Frequency of e+ helicity reversal

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Status

- with baseline design e+ with >30% polarization
- need reversal of e- AND e+ helicity for measuements

Action items from Zeuthen meeting

- justify the need for 5Hz spin flipping
- justify ability to reverse
- spin rotation @ 400 MeV design
- scheme to destroy polarization completely

Minimal Machine: Running Strategy

Physics between 200 GeV and 500 GeV
Luminosity: Year 1-4: L_{int} = 500 fb^{-1}
Energy stability and precision below 0.1%

➔ ee→HZ	at 350 GeV (mH≈120 GeV)	few 10^4
ee→ tt	at 350 GeV	10^5
ee → qq (μμ)	at 500 GeV	$5 \cdot 10^5$ ($1 \cdot 10^5$)
ee → WW	at 500 GeV	10^6

➔ statistical uncertainties at per-mille level !!

Uncertainties: $\Delta\sigma \propto \frac{1}{\sqrt{N}} \oplus \frac{\Delta L}{L} \oplus \frac{\Delta E}{E} \oplus \frac{\Delta P}{P}$ → **O(10^{-3})**

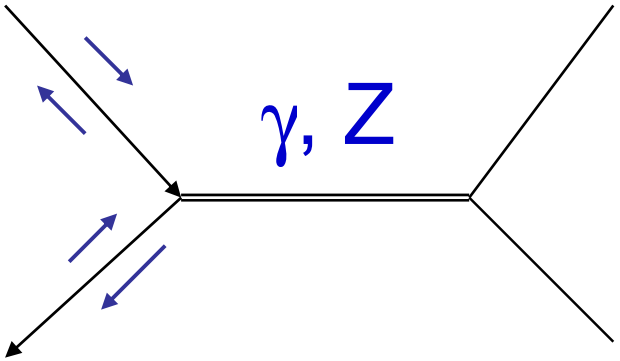
frequency of e+ reversal

Processes to be measured:

ee → ff, tt

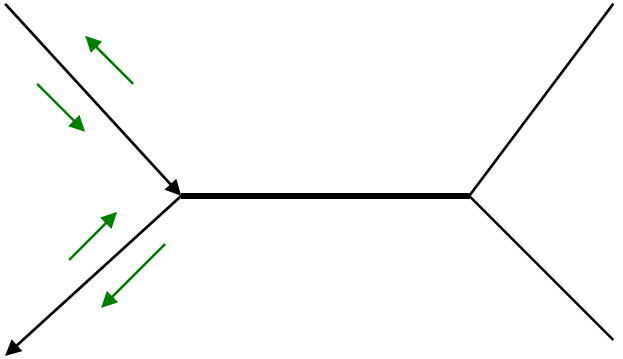
ee → WW

J=1



but not

J=0



s-channel cross sections with pol e+ beams

Can perform independent measurements

$$\sigma_{++} = \tfrac{1}{4}\sigma_u\left[1 + P_{e^+}P_{e-} + A_{LR}\left(+P_{e^+} + P_{e-}\right)\right]$$
$$\sigma_{--} = \tfrac{1}{4}\sigma_u\left[1 + P_{e^+}P_{e-} + A_{LR}\left(-P_{e^+} - P_{e-}\right)\right]$$

=0 (SM) if both beams 100% polarized

$$\sigma_{-+} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(-P_{e^+} + P_{e-}\right)\right]$$
$$\sigma_{+-} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(+P_{e^+} - P_{e-}\right)\right]$$

Standard Model
s-channel

$P_{e+,} = 0$ $\quad \sigma_u = \frac{1}{2}\left(\sigma_+ + \sigma_-\right)$

$P_{e+,} > 0$: enhancement ~$(1+P_{e-}P_{e+})$
For (80%, ~30%):
25% gain in effective luminosity

$$\sigma_u = \frac{1}{2}\frac{\sigma_{+-} + \sigma_{-+}}{1 + |P_{e-}P_{e+}|}$$

s-channel asymmetries with pol e+ beams

s-channel measurements

$$\sigma_{-+} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(-P_{e-} + P_{e+}\right)\right]$$
$$\sigma_{+-} = \tfrac{1}{4}\sigma_u\left[1 - P_{e^+}P_{e-} + A_{LR}\left(+P_{e-} - P_{e+}\right)\right]$$

Standard Model
s-channel

Left-Right asymmetry

$$A_{LR} = \frac{\sigma_{-+} - \sigma_{+-}}{\sigma_{-+} + \sigma_{+-}} \cdot \frac{1 - P_{e^-}P_{e^+}}{-P_{e^-} + P_{e^+}}$$

P_{eff}

Error propagation

➔ $$\frac{\Delta P_{eff}}{P_{eff}} < \frac{\Delta P_e}{P_e}$$

- Left-Right Asymmetry is a ‘robust’ quantity, most systematic effects cancel if
  - **equal luminosities delivered to + and – helicities**
  - **equal polarization for + and – helicities**

  Both realized at SLC due to fast random helicity flip

$$A_{LR} = \frac{\sigma_- - \sigma_+}{\sigma_- + \sigma_+} \cdot \frac{1}{P_{e^-}} \cong \frac{N_- - N_+}{N_- + N_+} \cdot \frac{1}{P_{e^-}}$$

- ILC:

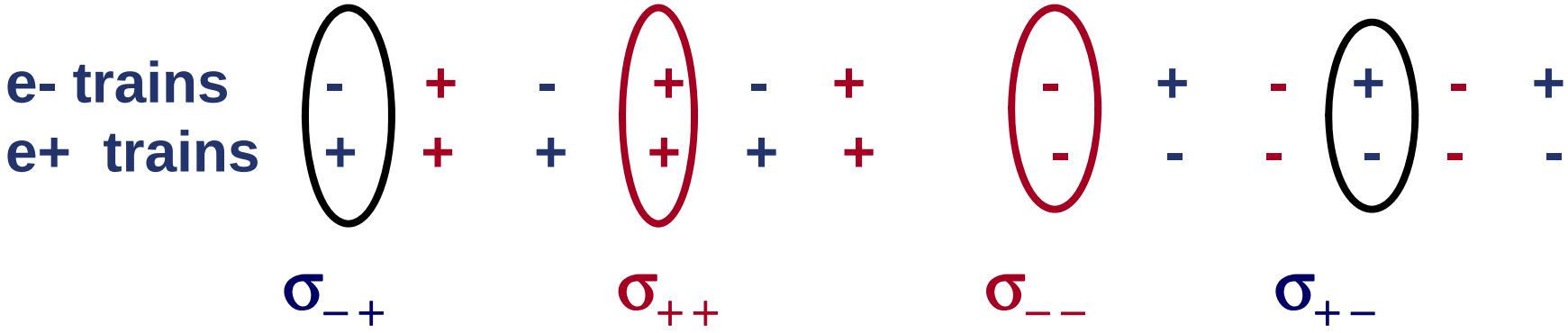
$$A_{LR} \cong \frac{N_{-+} - N_{+-}}{N_{-+} + N_{+-}} \cdot \frac{1 + P_{e^-} P_{e^+}}{P_{e^-} + P_{e^+}}$$

$$\sigma = \frac{N}{\varepsilon \cdot L}$$

In principle easy…. but…

e+ Helicity Reversal

e+ helicity flip less frequent than e- helicity reversal



➔ 50% spent to 'inefficient' helicity pairing σ_{--} and σ_{++} gain due to xs enhancement $(1+P_{e-}P_{e+})$ for J=1 processes with e+ pol is lost!!

➔ Have to combine σ_{-+} and σ_{+-} measured in different runs with different luminosities

Slow helicity reversal

- measure N_{+-} and N_{-+} in different runs with different P_{e+} and P_{e-} and different luminosities L_{+-} and L_{-+}

➔ **Additional uncertainty for averaged effective polarization**

➔ **Additional (systematic) uncertainty for combination of runs**

$$\sigma_{-+/+-} = \frac{\left(N^{S}_{-+/+-} - N^{Bgr}_{-+/+-}\right)}{L_{-+/+-}} = \frac{N_{-+/+-}}{L_{-+/+-}} = f\left(P_{e+}^{-+/+-}; P_{e-}^{-+/+-}\right)$$

$$A_{LR} = \frac{N_{-+} \cdot \left\langle 1 - P_{e-}^{+-} P_{e+}^{+-} \right\rangle L_{+-} - N_{+-} \cdot \left\langle 1 - P_{e-}^{-+} P_{e+}^{-+} \right\rangle L_{-+}}{N_{-+} \cdot \left\langle -P_{e-}^{-+} + P_{e+}^{-+} \right\rangle L_{+-} + N_{+-} \cdot \left\langle -P_{e-}^{+-} + P_{e+}^{+-} \right\rangle L_{-+}}$$

Slow helicity reversal

unpolarized cross section:

$$\sigma_u \sim \frac{N_{-+}\left\langle -P_{e-}^{+-} + P_{e+}^{+-}\right\rangle L_{+-} + N_{+-}\left\langle -P_{e-}^{-+} + P_{e+}^{-+}\right\rangle L_{-+}}{\left\langle -P_{e-}^{+-} + P_{e+}^{+-}\right\rangle L_{+-} \cdot \left\langle 1 - P_{e-}^{-+} P_{e+}^{-+}\right\rangle L_{-+} + \left\langle -P_{e-}^{-+} + P_{e+}^{-+}\right\rangle L_{-+} \cdot \left\langle 1 - P_{e-}^{+-} P_{e+}^{+-}\right\rangle L_{+-}}$$

→ systematic errors have to be known and small

- time dependent intensity/polarisation tolerances
- $P_{e-} \bullet P_{e+}$ ⇔ need to understand correlations

→ Need long-term stability at the level of (few) 10^{-3}

Fast helicity reversal

→ ‘unbiased’ combination of all runs

$$A_{LR} = \frac{N_{-+} - N_{+-}}{N_{-+} + N_{+-}} \cdot \frac{\langle 1 - P_{e-} P_{e+} \rangle}{\langle -P_{e-} + P_{e+} \rangle}$$

$$\sigma_u \sim \frac{N_{+-} - N_{+-}}{L \cdot \langle 1 - P_{e+} P_{e-} \rangle}$$

Polarization measurement possible with $\Delta P_{e+,e-} \sim 0.25\%$

Pro's and con's for fast reversal

Pro's

- Higher effective luminosity
- Control of systematic effects
- Smaller error for eff. polarization
- High flexibility for new physics beyond the Standard Model ⇔ results from LHC
- Essential for GigaZ (random heli choice minimizes systematic effects)

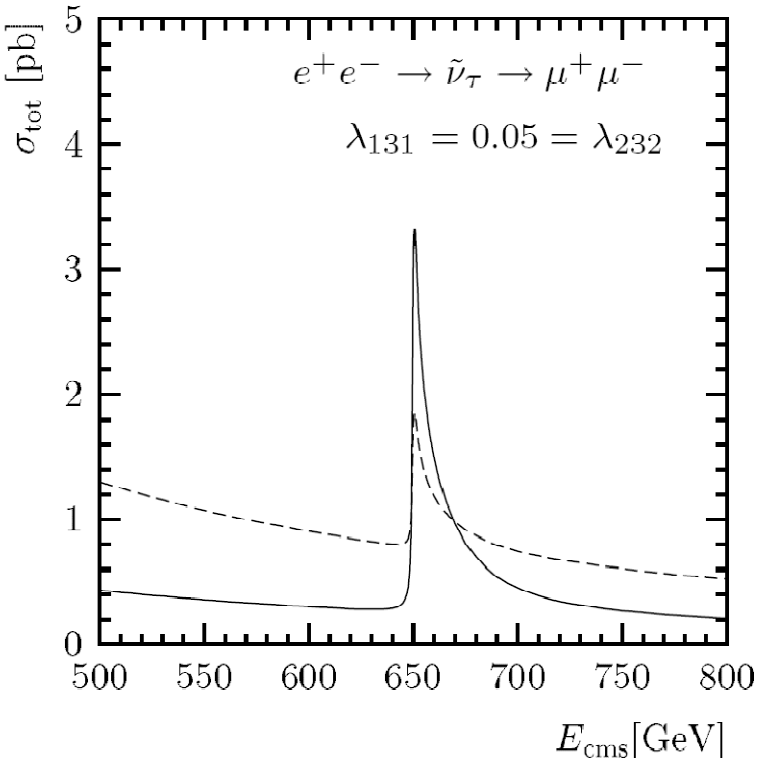
Con's

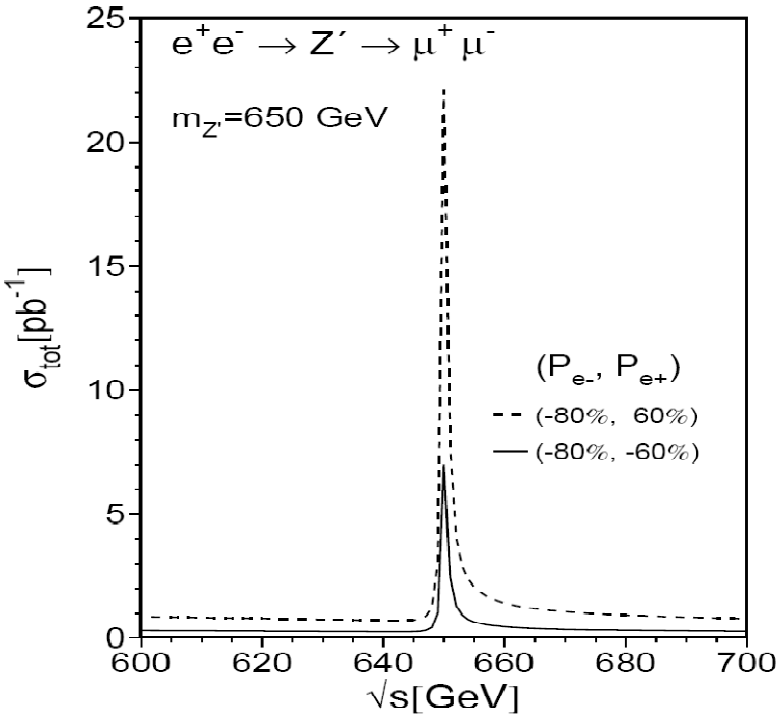
- More easy
- Stability of machine (RDR) should allow slow reversal:

  Remaining systematic errors should be small, polarisation and lumi can be monitored and measured with high accuracy

Disentangle new physics with e+ pol

Enhance/suppress new physics → differentiate models



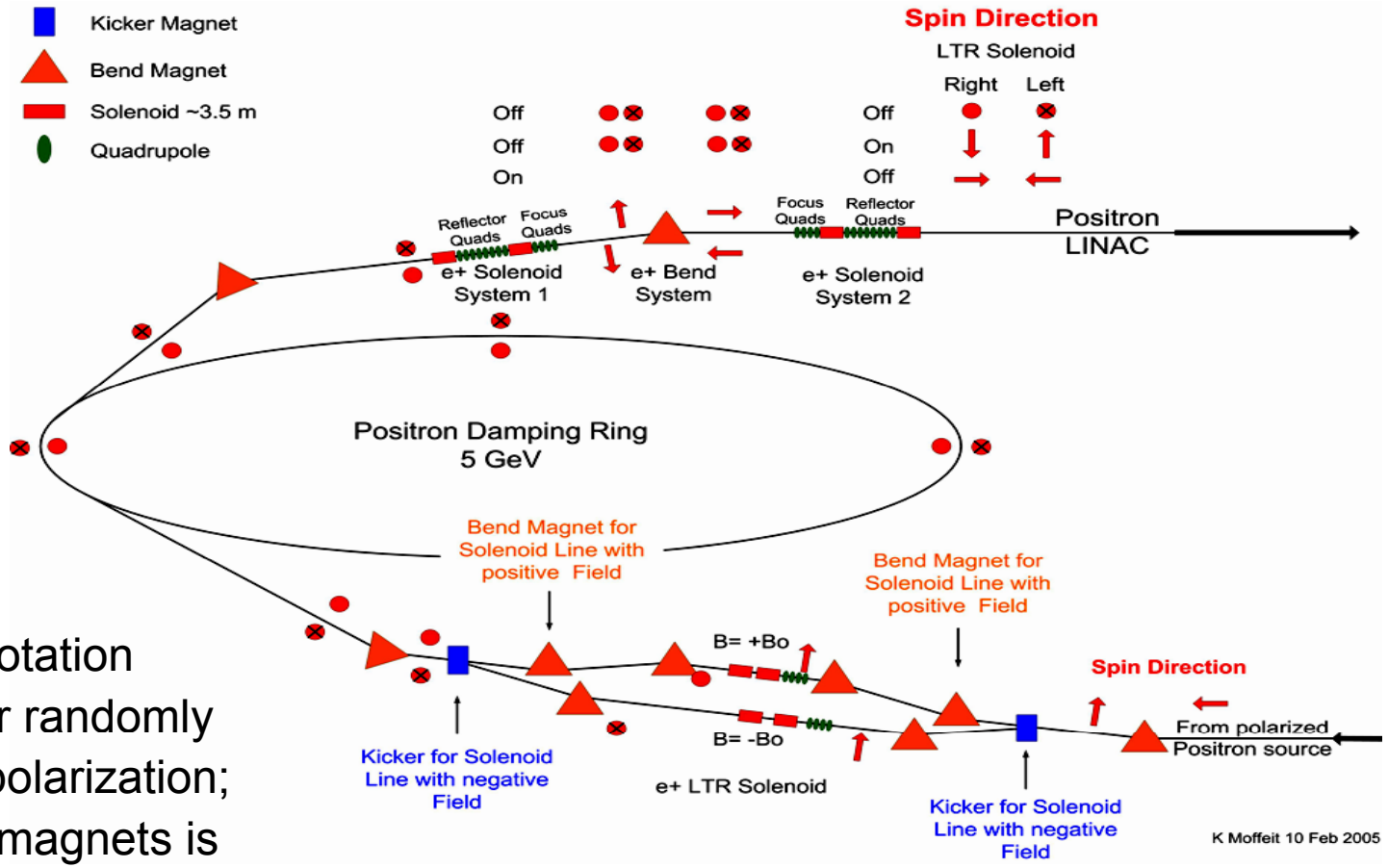


J=0 (s-channel sneutrino)

J=1 (Z')

Spin rotation and helicity reversal @ 5GeV

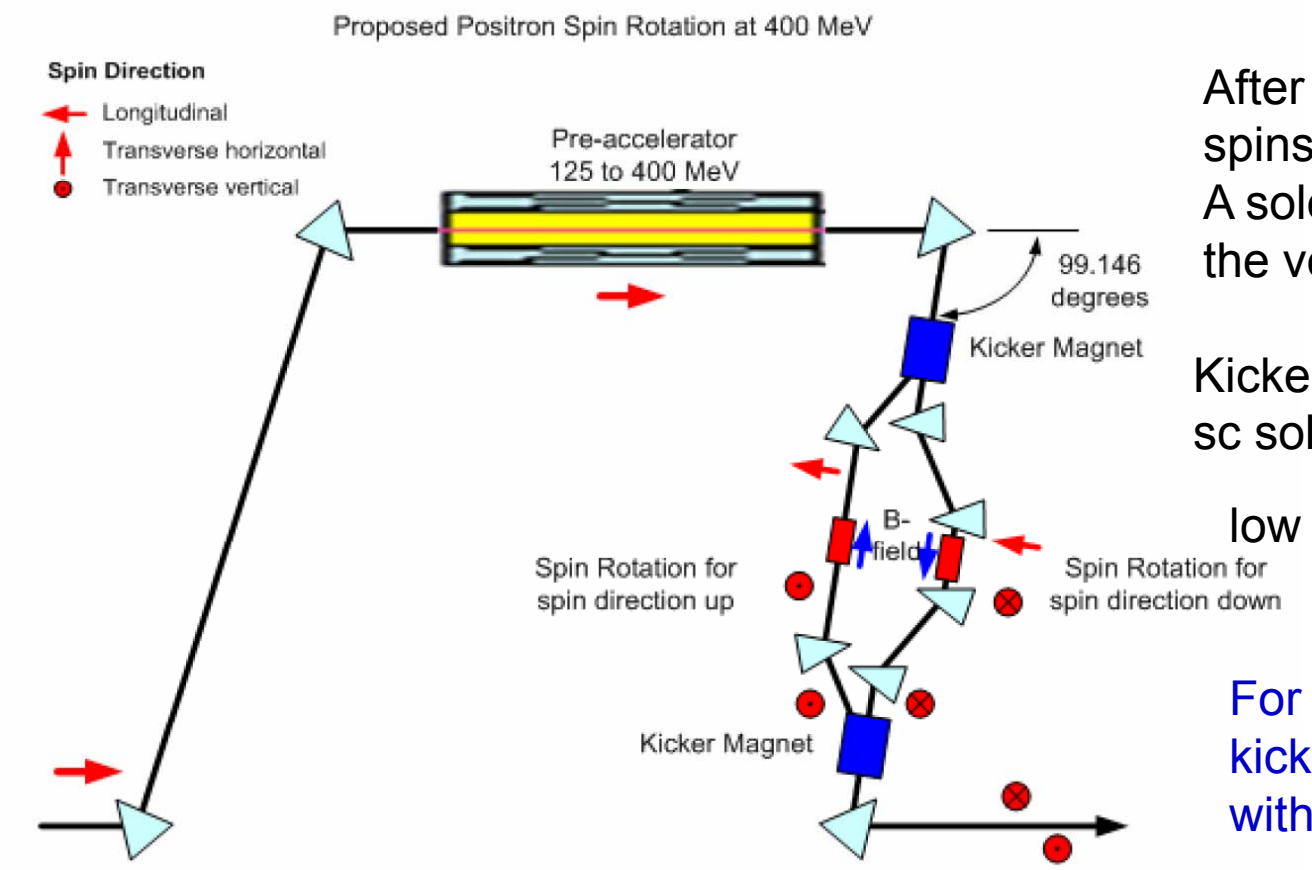
K. Moffeit et al., SLAC-TN-05-045 → fast reversal before DR (5 GeV)



parallel spin rotation beam lines for randomly selecting e+ polarization; pair of kicker magnets is turned on between pulse-trains

Spin rotation and helicity reversal @ 400 MeV

New proposal: K. Moffeit, M. Woods,Walz, ILC-NOTE-2008-040
→ Fast reversal at ~400 MeV



After bend of 99.146 degrees spins are transverse.
A solenoid will rotate spin to the vertical:

Kicker → 2 parallel lines with sc solenoids for fast rotation

low syst. errors ⇔ random kicks

For high effective lumi kicker must be 'in phase' with e- helicity flip

Figure 5: Layout of proposed positron spin rotation systems in the Chicane for the Pre-accelerator. Kicker magnets and parallel spin rotator beamlines allow fast polarization reversals for the positron beam.

GigaZ

- Has not highest priority in ILC schedule
- Is important for checks of
  - **electroweak symmetry breaking ($\sin^2\theta_W$)**
  - **Understanding of LHC results ?**
- Need all four combinations $\sigma_{+-/-+}$ $\sigma_{\pm\pm}$ to determine simultaneously A_{LR} and effective polarization
- Calibration data?

  →Gudi's talk

  →discussion at Warsaw meeting

Summary

- With fast helicity reversal
  - **'in phase' with electrons → increase of lumi (>25%),**
  - **smaller systematic uncertainties**
  - **smaller pol error**
  - **best flexibility for new physics**
- Large syst. uncertainties with slow helicity reversal could reduce physics output substantially
  - **Realistic stability (Lumi, Pol) in ILC ?**
- GigaZ: does not work with slow helicity flipping
- Next steps:
  - **realistic evaluation of uncertainties ⇔ take into account instabilities, fluctuations in models**
  - **Check whether 4oo MeV reversal works for realistic beam**
- ideas to destroy e+ polarization → see Larisa

‘Slow’ vs. ‘fast’ helicity reversal

no reversal

→ **wrong strategy for measurements**

Better, but poor men solution: destroy e+ polarization

→ **Polarimeter needed to verify $P_{e+} = 0$**

Better: keep e+ with ‘slow’ helicity reversal

→ **systematic bias between runs ?**

→ **larger uncertainties**

Best: Fast reversal as for electrons

- High lumi
- Small errors, controlled systematics
- Flexible to study physics beyond the Standard Model