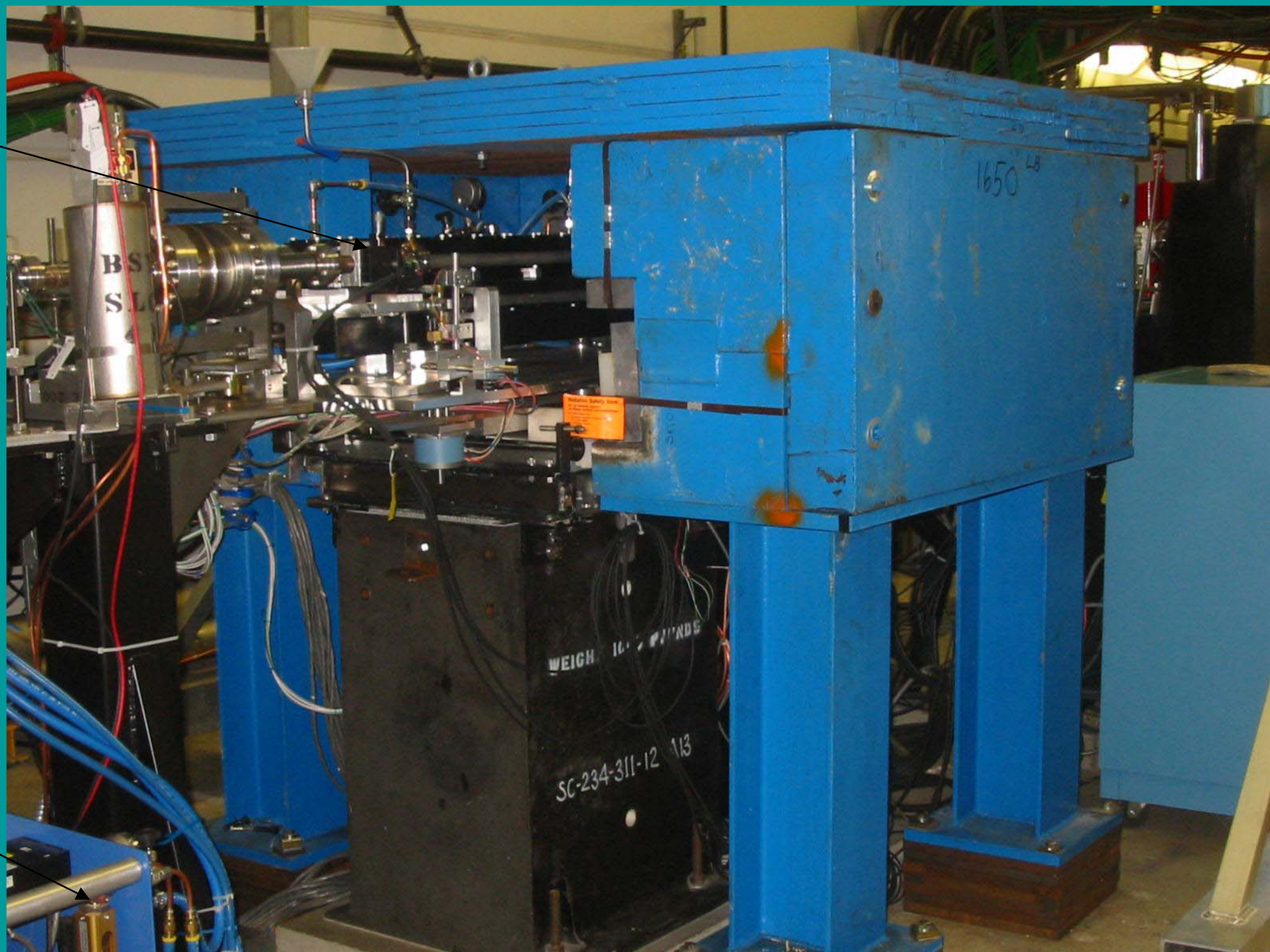
Figure 1. E166 Oct2004 Design Optics – rhi 16JUL2004

3D drawing of all (and each) of these elements (AM)

Undulator Setup (Cave)

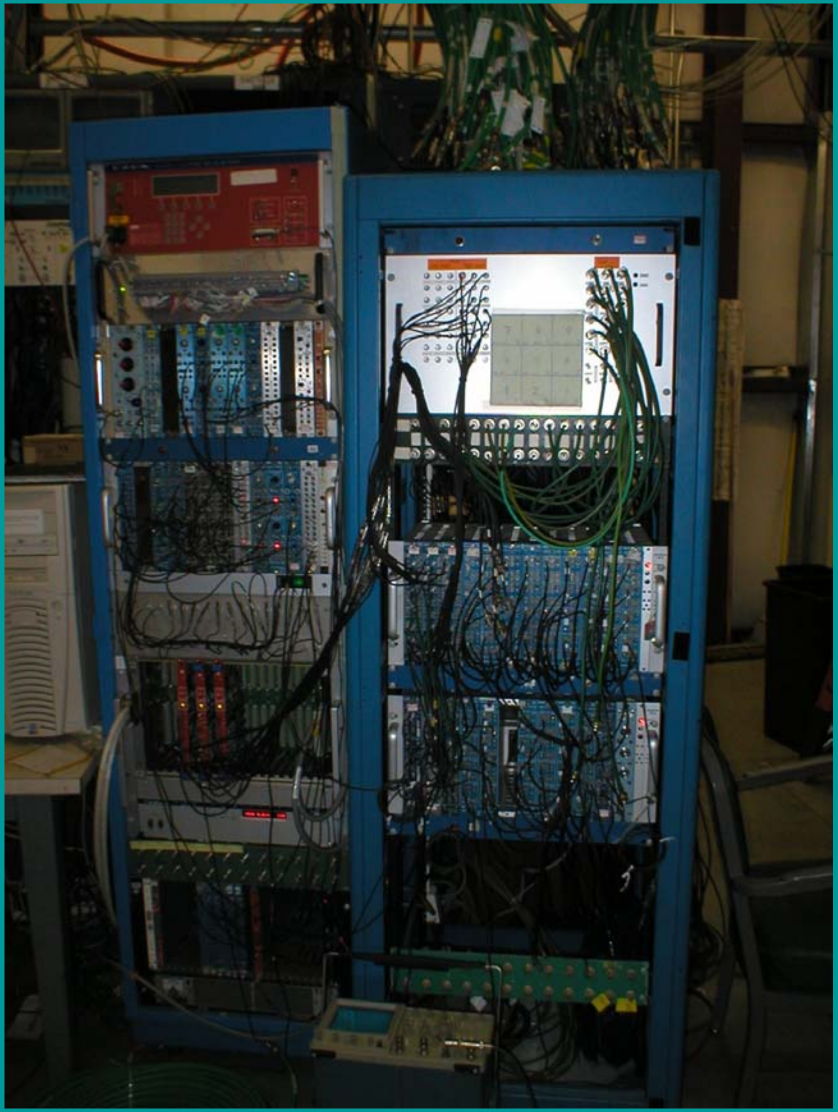
Undulator

Cooling unit



Power Supply Rack

E166 Data Acquisition Rack
Building 407

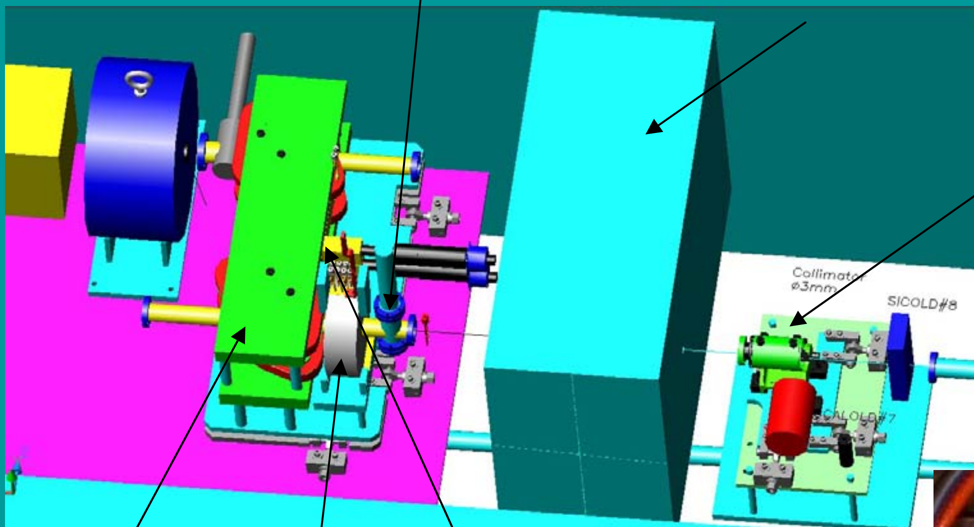


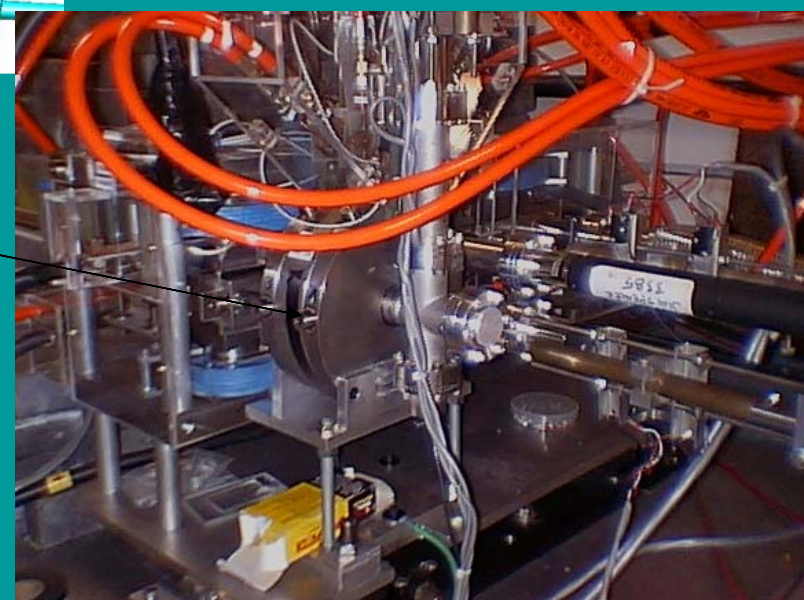
Positron Table

Target

Lead wall

Collimator, 3mm in dia





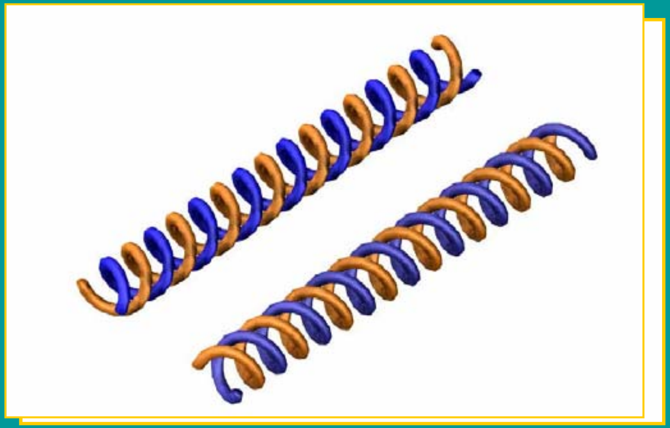
S-type spectrometer

Solenoidal lens; 45 A/mm^2

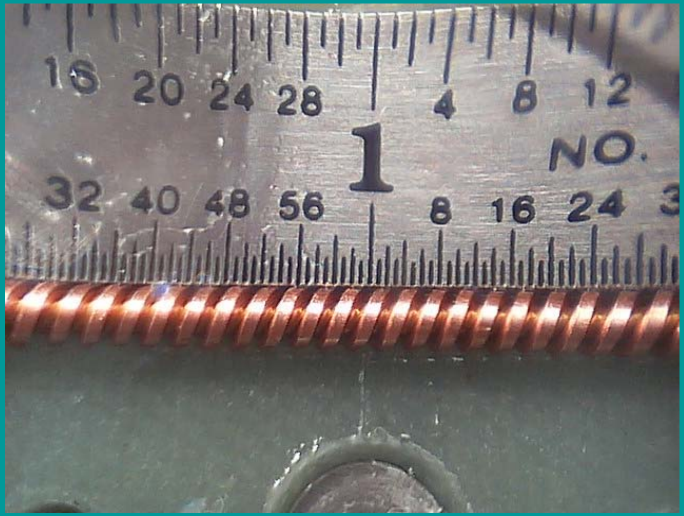
Jaws located at high dispersion region

HELICAL UNDULATOR

Cornell



- Helical magnetic field
- Wound left hand
- Inner diameter 0.88 mm
- Magnetic field: 0.76 T
- Pulsed current: **2300** A in **0.6x0.6** mm^2 wire, 12usec
- Rate 30 Hz



Stretched wire for aperture measurements uses galvanic contact

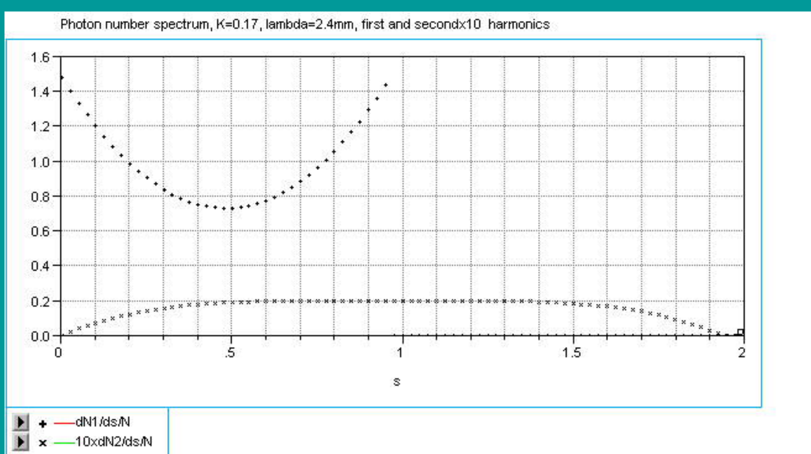
Undulator radiation

$$\frac{dN_\gamma}{dL} = \frac{30.6}{\lambda[mm]}\cdot\frac{K^2}{1+K^2}\frac{phot}{m\ e^-} = 0.37\frac{phot}{m\ e^-}; K = 0.17$$

$$E_C = 24.8[MeV]\frac{\left(E_e/50[GeV]\right)^2}{\lambda\,[mm]\left(1+K^2+\gamma^2\theta^2\right)} \sim 9.6\ MeV$$

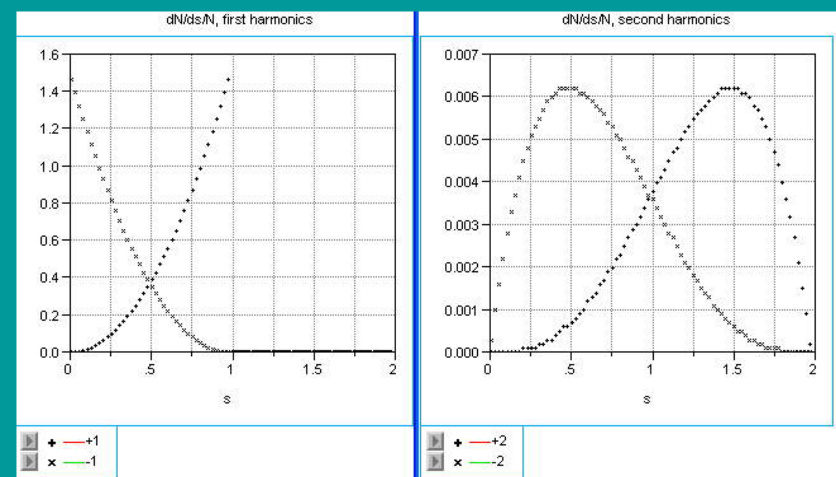
Energy spectrum

Polarization



K=0.17

=



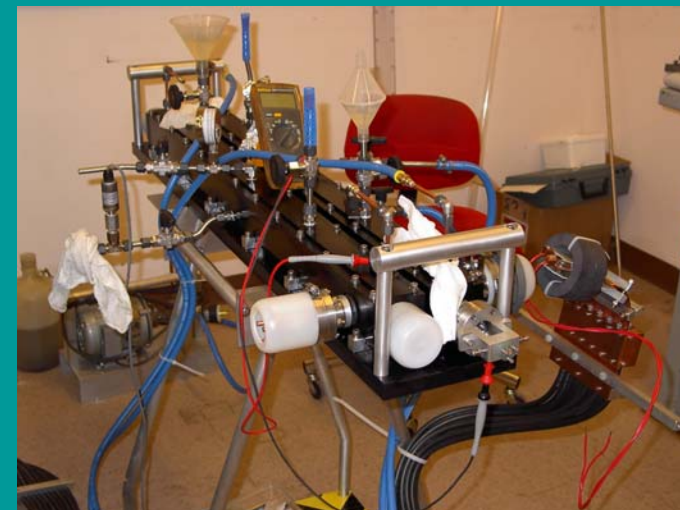
K=0.1

UR is a mixture of photons with opposed helicity in equal quantity

Helical undulator-Cornell

Unique technical solutions

Undulator installed in FFTB



Undulator

Pulser

Coolant unit

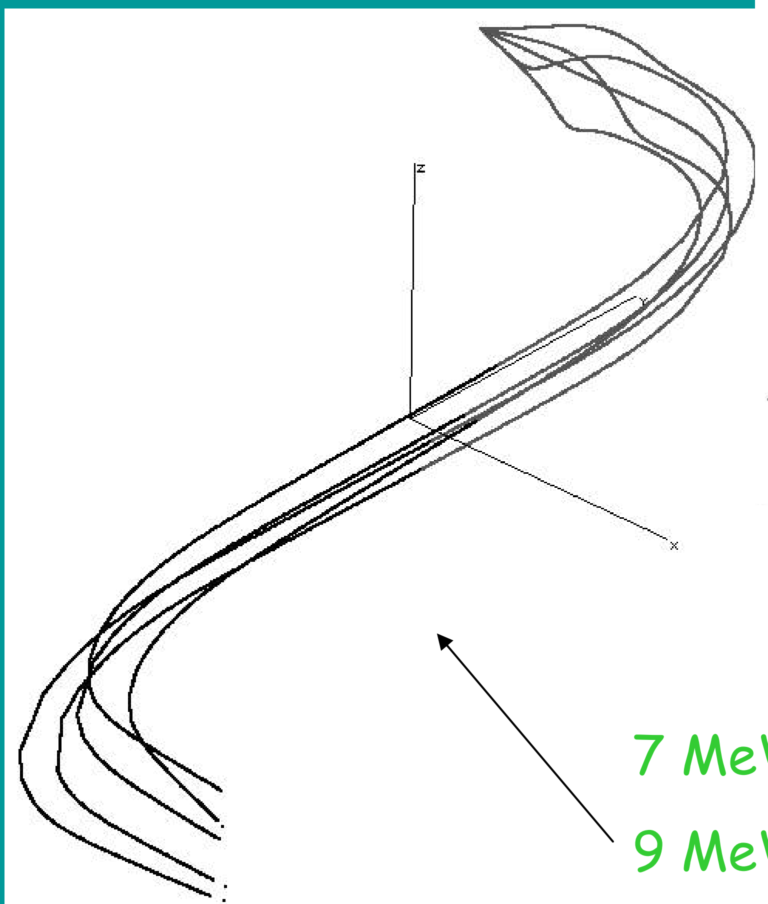
SPECTROMETER

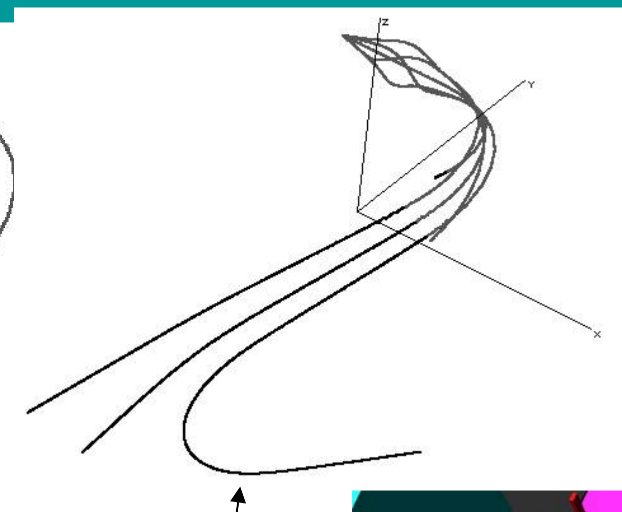
Princeton, SLAC, Cornell

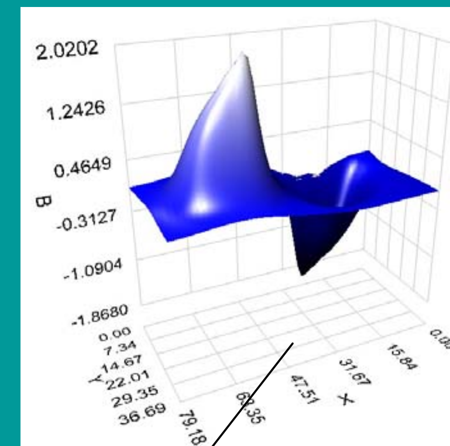
Developed spectrometer of new type

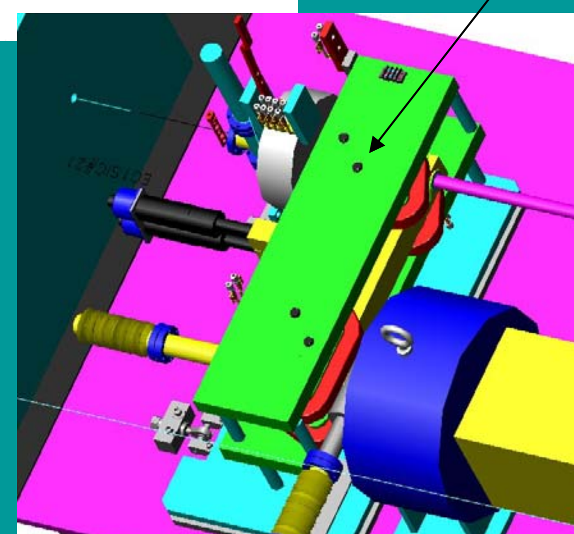
Trajectories calculated in 3D field

3D fields/ MERMAID







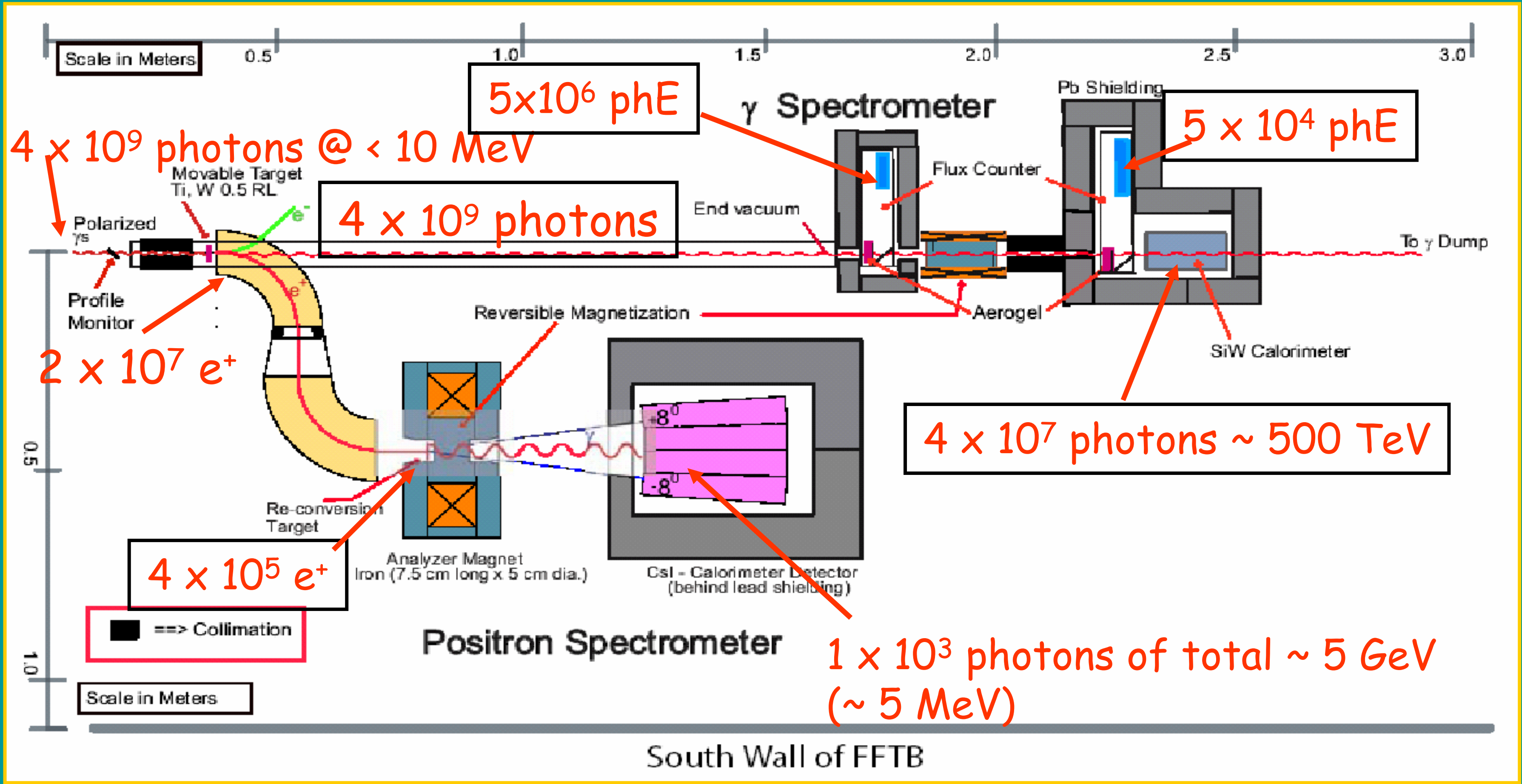


7 MeV positrons

9 MeV positrons

Beam Flow

~10^{10} electrons/bunch @ ~50GeV into the undulator



Transmission Polarimetry

- Compton scattering depends on polarization
- Attenuation: $T(L) = e^{-nL(\sigma_{phot} + \sigma_{pair} + \sigma_{comp0})} e^{\pm nLP_\gamma P_e \sigma_{pol}}$
- Asymmetry: $\delta(L) = \frac{T^+ - T^-}{T^+ + T^-} \approx nLP_e P_\gamma \sigma_{Pol}$

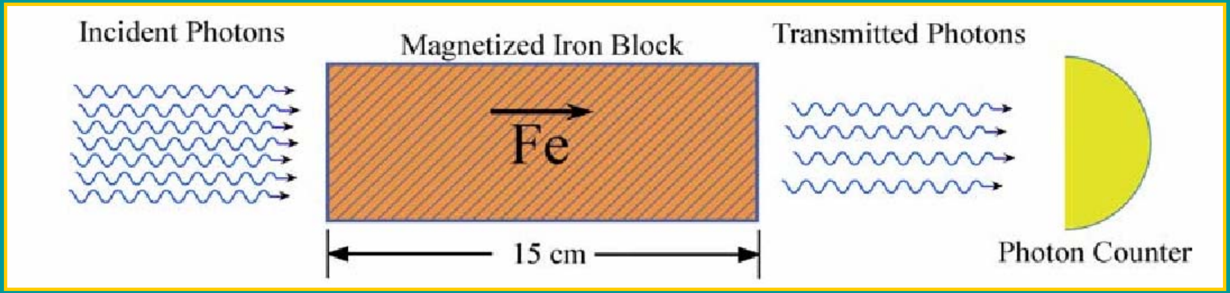
Cross-section depends on polarization

- By knowing P_e => P_γ can be calculated:

$$P_\gamma = \frac{\delta}{nL\sigma_{pol}P_e} = \frac{\delta}{A_\gamma P_e}$$

A-analyzing power

$$\delta = 0.0266$$
$$P_e = 0.07$$
$$\langle A_\gamma^E \rangle = 0.62$$



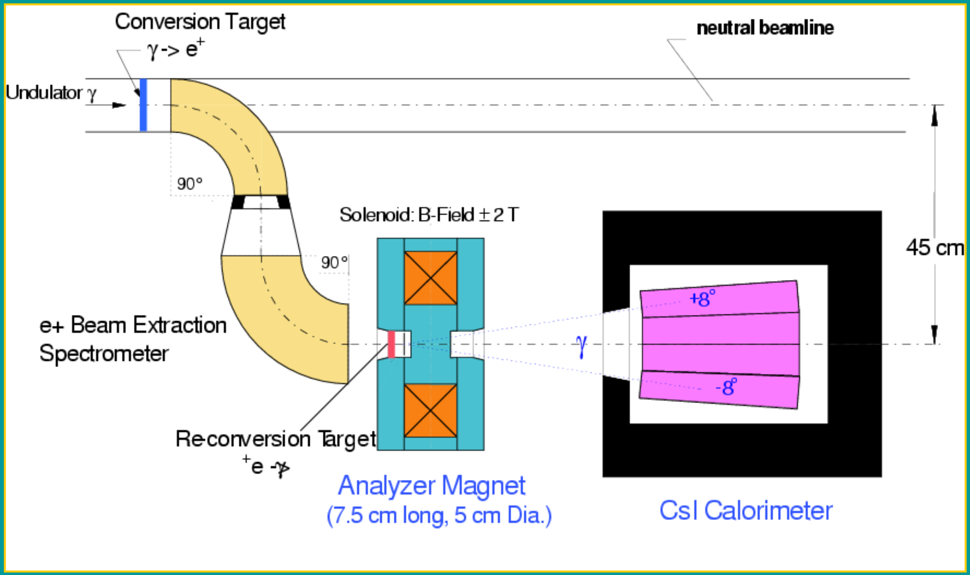
Polarimetry of positrons

Longitudinal polarized positrons are **re-converted** to circular polarized bremsstrahlung photons in reconversion target (W with 0.5 rad. lengths)

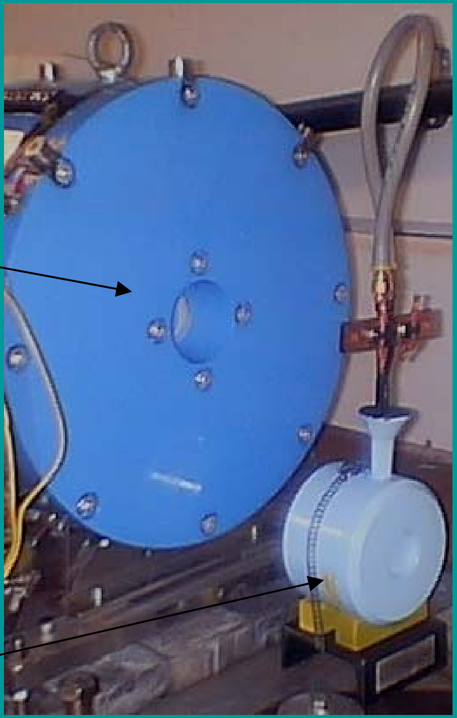
Polarization of photons measured by transmission polarimetry

Effective analyzing power A_{e+} determined by simulation

$$P_{e^+} = \frac{\delta}{P_{e^-} A_{e^+}}$$



Analyzing Magnets



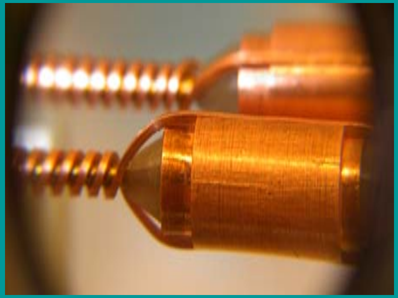
Optimized design done at Cornell

Same size of magnetized Iron core

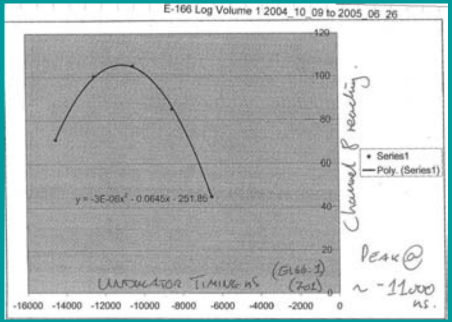
OPERATION

Every 10th undulator pulse is shifted in time. Later -every next pulse is shifted
Photon flux and polarization as a function of K.
Positron flux and polarization vs. energy.
Positron flux and polarization for 0.25 r.l. and 0.5 r.l. Ti and for 0.5 r.l. W targets.
Each measurement takes about 20 minutes

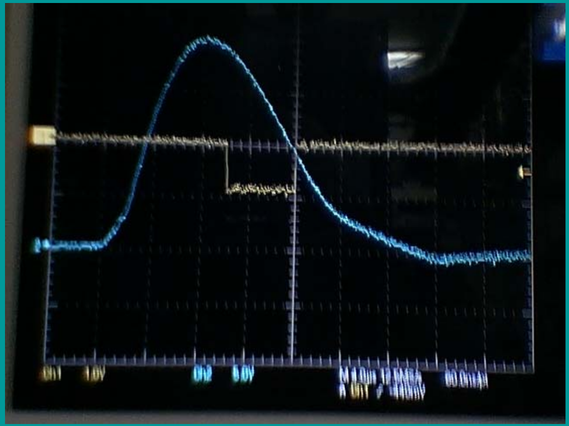
Undulator kicks e^- beam ~23μrad



Simplified end jumper



Gamma-flux as a function of timing around maximum



Shunt signal, 2300A

Typical signal

“No beam” level of signal

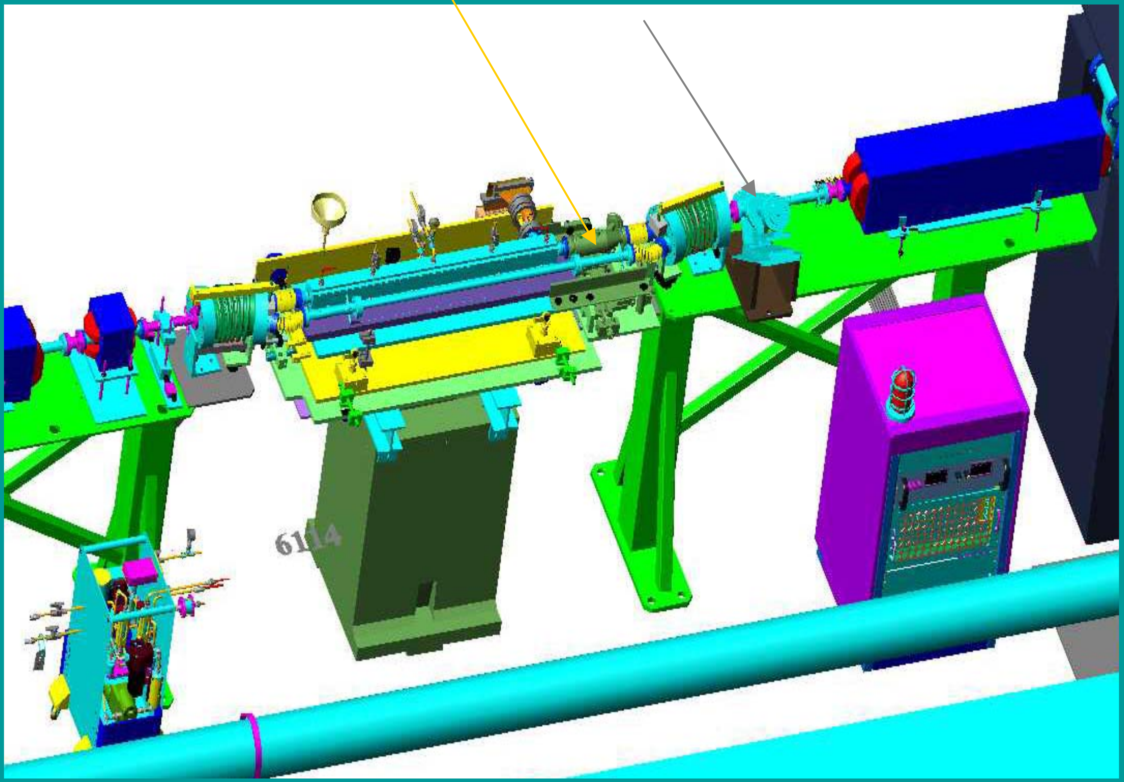
Transport through undulator

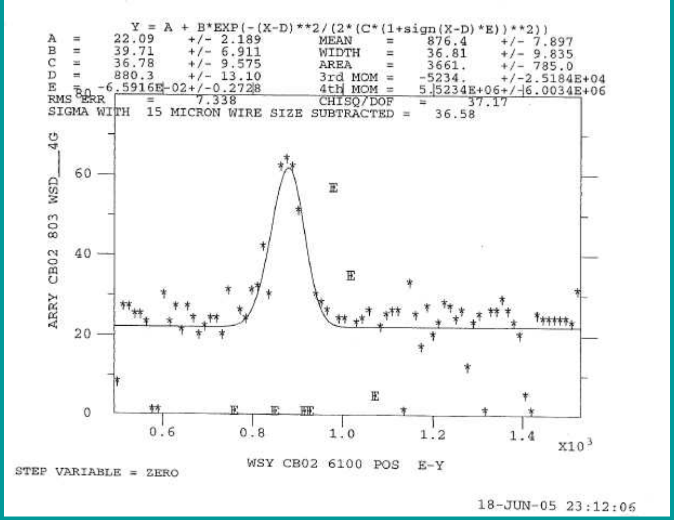
First, the beam transported through the undulator
>1m with collimator in front having ~30mils in dia

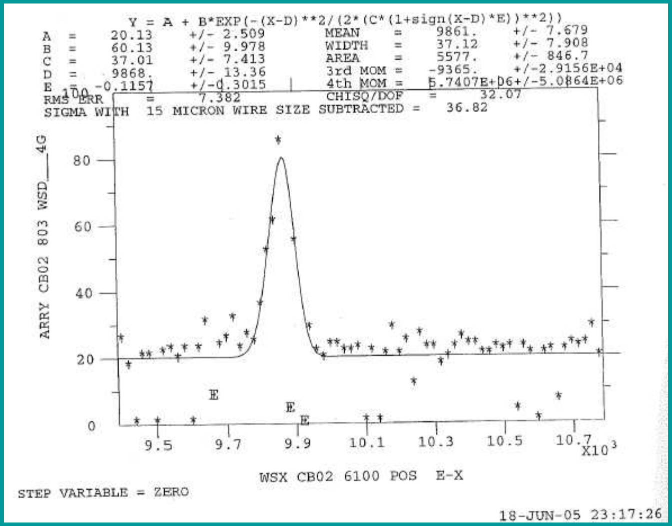
Table motion, steering magnets, …

σ_x =36.8μm, σ_y=36.58μm

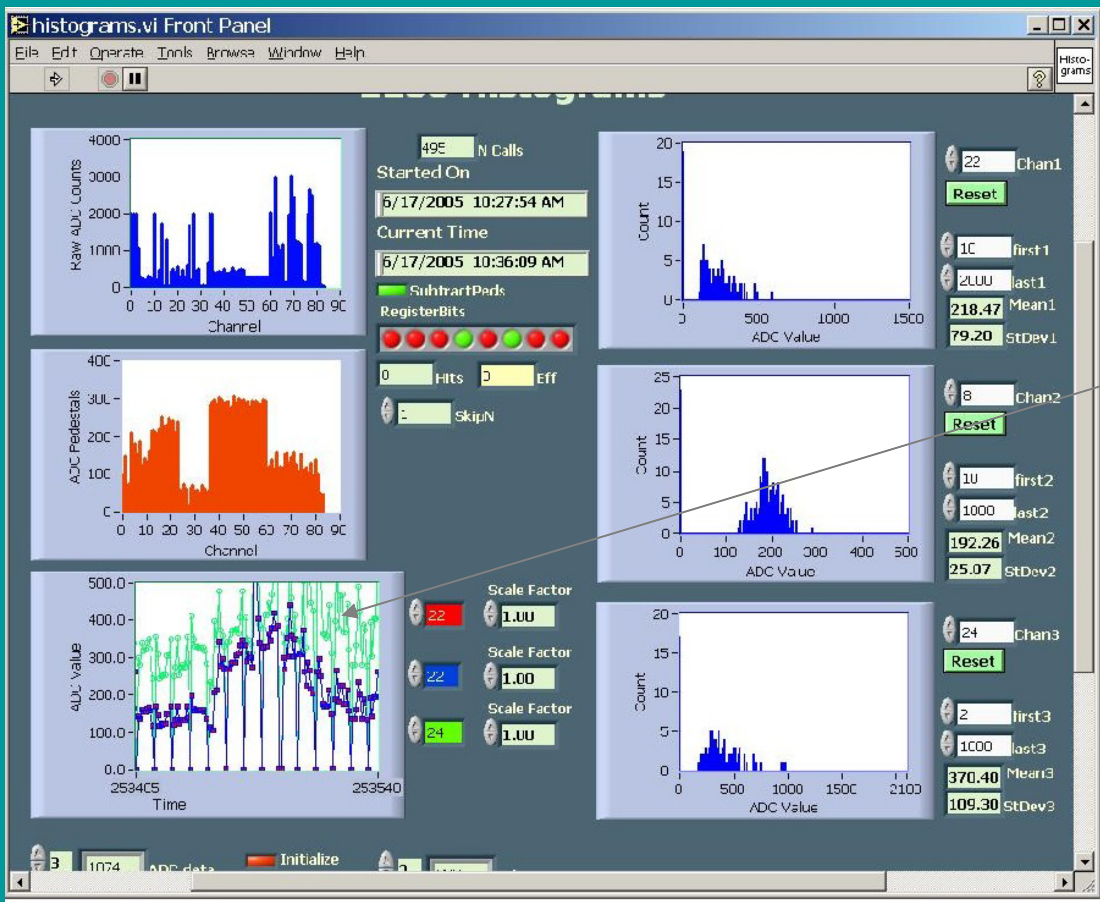
Measurements with 15μm wire scanner







Very first gammas



Control panel under permanent improvement

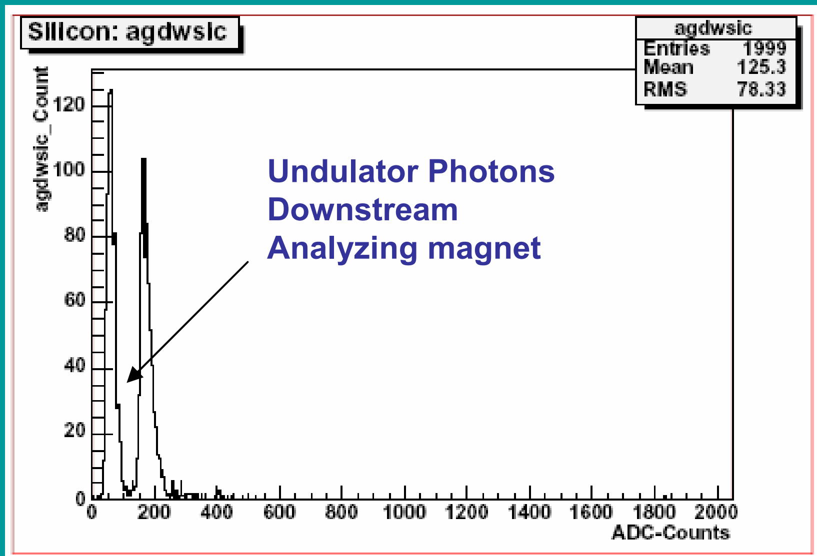
The very first photons seen after undulator was turned on for the first time June 17

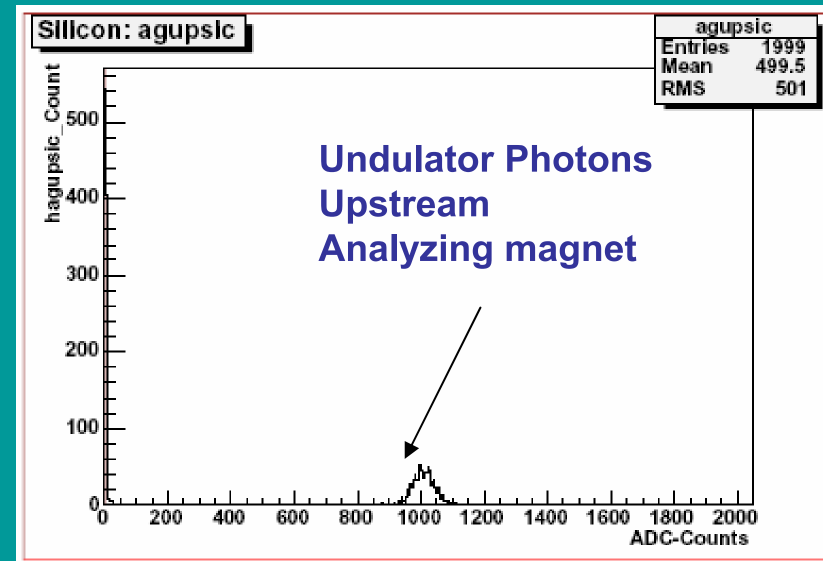
Signals from all 120 channels are written for each run

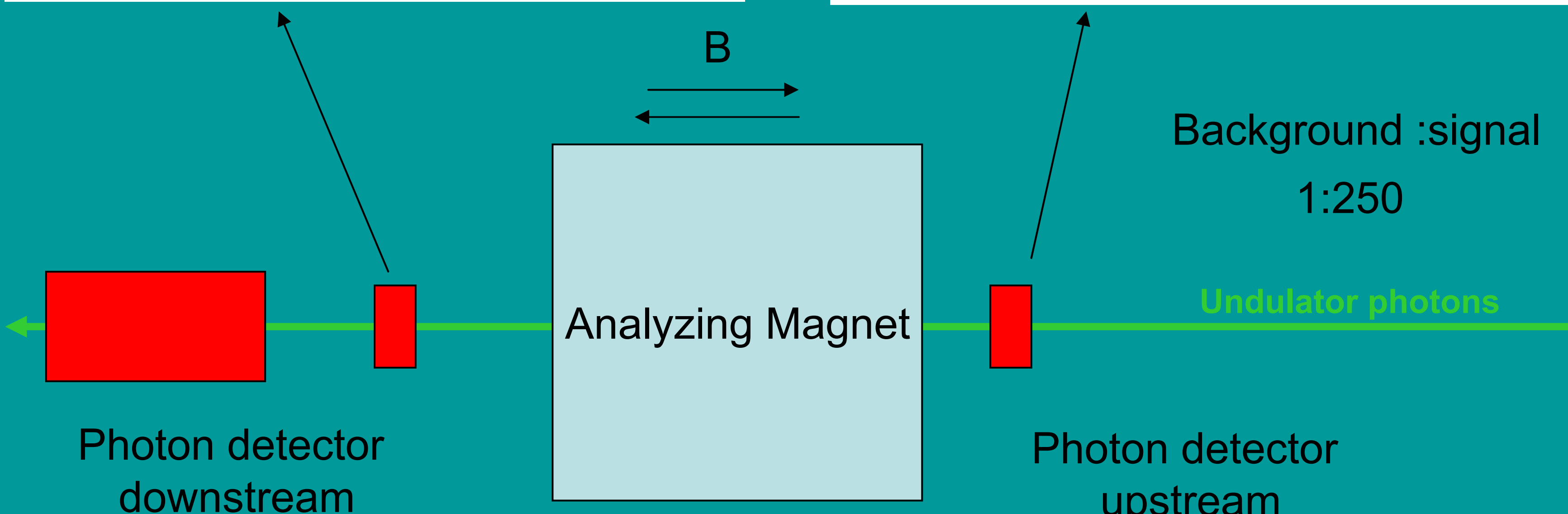
Beam parameters are written also

Amount of gammas agrees with K=0.17

Undulator photons





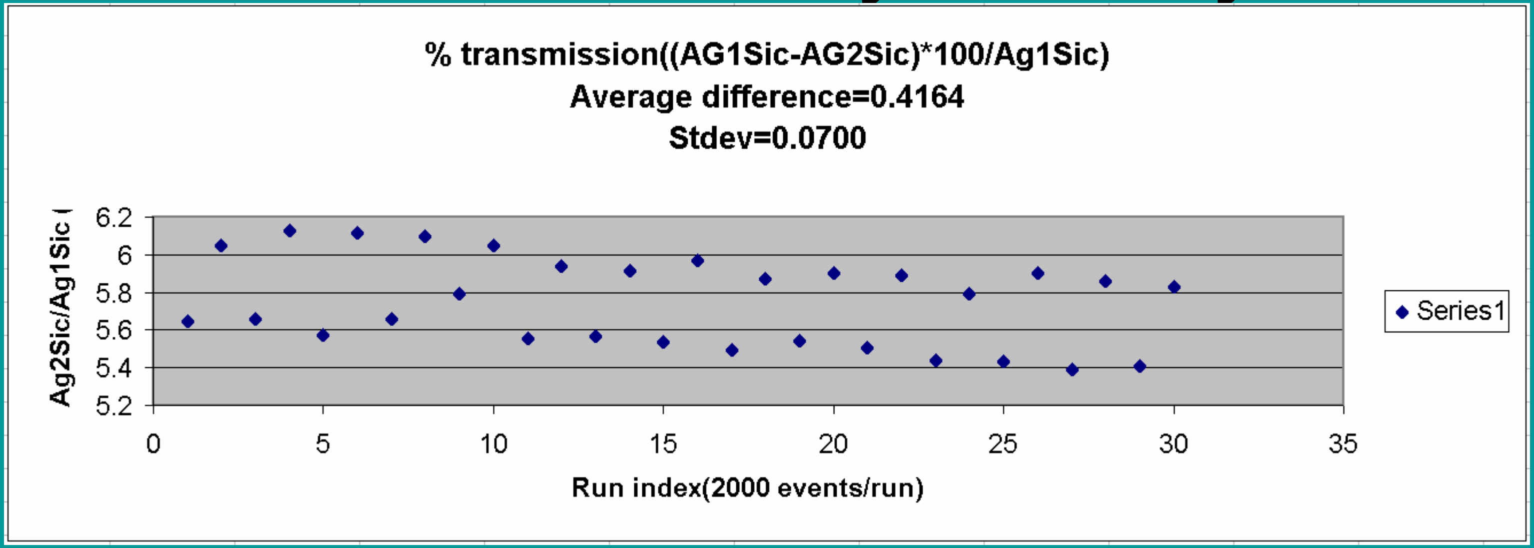


Background :signal

1:250

Used Aerogel and Si detectors

Photon asymmetry



Asymmetry=$(T^- - T^+)/(T^- + T+)$

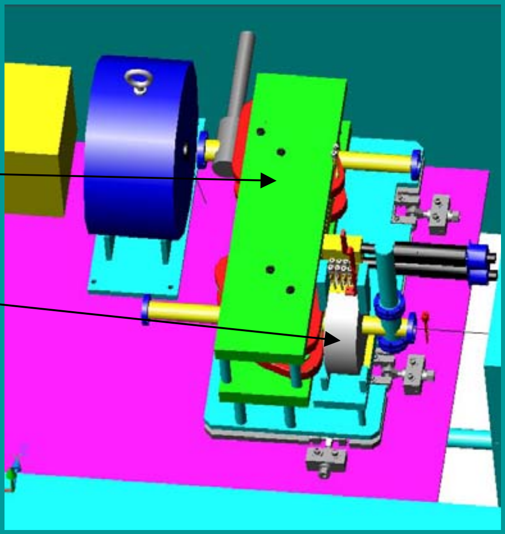
Runs	1150-1160	1220-1248
Ag1sic, Ag2sic	3.57±0.029%	3.7±0.07%
Gcal	3.77±0.15 %	3.28±0.13%
Ag1,Ag2	4.31±0.47 %	2.66±0.3 %

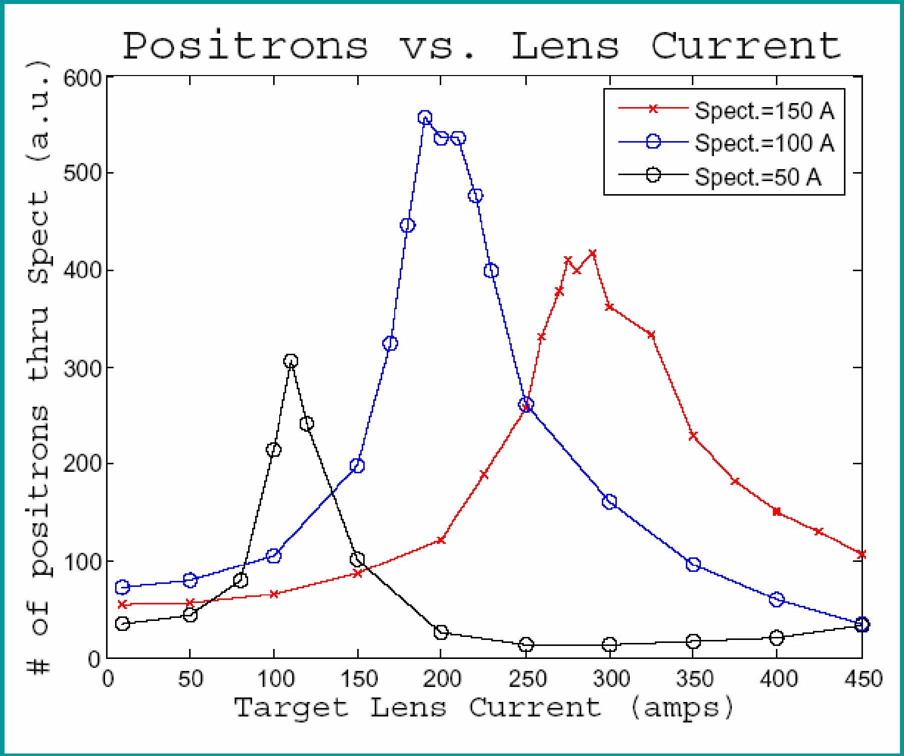
Gamma-polarization found to be ξ_2 =90.3 %±10% (preliminary)

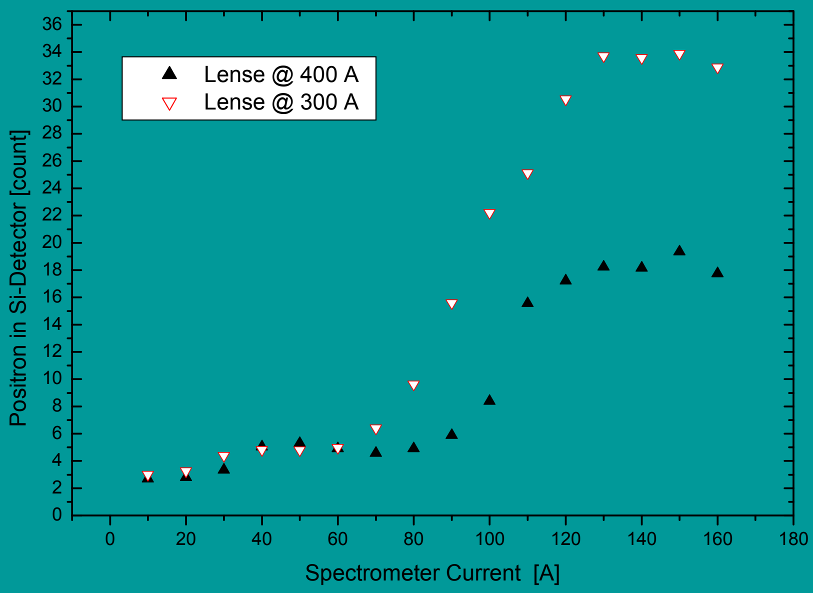
POSITRONS IN SPECTROMETER

For fixed current in magnet

Scanned current in lens







CsI Calorimeter Array

DESY Zeuthen and Humboldt University Berlin

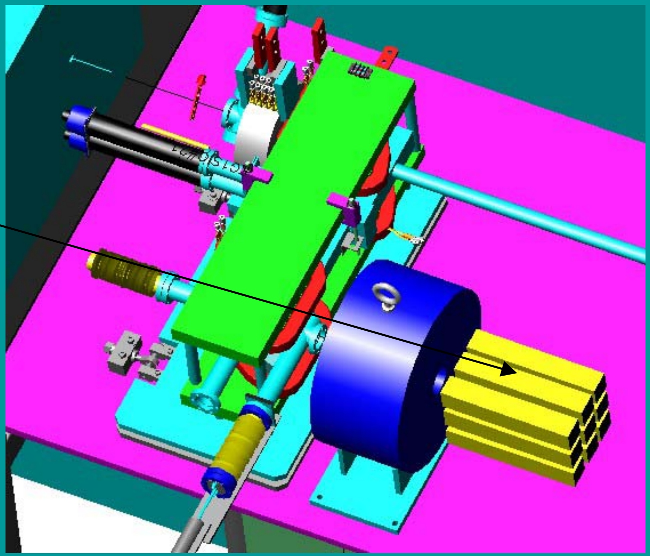
Pack 3 x 3 crystals in a stack

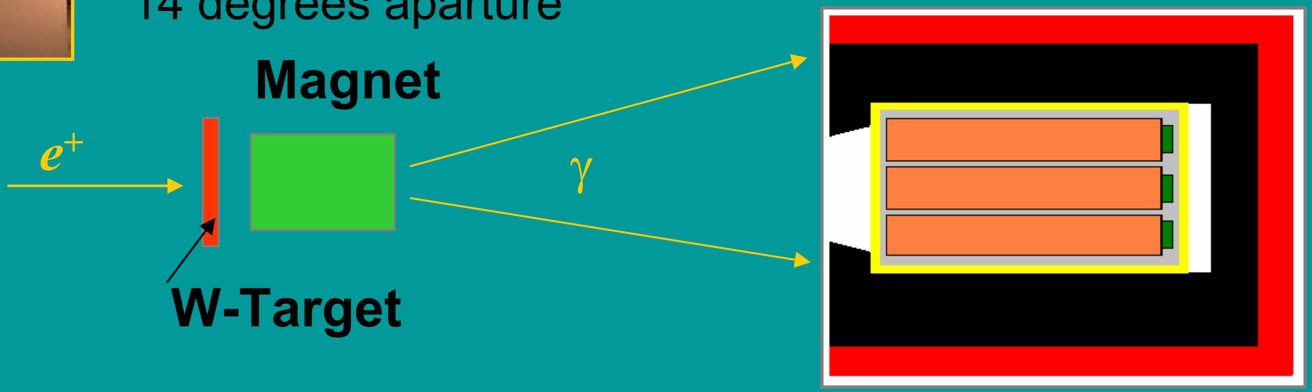
CsI crystals: ~ 6 cm X 6 cm X 28 cm from DESY

~1000 Re-converted photons -> Max 5 GeV

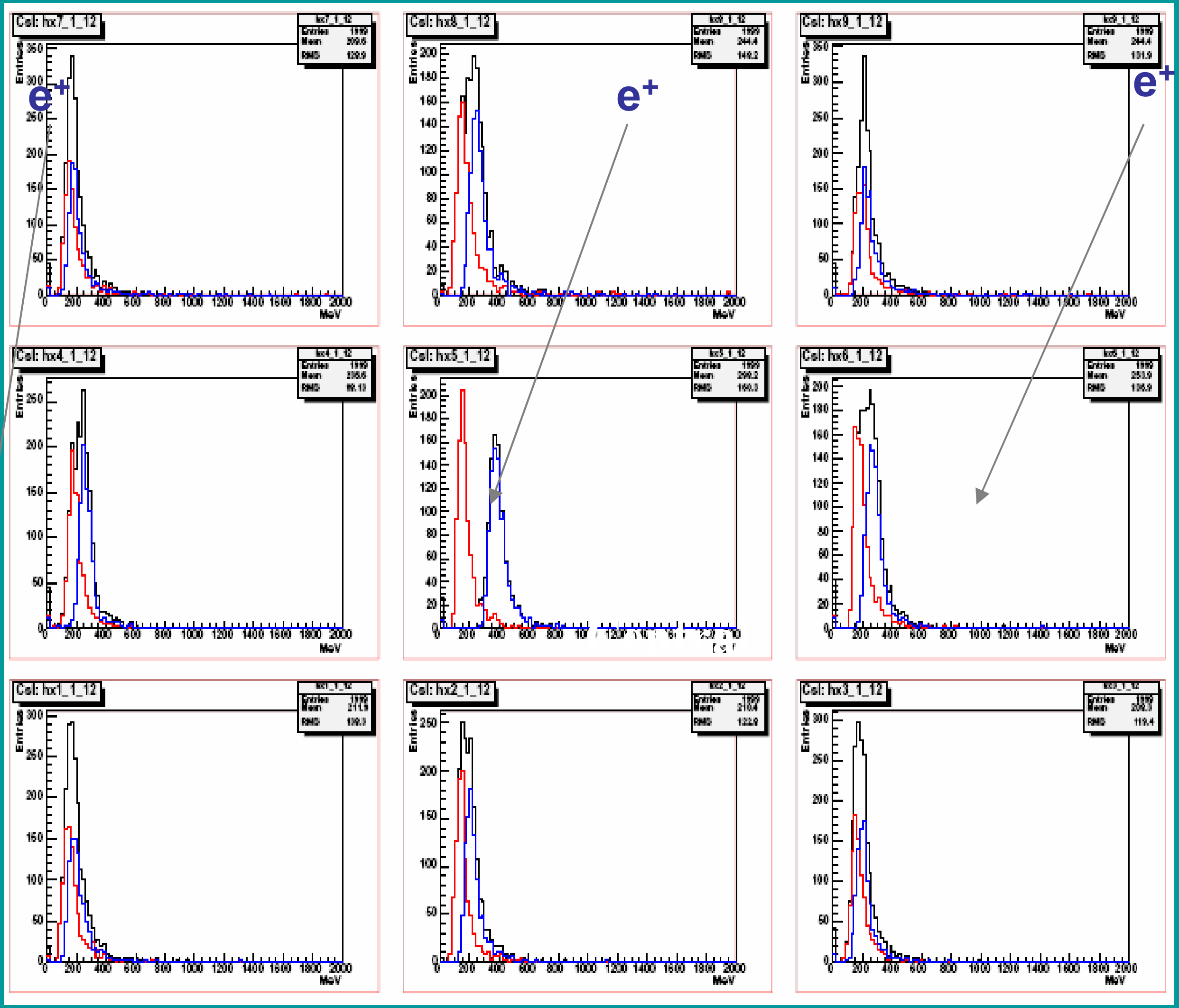
Readout by PIN diodes (large linear dynamic range)

14 degrees aparture





Positrons Signal in CsI(Tl) Calorimeter **3x3** Array



Polarization (preliminary)

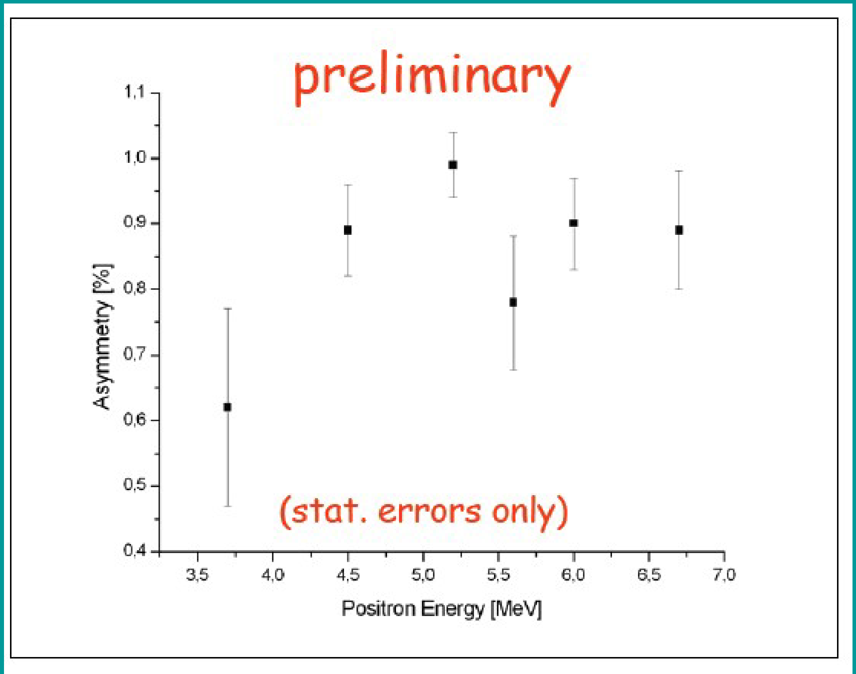
Positron asymmetry measured with maximal transmission through spectrometer

- For analyzing power A~17%
- Asymmetry measured $\delta \sim 1\%$

P_e =7%

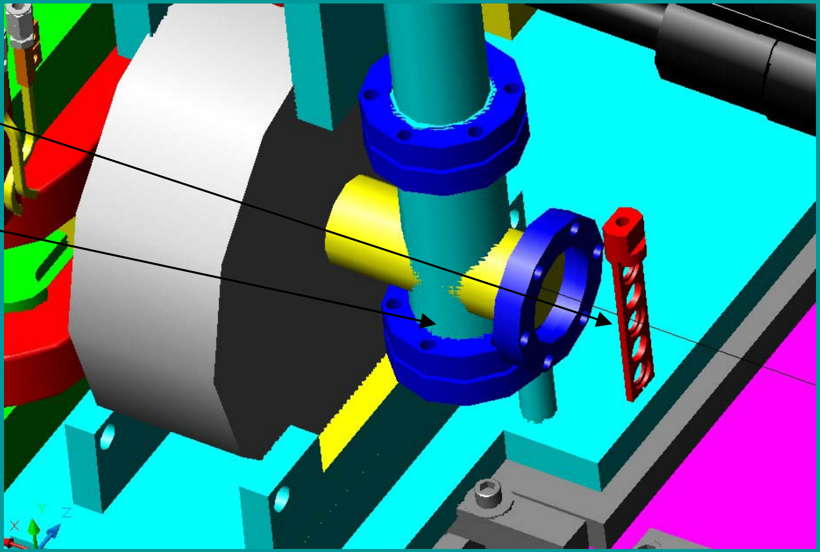
$\zeta \sim$ 100/(17*7)~0.85=85%$\pm$ 10%

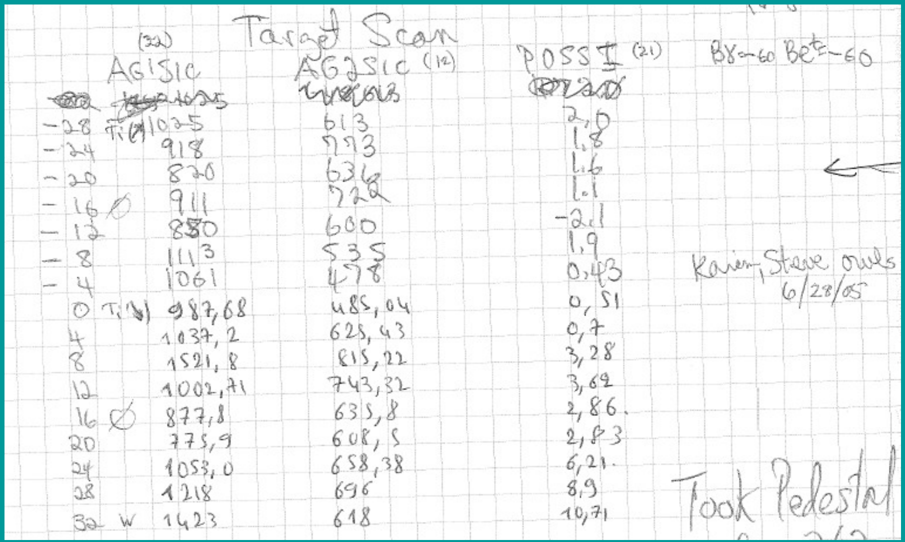
- Simulated -84%



Target Scan

- Target holder has 5 slots
- Located inside the chamber and can be moved remotely





Target Scan

Bγ~60 Be±~60

	(32) AG1SIC	AG2SIC (12)	POSS I (21)
−28	Ti(✗) 1025	613	2,0
−24	918	773	1,8
−20	820	636	1.6
−16 ∅	911	722	1.1
−12	850	600	−2,1
−8	1113	535	1,9
−4	1061	478	0,43
0 Ti(✗)	987,68	485,04	0,51
4	1037,2	625,43	0,7
8	1521,8	815,22	3,28
12	1002,71	743,32	3,62
16 ∅	877,8	635,8	2,86
20	775,9	608,5	2,83
24	1053,0	658,38	6,21
28	1218	696	8,9
32 W	1423	618	10,71

Karien, Steve owls
6/28/05

Took Pedestal

W target gives ~45% higher yield, than Ti of the same thickness, $\sim 0.4X_0$

Strong argument against Ti target

E-166 Results

- First polarized positrons created from gammas generated in helical undulator
- Amount of gammas and positrons agrees with calculation
- Asymmetries measured for photon flux and for positrons well above background
- All components or prototypes work properly
- September-October run 2005 finalized polarization measurements*)
- Very productive ILC collaboration working in practice!
- E-166 paved the road for ILC positron production system

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*) Accomplished successfully

CONCLUSIONS

There is a broad area for ILC activities initiated

4-m long Undulator module fabrication and its test is a priority job taking into account pressure from EuroTeV

Practically for all elements we have original design, much more effective and compact, than others

E-166 experiment emerged as a great success of Scientific Community

Confirmed undulator based gamma-production for generation of polarized positrons and electrons

UNDULATOR SCHEME ACCEPTED AS A BASE LINE FOR ILC