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FEW COMMENTS ON POSITRON CONVERSION SYSTEM

Requested to be concentrated on low K and multi-target case

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One introductory remark…

• Undulator does not require any focusing lenses between sections, at all length the beam is weakly focused only by helical magnetic field of undulator. So the ratio of length with helical field to the total length of undulator ~0.99

Beta-function in undulator chosen to be of the order of the undulator length (Code KONN takes this into account)

In undulator the particle's trajectory is a helix

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	$\sqrt{\langle x^2\rangle} \cong \sqrt{\gamma\varepsilon_x\beta/\gamma}$	$2.6\cdot 10^{-3}\,cm$

Radius of helixes is 0.005 µm- much smaller, than the beam size ~2.5 µm

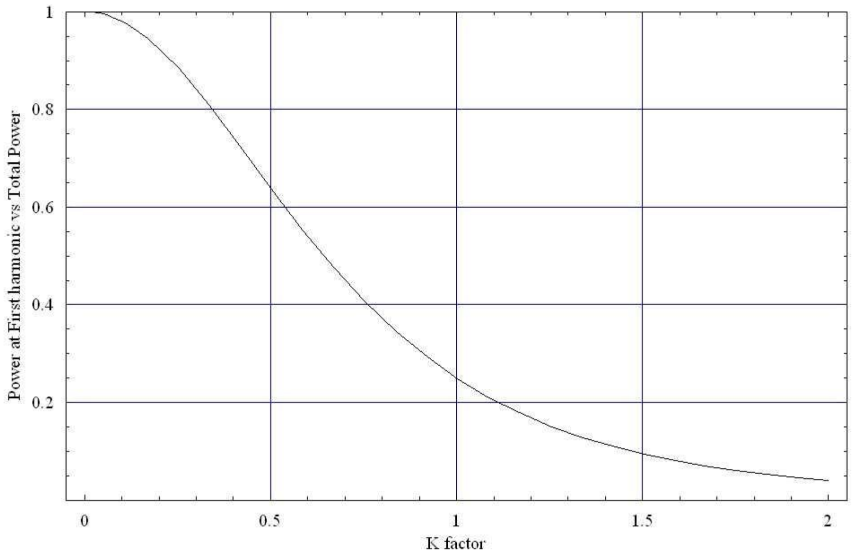
LOW K-FACTOR

- Now the idea, that K-factor ($K = eH\lambda_u / 2\pi mc^2$) should be small. attracting attention at last (Bulyak, Shulga).
- With reduced K-factor the aperture of undulator could be increased up to 8 mm.
- Daresbury sections could be made longer.
- At Cornell, the undulator sections with the length of 3-m was developed; these sections arranged by pairs, so the undulator unit is ~6m-long.
- Vacuumed system runs through all undulator length, however, pretty much as in SC linacs. Aperture of Cornell undulator is 8 mm in diameter. Sections arranged by pairs for cancellation of first and second integrals of magnetic fields by relative twist of section one with respect to the other ~90^o. That is a peculiarity of helical undulator. Small dipole correctors of ~2 cm-long installed between sections.

Undulator yoke under test at Cornell

• The energy of gammas is below 20 MeV at first harmonics, this means that the absorber (dump) could be designed so it takes into consideration the fact, that gamma-neutron production has a threshold (for Al~13 MeV, C~19 MeV), so radioactivity could be made very low. Again, low K-factor is preferable.

VLEPP was optimized for K=0.3



The ratio of power radiated at the first harmonic to the total power as a function of *K* factor.

Parameters of conversion at different energy. Calculated with KONN; focusing by Lithium lens

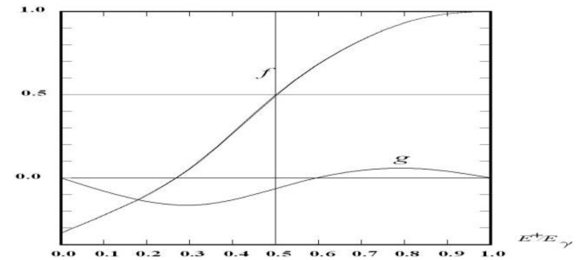
Beam energy, GeV	150	250	350	500
Length of undulator, m	180	200	200	200
K factor	0.45	0.44	0.35	0.27
Period of undulator, cm	1.0	1.0	1.0	1.0
Distance to the target, m	150	150	150	150
Radius of collimator, cm	0.049	0.03	0.02	0.02
Emittance, cm·rad	1e-9	1e-9	1e-9	1e-9
Bunch length, cm	0.05	0.05	0.05	0.05
Beta-function, m	400	400	400	400
Thickness of the target/X_0	0.57	0.6	0.65	0.65
Distance to the length, cm	0.5	0.5	0.5	0.5
Radius of the length, cm	0.7	0.7	0.7	0.7
Length of the length, cm	0.5	0.5	0.5	0.5
Gradient, MG/cm	0.065	0.065	0.08	0.1
Wavelength of RF, cm	23.06	23.06	23.06	23.06
Phase shift of crest, rad	-0.29	-0.29	-0.29	-0.29
Distance to RF str., cm	2.0	2.0	2.0	2.0
Radius of collimator†, cm	2.0	2.0	2.0	2.0
Length of RF str., cm	500	500	500	500
Gradient, MeV/cm	0.1	0.1	0.1	0.1
Longitudinal field, MG	0.045	0.045	0.045	0.045
Inner rad. of irises, cm	3.0	3.0	3.0	3.0
Acceptance, MeV·cm	5.0	5.0	5.0	5.0
Energy filter, E > -MeV	54	74	92	126
Energy filter, E< -MeV	110	222	222	250
Efficiency, e^+/e^-	1.5	1.5	1.5	1.5
Polarization, %	69	78	78	73

Collimator before target → Radius of collimator

Collimator before RF structure → Radius of collimator†

One can see than K<0.45
Could satisfy all needs…

Polarization of created positron as function of its energy E_+ :



$$\vec{V} = x_2 \cdot [f(E_+/E_g)\cdot \vec{n}_\parallel + g(E_+/E_g)\cdot \vec{n}_\perp] = \vec{V}_\parallel + \vec{V}_\perp$$

Circular polarization of initial gamma-beam is a function of collimation diameter;
For low K-factor however, when the first harmonic is dominating, the function of collimator is in *reduction* of second and other harmonics as they have zero intensity at the axis and only 50% polarization in this direction;
further selection by energy automatically selects the particles with highest energy and hence, with small angular deviation from the axis.

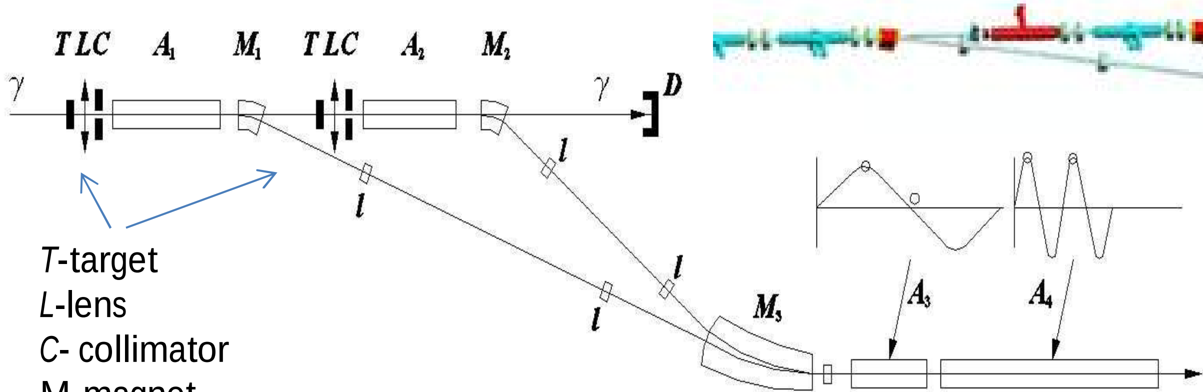
As the radiation of electron in a back- scattered radiation from a laser, can be described in a same way as the radiation from an undulator, while the energy of secondary photon is much lower than the energy of electron, so the recommendation for lowering *K* factor automatically fulfilled here due to limitation of power achievable in a laser system.

Operation with low *K*-factor in E-166 experiment (*K*~0.17) together with selection the energy of the secondary positrons by the two-magnet spectrometer delivered the polarization measured ~85-90% .

FEW TARGETS

- Mostly of 200 kW energy associated with the gamma-beam is deposited *in the gamma-beam dump*; only ~16% of this 200 kW power deposited in a target. So few targets could be installed in series, and positron collection could be carried from each target and combined further in longitudinal phase-space. The length of undulator could be reduced accordingly. (Probably , the number of targets could be up to 4)

Gammas from undulator

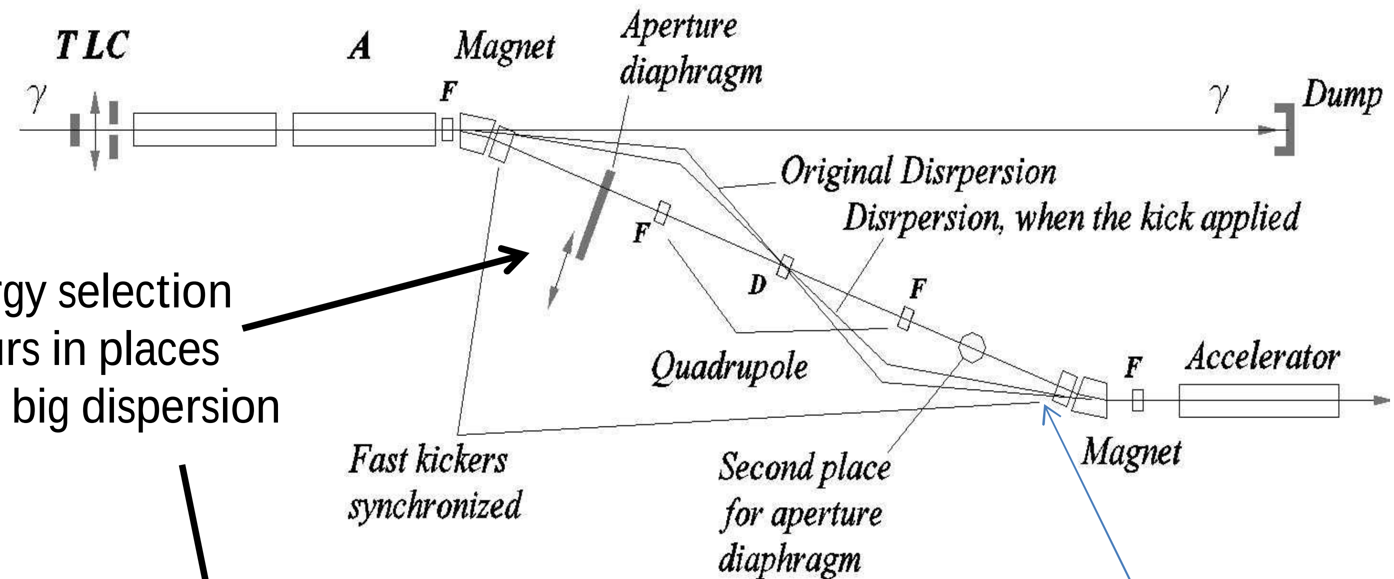


T-target
L-lens
C- collimator
M-magnet
D-gamma dump

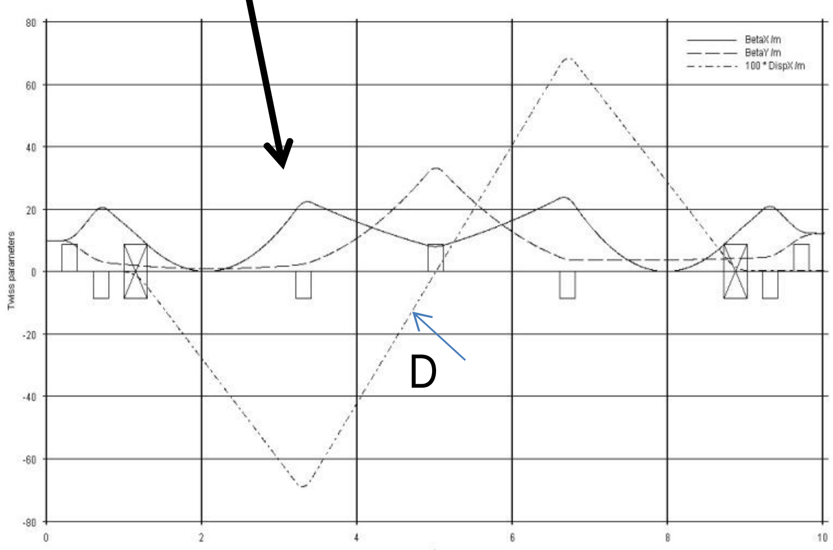
Section A_0 operates @¼ frequency of A_4

The energy provided by acceleration structures *A*1 and *A*2 are slightly different, *A*1>*A*2. Difference A_1-A_2 should be big enough to separate the beams with reasonable energy spread. In acceleration structure A3 the bunches are going in different phases. For given Eγ the energy spread is less than ½ Eγ~10 MeV, so the difference A_1-A_2 of 30 MeV is enough

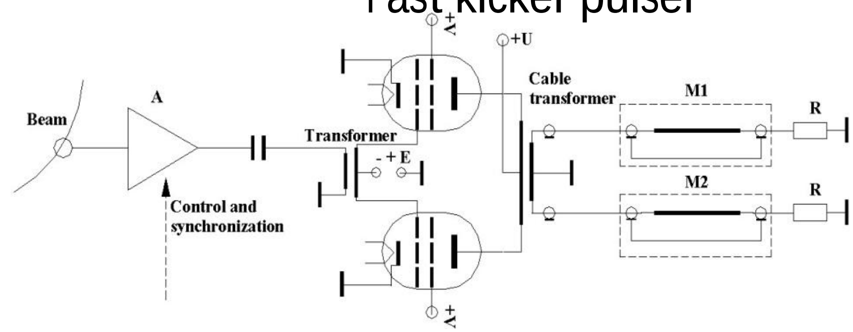
THE ENERGY SELECTION



Energy selection occurs in places with big dispersion



Fast kicker pulser

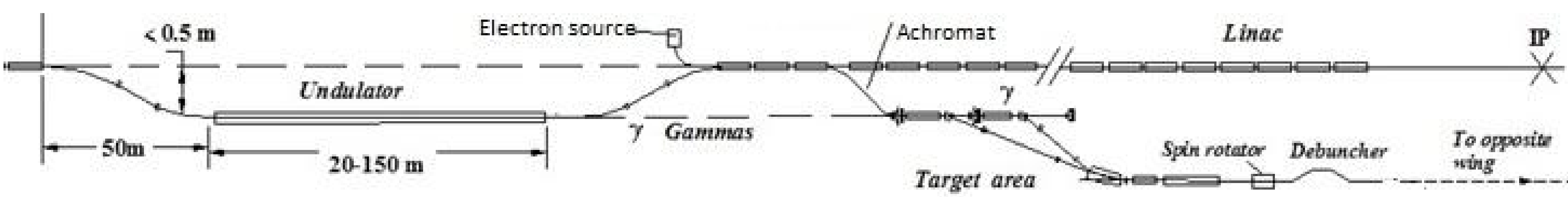


Tetrode amplifier for fast feedback. Required if positrons generated by positrons (so the undulator located in positron wing); otherwise not required

- Active length of undulator for single target required ~20-180 m for the energy 120-500GeV.
- Undulator radiation could be created by positrons as well as by electrons, so this might help in optimization of allocation of elements of beam tract; in this case undulator located in positron line.
- Do not forget to look at the bunch length, as it might be too short for damping ring (instabilities).
- Bunch compression on the basis of wiggler is extremely ineffective.

$$\Delta l \cong \frac{\rho \phi^3}{3}\frac{\Delta p}{p}$$

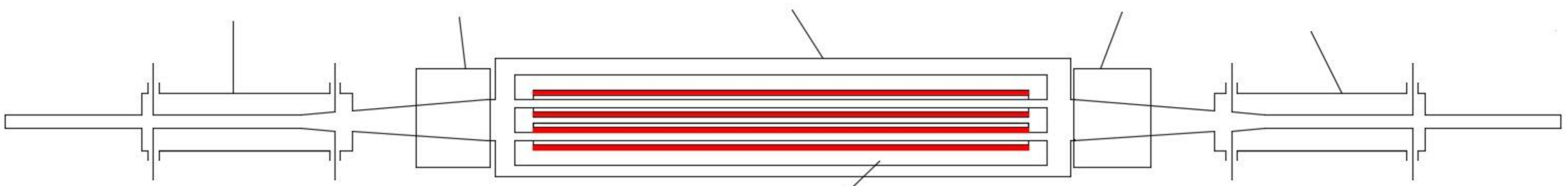
ρ is a bending radius, ϕ is a bending angle, ϕ~K/γ x (Number periods) which still much smaller, than the bend in a magnet with ϕ~1



Implementation of multi-target system in a collider pattern requires just a little extra space, but undulator could be two times shorter…

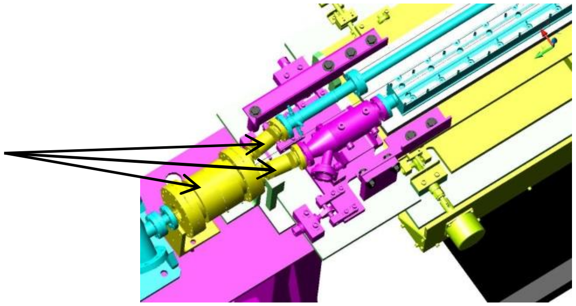
KOMMENT ON SPIN-FLIPPING SYSTEM

- For the spin flipping system with two solenoids (which is not the best idea) the offset of axes of solenoid could be as small as ~5 cm, so these solenoids can share the same cryostat having combined cold mass. System equipped with bellows, so for rhe regimes with some definite polarization, which does not require fast spin-flip, the system temporary could be shifted mechanically, pretty much the same as in E-166.



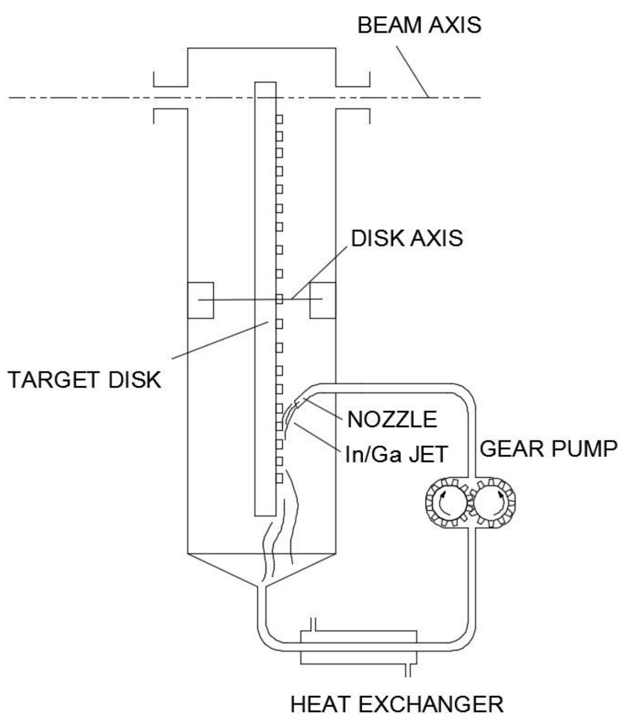
- Additional vertical focusing lenses are not shown;
- Fast kickers feed from the same pulser (in series)

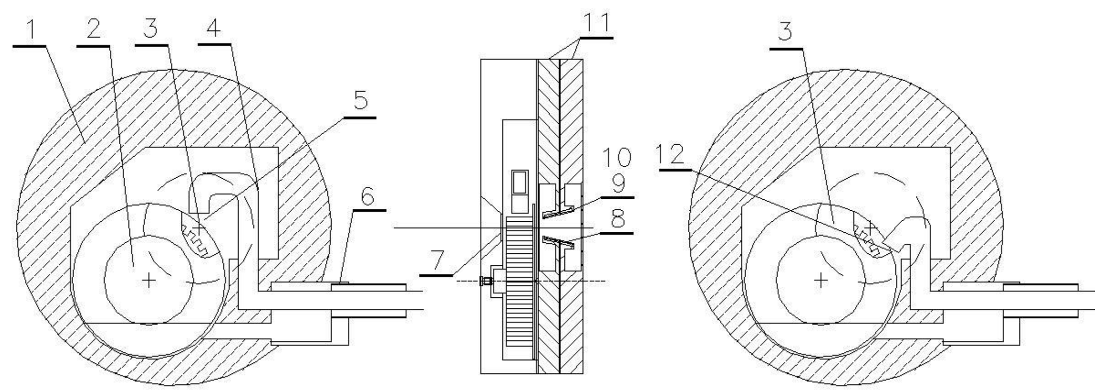
E-166



EVACUATION OF HEAT FROM SPINNING TARGET DISC BY LIQUID METAL

- The idea of contact heat evacuation (W.Gay et.al) could be moved further by suggestion to use the liquid metal jet (In/Ga aloy). This jet can spin the target wheel as a kind of turbine. Simple feedback stabilizes the rotation speed.





Liquid metal target for VLEPP. Variant 1. 1-Titanium case, 2-is the teethed wheel, 3-is the target focusing point, 4-is the nozzle, 5-is the Mercury jet, 6-is the feeding tubes, 7-is secure Titanium foil, 8-is the conically shaped lens, 9-is the volume with liquid Lithium, 10-is Beryllium made flange, 11-are the current leads made from Titanium. Variant 2. 3 is the target focusing point, 12-is the nozzle. Diameter in Lithium cone at the exit of lens is ~1 *cm*.

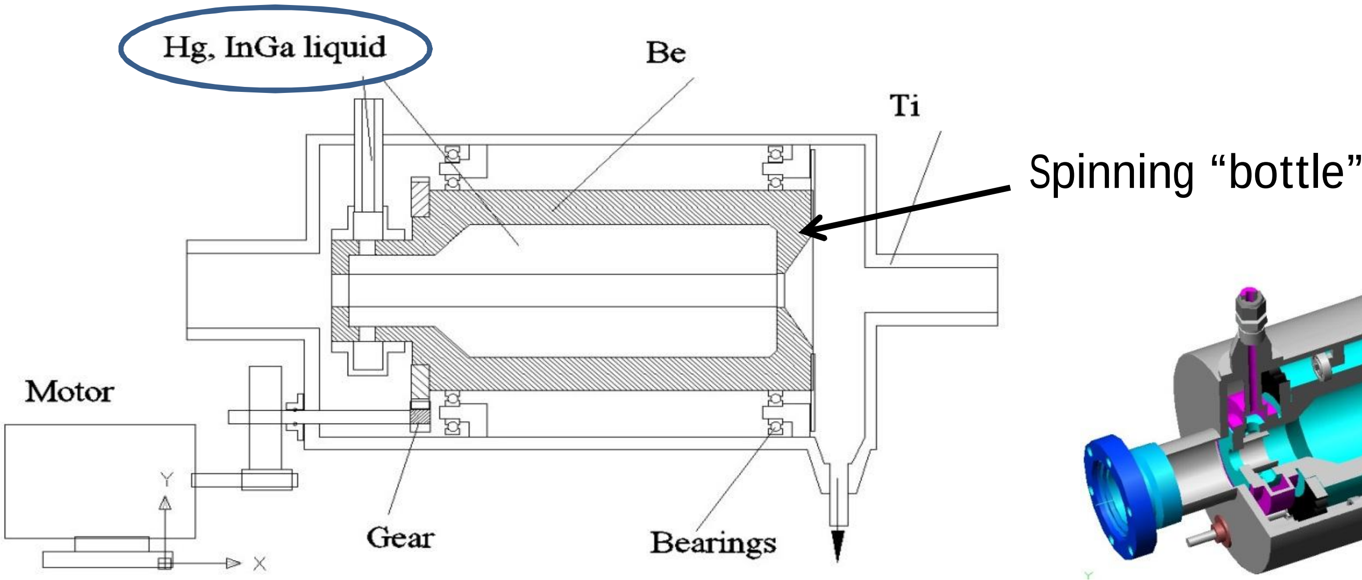
This concept solves all problems

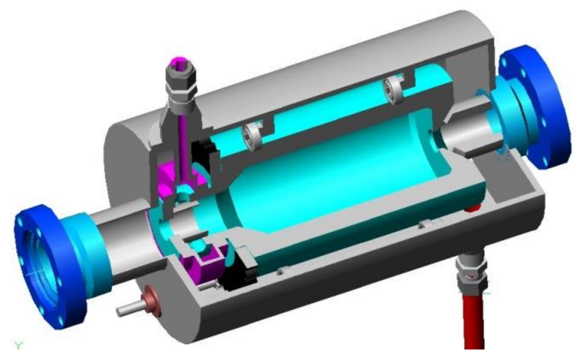
Argonne Lab has experience with liquid metals.

This idea was reserved for use in VLEPP (1986);
1 variant the liquid jet just spinning the target disk and evacuating heat, second variant –jet itself serves as target and spins thinprotecting disk

FULL POWER COLLIMATOR

- Collimator at the entrance of undulator and along the beam path in few critical places of ILC. This collimator should be able to accept full energy of beam train.





As the main problem with collimator is destruction of its walls hit by train or by single bunch, the inner surface of collimator should be an open surface of liquid metal. So this liquid metal surface could be formed as result of *centrifugal force*.

ONE COMMENT ON THE HYBRID CONVERSION

First target generates photon(s). Electrons are separated by magnet. Photons illuminating the second (thin) target, where the positron-electron pairs created.

For thickness of first target ~X_0 each electron generates ~ 1 photon in all spectra. Meanwhile in undulator each electron generates ~100 photons.

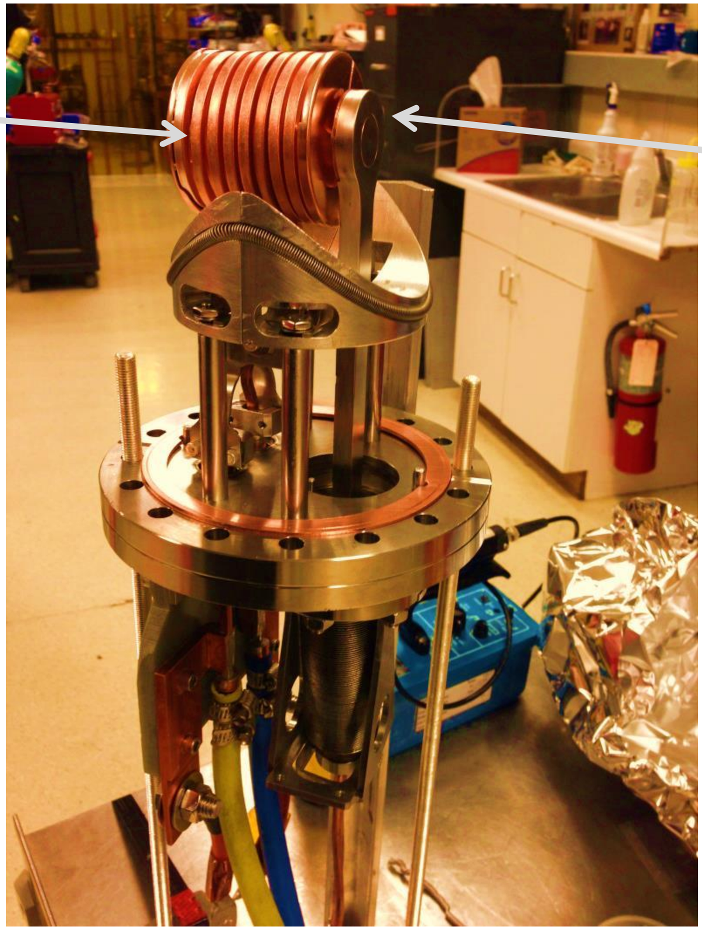
So, to be compatible, the system with hybrid target should compensate this factor 100. Usage of channeling effects gives hope to compensate maximum 5 (looks optimistic, however), so residual 20 should be compensated by repetition rate.
So 300 Hz looks more or less realistic.

THE END

Return comments are appreciated

Extremely effective positron conversion system at Cornell

Focusing bi-layer coil with partial flux concentrator



W target mounted on the pendulum for the possibility to be moved out of the beam pass.

Absence of transverse kick ß

arXiv:1505.01406

Delivers >100 mA/min e+ in CESR (after acceleration in a buster synchrotron, ejection, injection in CESR); operates at 50 Hz;water cooled;
average radius of CESR ~70 m;