Compact sources of intense polarized positron beams.

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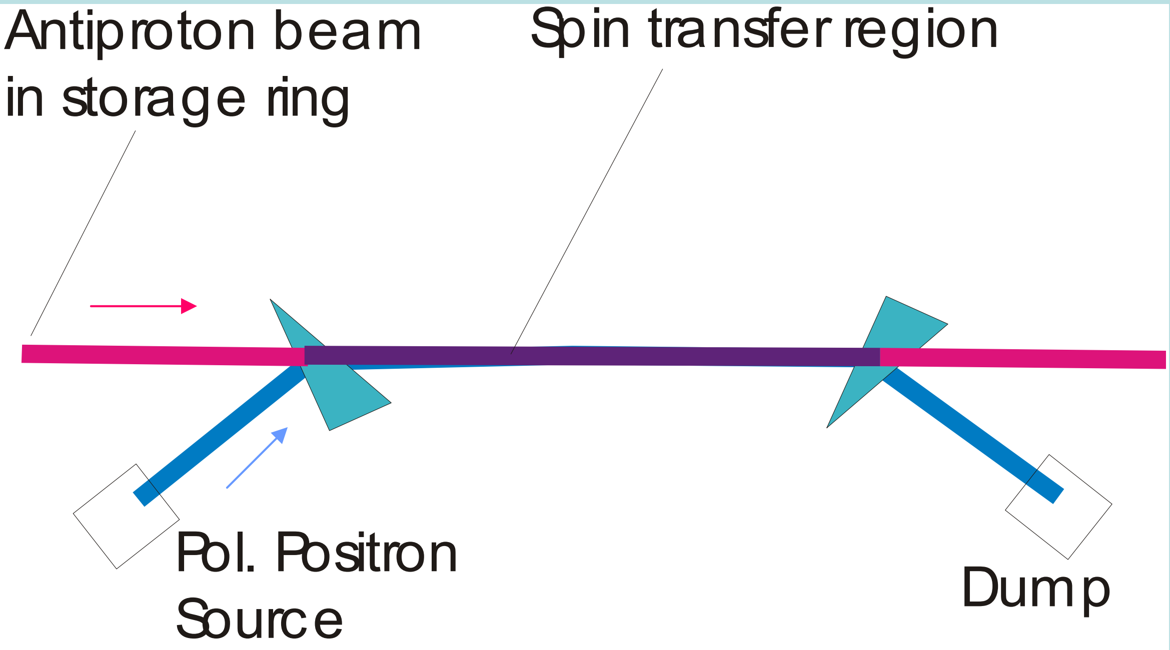
Kurt Aulenbacher

Institut für Kernphysik
der Uni Mainz

Outline

- Goal: Best brightness at 0.1-1MeV
- d.c.-sources with brightness enhancement
- e^+-storage ring at 0.1-1MeV
- Pulsed pol. e^+ sources for storage ring injection.

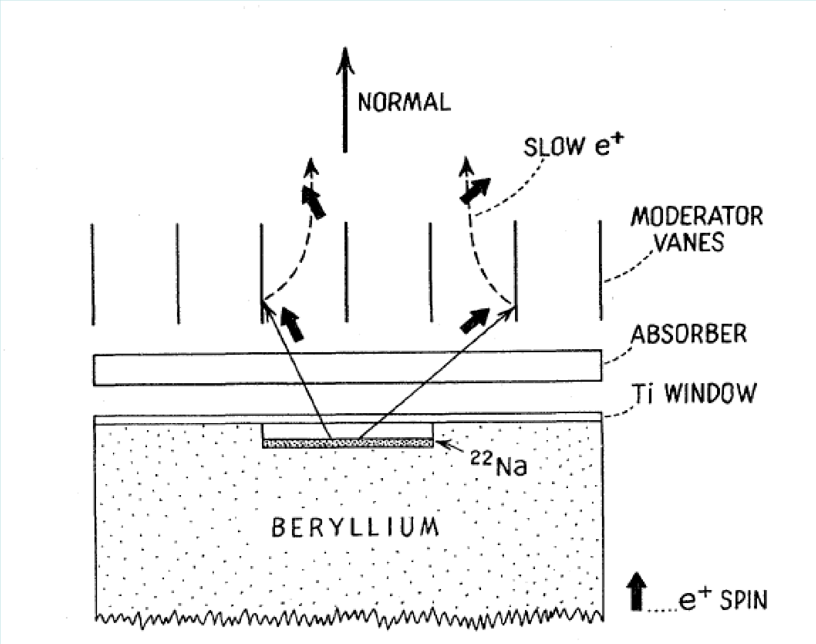
d.c-source



Spin transfer in 'cooler arrangement':
relative velocity: 0.0016c
positron flux density (lab) > $10^{9} mm^{-2} s^{-1}$

Relative energy spread $< 10^{-4}$ (0.1keV @1MeV)

Principle of d.c. source



J. van House et al.
Phys. Rev. A 29,1 96 (1984)
$5*10^5$/s at P=0.48 from Na-22.
Efficiency: $2.5*10^{-4}$

- Absorber necessary in order to shift high intensity part of β-Spektrum to ~10keV.

- Absorber also suppresses positrons which large emission angles!

- ~10keV Electrons are stopped close to moderator surface and escape because of negative positron work function.

- Liouville theorem does not apply to moderation process! → Brightness enhancement !!

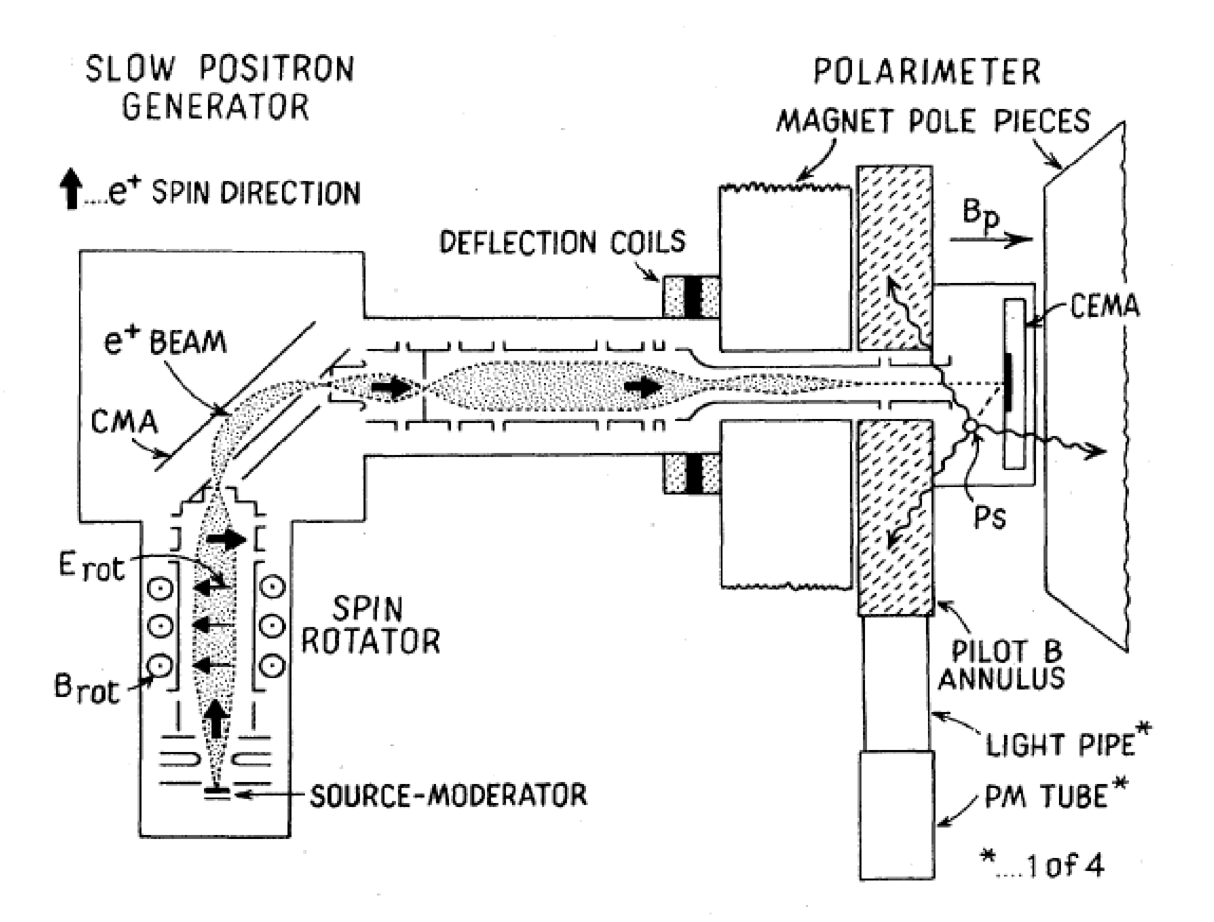
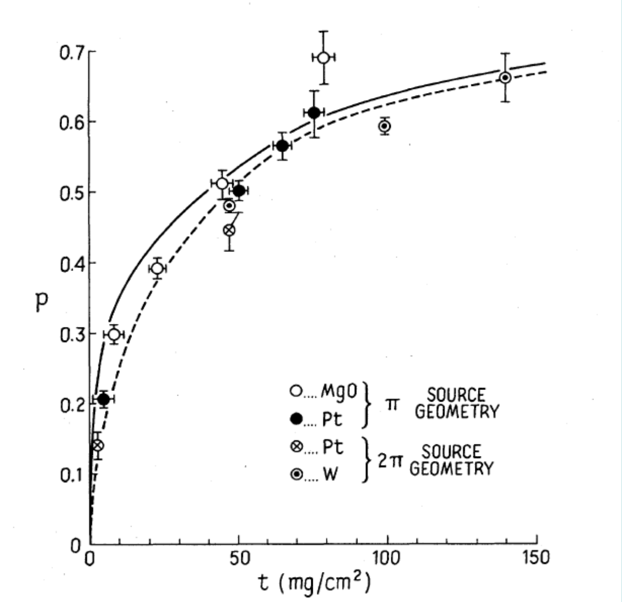


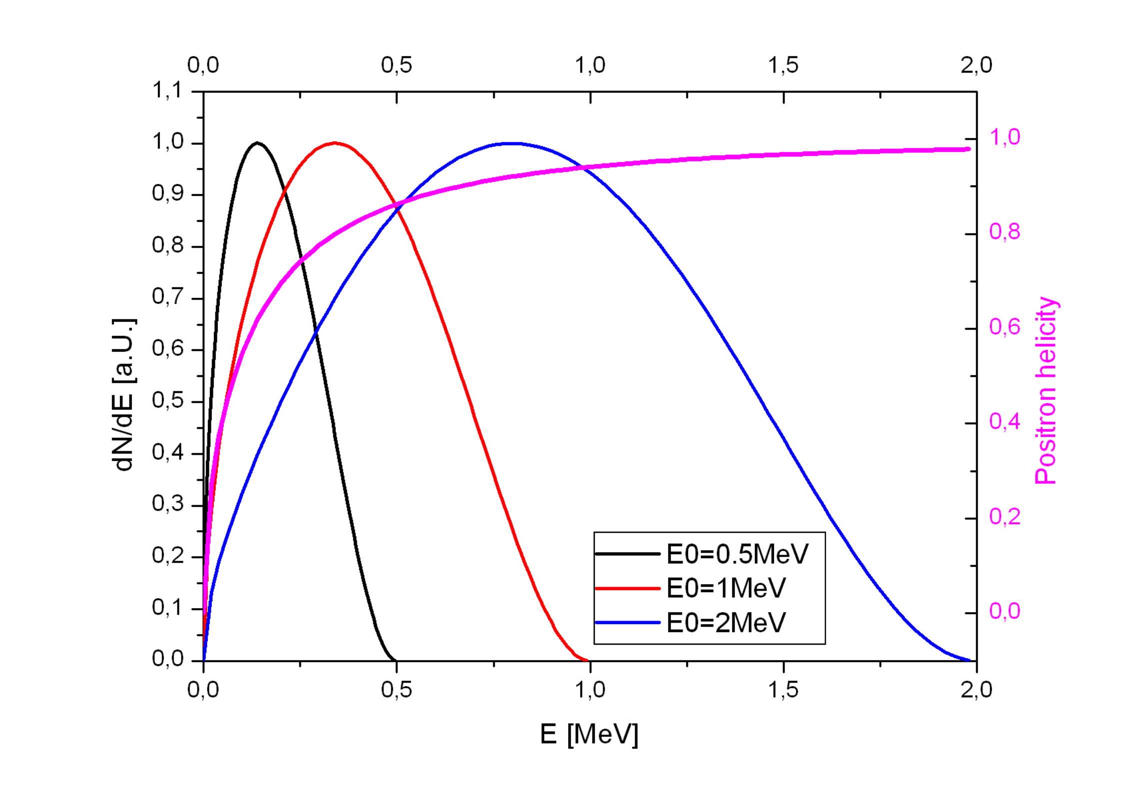
Figure from van House et al. (1984)
Beam energy: 500eV

Once established, an e+ source operates like an e- source…..

P^2I-optimization

also from van House et al.





‚Optimum‘ positron source: Carbon-11 (E0=1MeV). Higher Polarization, far higher activity

03/10/2006

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Intensity Limit of d.c. source?

Isotope	E_{max} [MeV]	$T_{1/2}$	A_{max} [Bq/mg]	REM
22-Na	0.5	2.6 a	$2*10^{11}$	Van House: $2*10^{10}$
64-Cu	0.6	12.7h	$1.4*10^{14}$	Highest activity:10^{15}
18-F	0.6	109.7m	$3.3*10^{15}$	PET
11-C	1.0	20.38m	$3.1*10^{16}$	PET
15-0	1.7	2.03m	$2.2*10^{17}$	

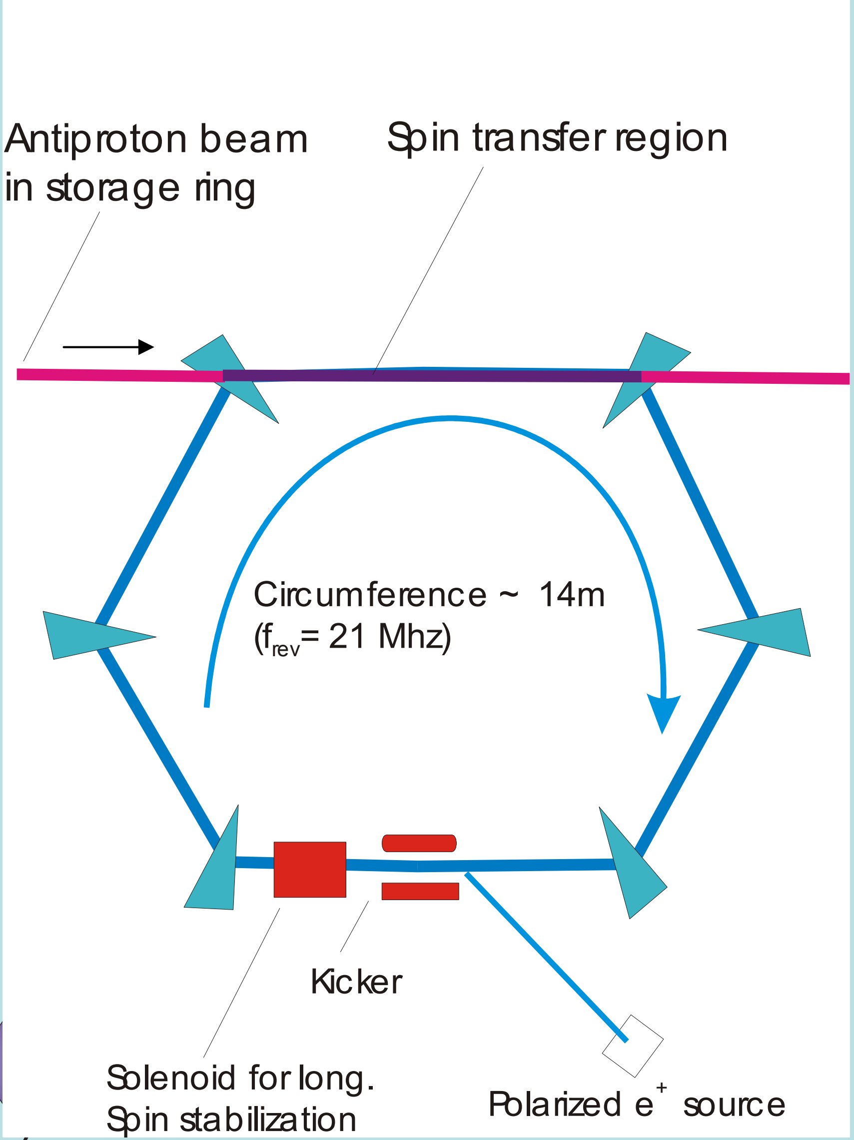
Commercial PET-Isotope production:
Proton cyclotron 20 MeV, 14N(p,α)11C:
Yield: $0.8*10^{10}$Bq/μA.

Online C-11 production with
Commercial superconducting Linac*:
1.2 mA, 20MeV→
10^{13} Bq source activity
Expected Efficiency increase: factor 2
compared to 1980-s experiment

Expected d.c.-source parameters

Current: $5*10^9$ e^+/s
Polarization: 0.7
Energy width: <0.1eV
Normalized beam emittance 1 mm mrad

e^+-Storage ring option



1. Profit from enhanced Beam current due to revolution frequency.
2. Conventional AG-storage ring offers beam lifetime of several seconds @1MeV
3. longitudinal spin stabilization with π-rotating solenoid seems feasible.
4. Space charge limit 10mA.
5. Aim at >3*10^5 stored particles (1 Mikroamp i.e 3 orders of mag. w.r.t. d.c. source)
6. Task: Produce 3*10^5 pol e+ in acceptance of 5keV*ns.

General Idea:

$$\vec{\gamma} \Rightarrow \vec{e}^{+} + \vec{e}^{-}$$

Problem shifted towards production of circularly polarized γ-Radiation in the multi MeV region.

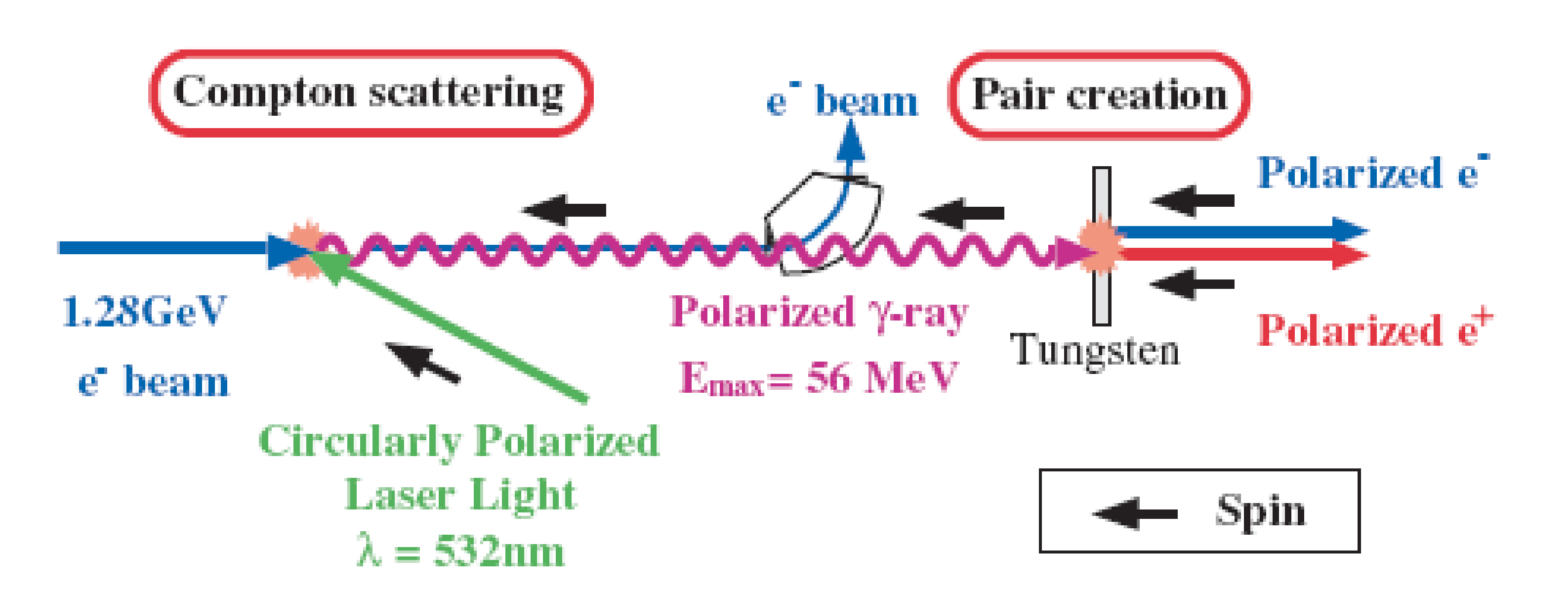
Two options beeing discussed for ILC:

1.) Synchrotron radiation from helical undulator (40 GeV e-beam)

2.) Compton backscattering of laser pulse off 1GeV high charge density buch in storage ring.

→ far too involved ! (damping rings!)…. however

T. Omori et al: PRL 96,114801 (2006)



Achieves about 10^3 polarized positrons with P=0.73 inside required acceptance. But: get rid of e-storage ring!

Increasing charge has two options

1.) Use polarized Bremsstrahlung and apply moderation technique to reduce energy width.

2.) Get rid of storage ring and reduce gamma-ray duration (Pocket accelerator with micro bunch).

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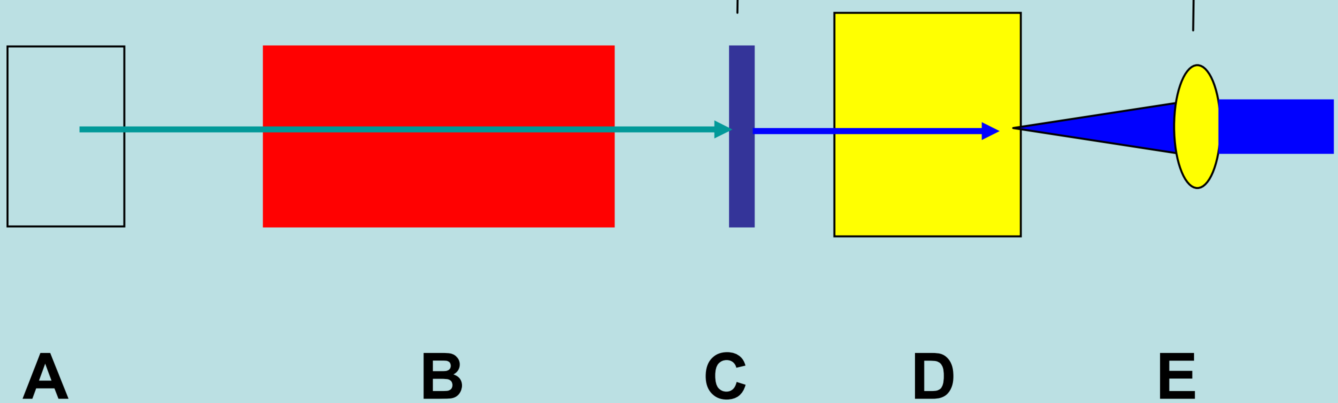
Pulsed source with present day technology

- Generate circularely polarized gammas by Bremsstrahlung from polarized electrons
- If compared to the KEK-Ansatz we profit from the relatively long pulse length required.
- Will allow for compact (~15 m long) set up
- only well established components

C;Conversion target
1mm Tungsten
(or liquid lead)

E:Beam collimation



A:Source:
Pol. e pulse
200keV,4μs
I_{peak}=5A

B:High charge
r.f.-LINAC,
23MeV,
I_{peak}=1.7A
Ne-=$4.3*10^{13}$

D:Positron energy (E) +
Angular (θ)-selection
E=14.25MeV
ΔE=+-350keV,
$\Delta\theta$= 2deg.
Conversion efficiency:
ε_1=e+/e-=$9*10^{-7}$
P=0.76

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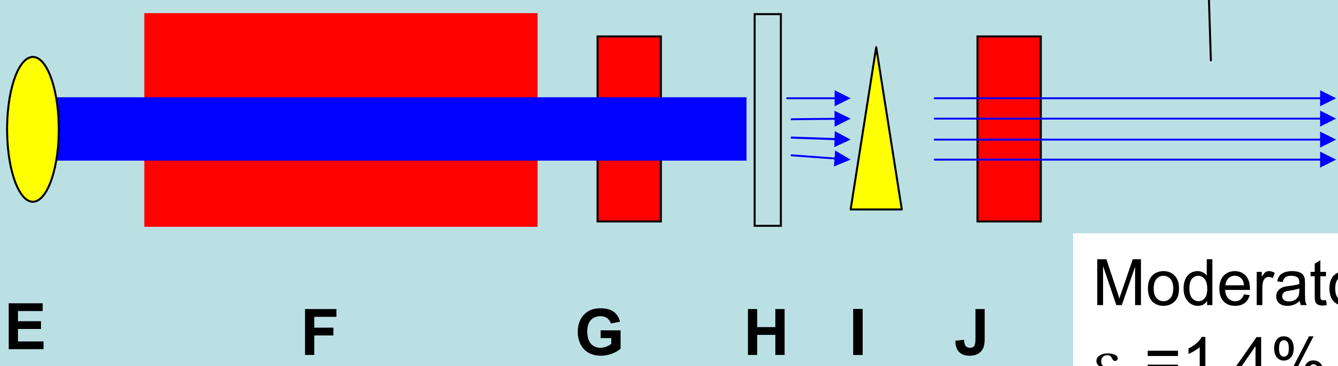
F:Positron decelaration (r.f.-LINAC) 14.25 to 1.75 MeV

Bunched e+ to storage ring E=1MeV, 50ns I_{peak}=2μA



Moderator efficiency: ε_2=1.4%.

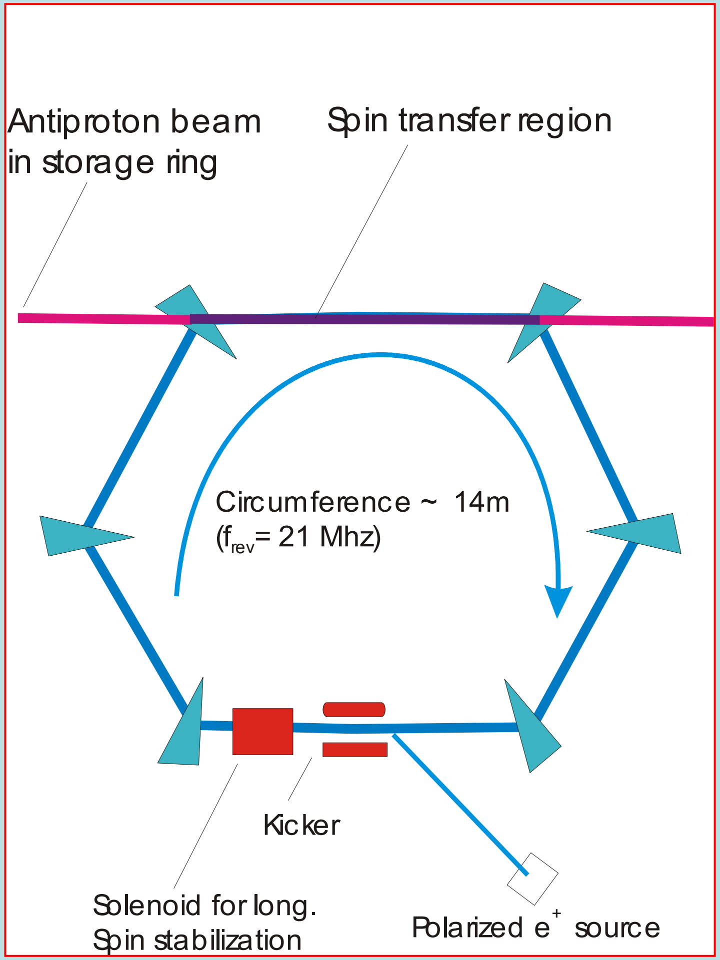
G: Electrostatic deceleration to E_{kin}= 1 MeV at terminal

Terminal with absorber/ moderator (**H**) (at +1MV) and Buncher (**I**) (+ 0.99MV), reacceleration to ground potential (**J**)

Expected parameters for pulsed source (conventional version)

- Bunch charge $6*10^5$ (from $1.2*10^{14}$ pol. electrons)
- Polarization 0.76
- normalized emittance 9 mm mrad
- longitudinal phase space 4 keV*ns
- Current in storage ring 2 μA.
- repetition rate 10 Hertz→ no lifetime problem for polarized electron source.

Can it be improved even further?



1. Increase storage time (and space charge limit) by longitudinal (toroidal) Magnetfield (Stellatron)
2.) The Stellatron (aka LEPTA) Is intended for electron cooling of stored positron beams! with ~mA current.
3.) But: Not investigated:
i) Is it possible to stack?
ii) Cooling time??
iii) Lifetime???
iv) positron spin dynamics

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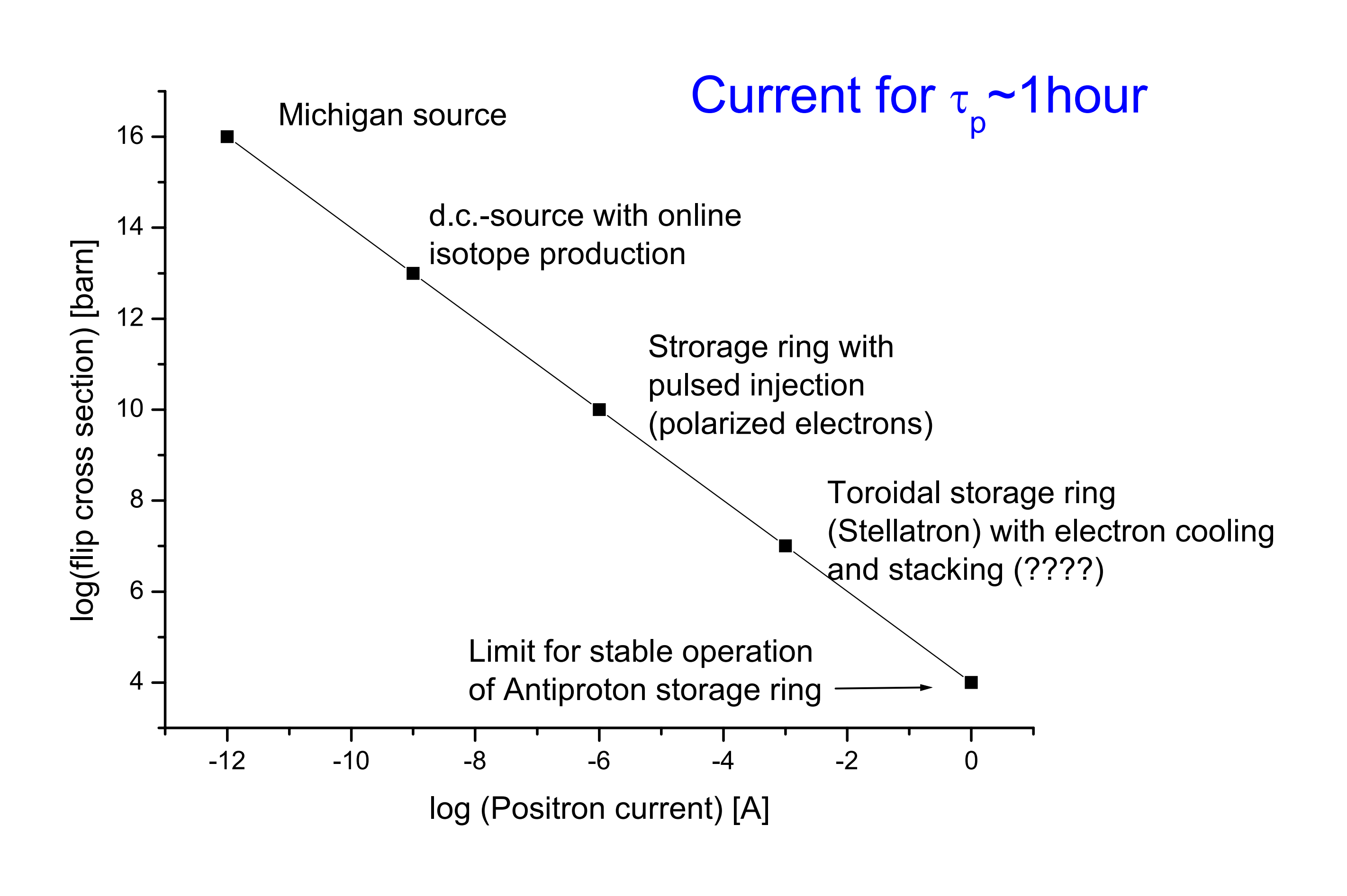
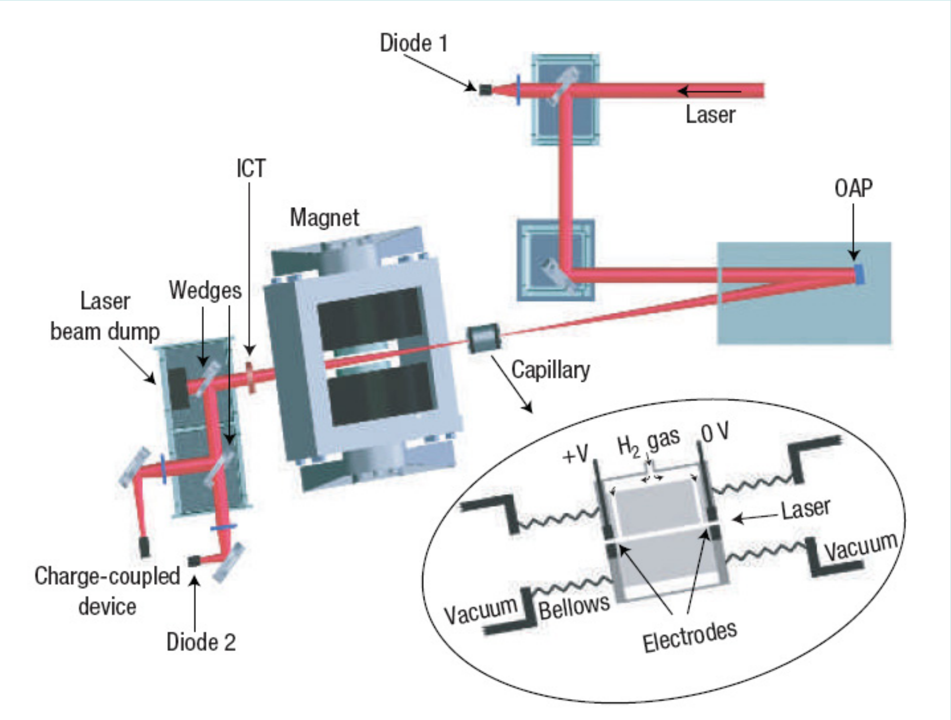
Which device for which cross section?



Summary

- d.c. source can produce ~1nA polarized positrons with brightness comparable to electron gun.
- Present day technolgy pulsed source + low energy storage ring can produce stored polarized positron current with several microampere and useful emittance.
- Low energy storage rings may perhaps allow for stacking and cooling which could increase the beam intensity even further.

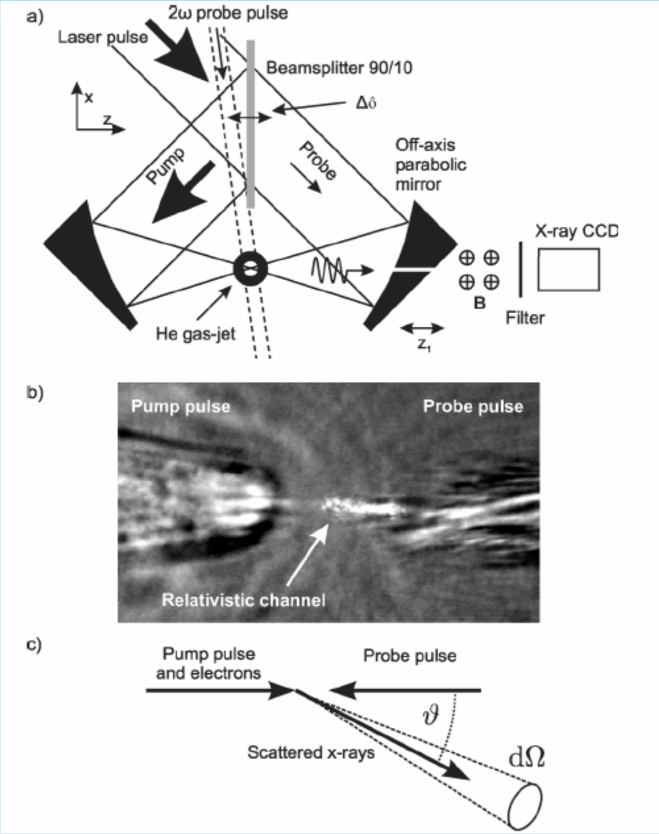
Laser-Plasma-accelerator*



3T-Laser:
1.5J,40fs, →40TW
d_{fok}=50μm→a_0=4.8
reprate:1Hz

*W.P. Leemans et al: Nature physics, 2, 696 (2006)

e/γ-collider

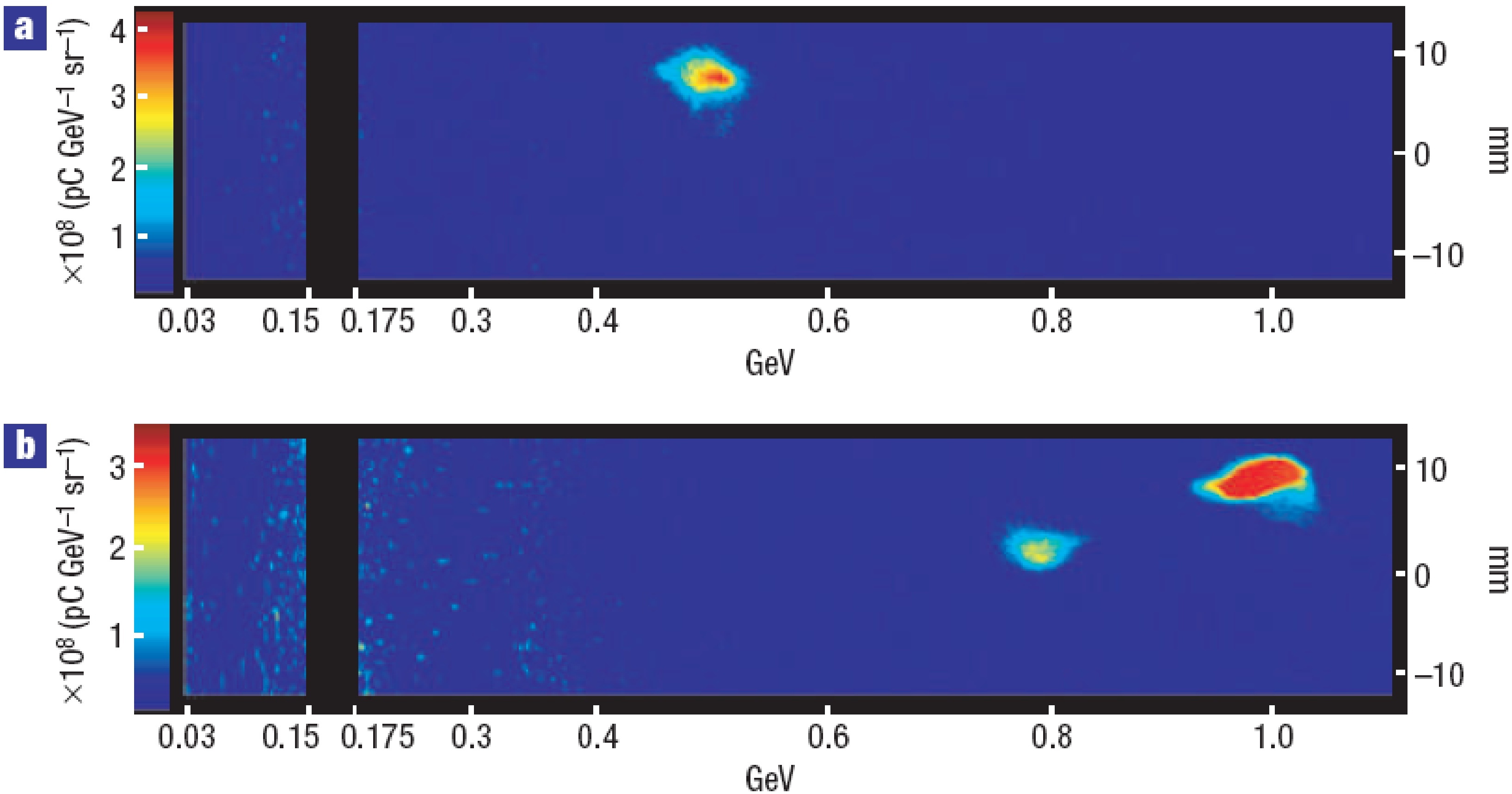


using part of the drive beam for compton backscattering!

→sub-picosecond duration circularely polarized gamma beam may be possible, thus increasing long. brightness by two orders of magnitude

*H Schwoerer et al. PhysRev.Lett., 96, 014802 (2006)

Laser-Plasma-accelerator*



*W.P. Leemans et al: Nature physics, 2, 696 (2006)

- Pocket accelerators may provide efficient

source for polarized gamma radiation

- at small size and investment/running cost (compared to 1GeV high charge storage ring)
- Potential for far higher luminosity could result in 2 orders of magnitude increase of bunch charge. (3*10^5 /pulse in storage ring acceptance)
- but: technology not (yet) well established.