

# Deuteron polarimetry from 1.0 to 1.5 GeV/c

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EDM discussion  
April 14, 2006

Based on work from:

France: **POMME**

B. Bonin *et al.* Nucl. Inst. Methods **A288**,389 (1990)

V.P. Ladygin *et al.*, Nucl. Inst. Methods **A404**, 129 (1998)

Japan: **DPOL**

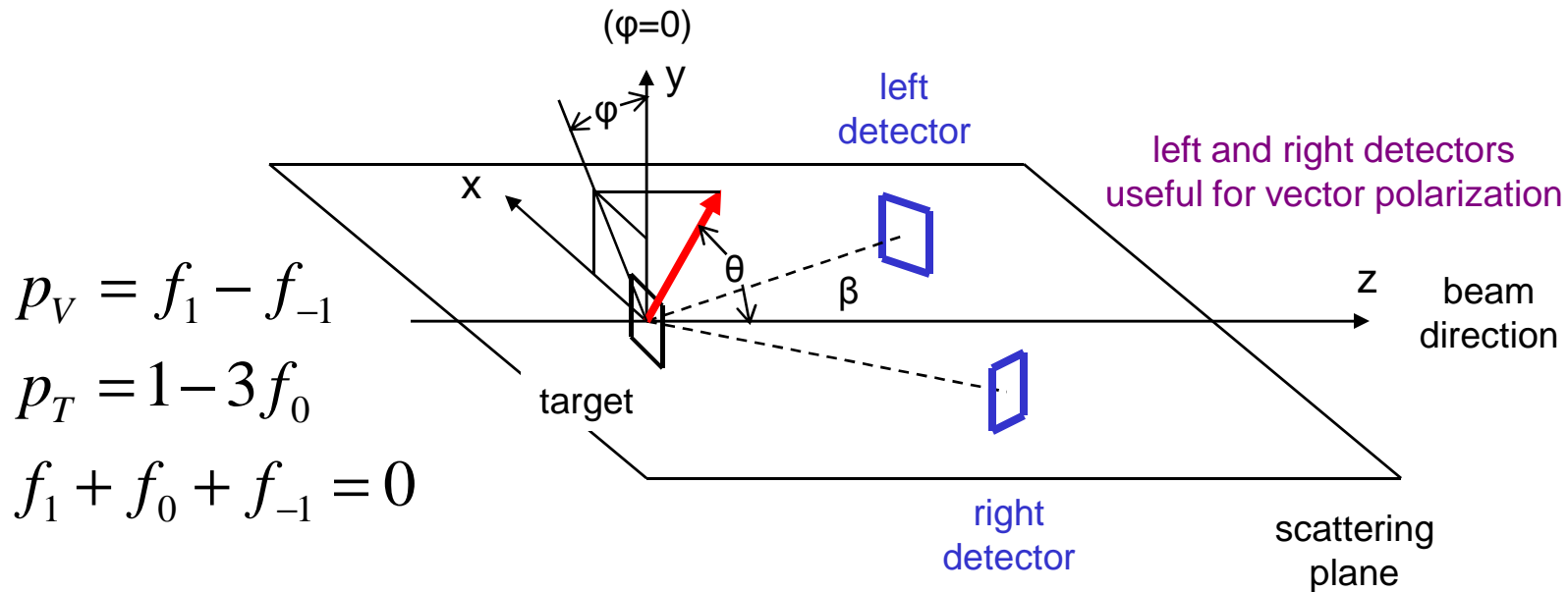
Y. Satou, private communication

Emphasizes elastic scattering

Carbon target

Want highest efficiency and vector spin dependence

A typical experimental layout contains:



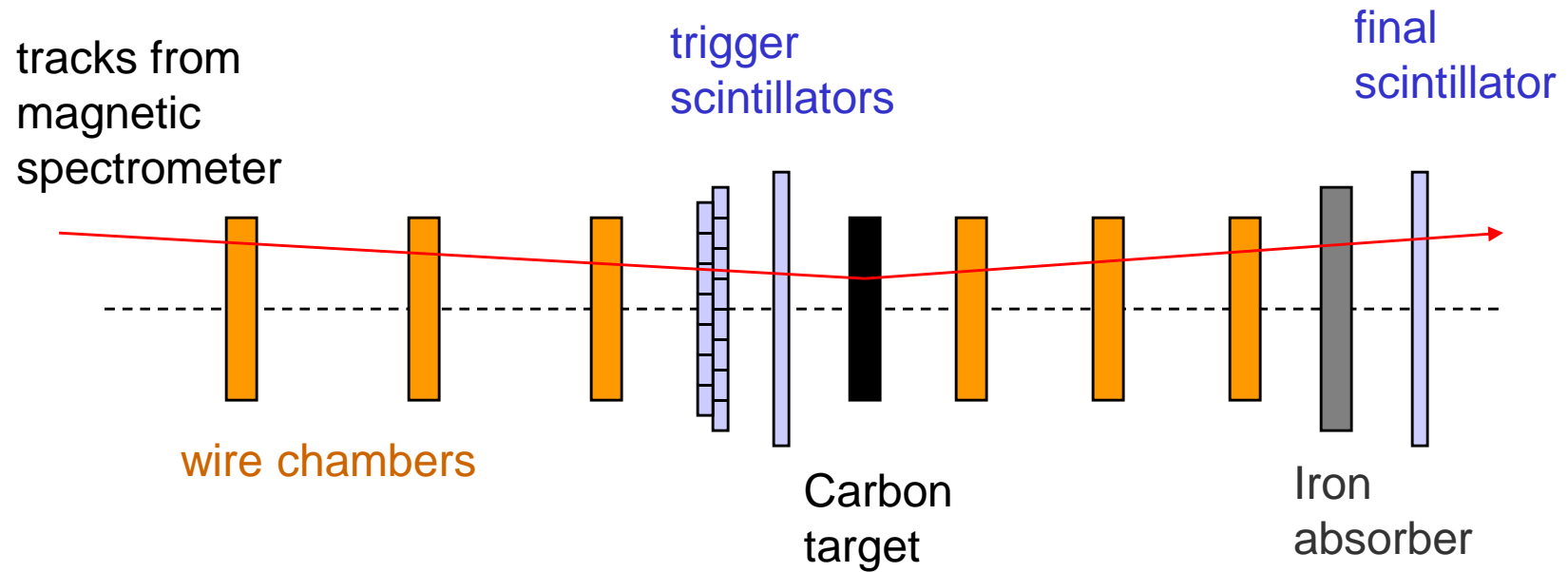
A polarization of the beam ( $p$ ) causes a difference in the rates for scattering to the left according to:

$$\begin{aligned}
 \sigma(\beta) = & \sigma_{unp}(\beta) [1 + \sqrt{3} p_V i T_{11}(\beta) \sin \theta \cos \phi \\
 & + \frac{1}{\sqrt{8}} p_T T_{20}(\beta) (3 \cos^2 \theta - 1) - \sqrt{3} p_T T_{21}(\beta) \sin \theta \cos \theta \sin \phi \\
 & - \frac{\sqrt{3}}{2} p_T T_{22}(\beta) \sin^2 \theta \cos 2\phi]
 \end{aligned}$$

unpolarized cross section  
 (determined by nuclear  
 effects in scattering)  
governs efficiency

analyzing power  
 (determined by nuclear  
 effects in scattering)  
governs spin sensitivity

# POMME layout

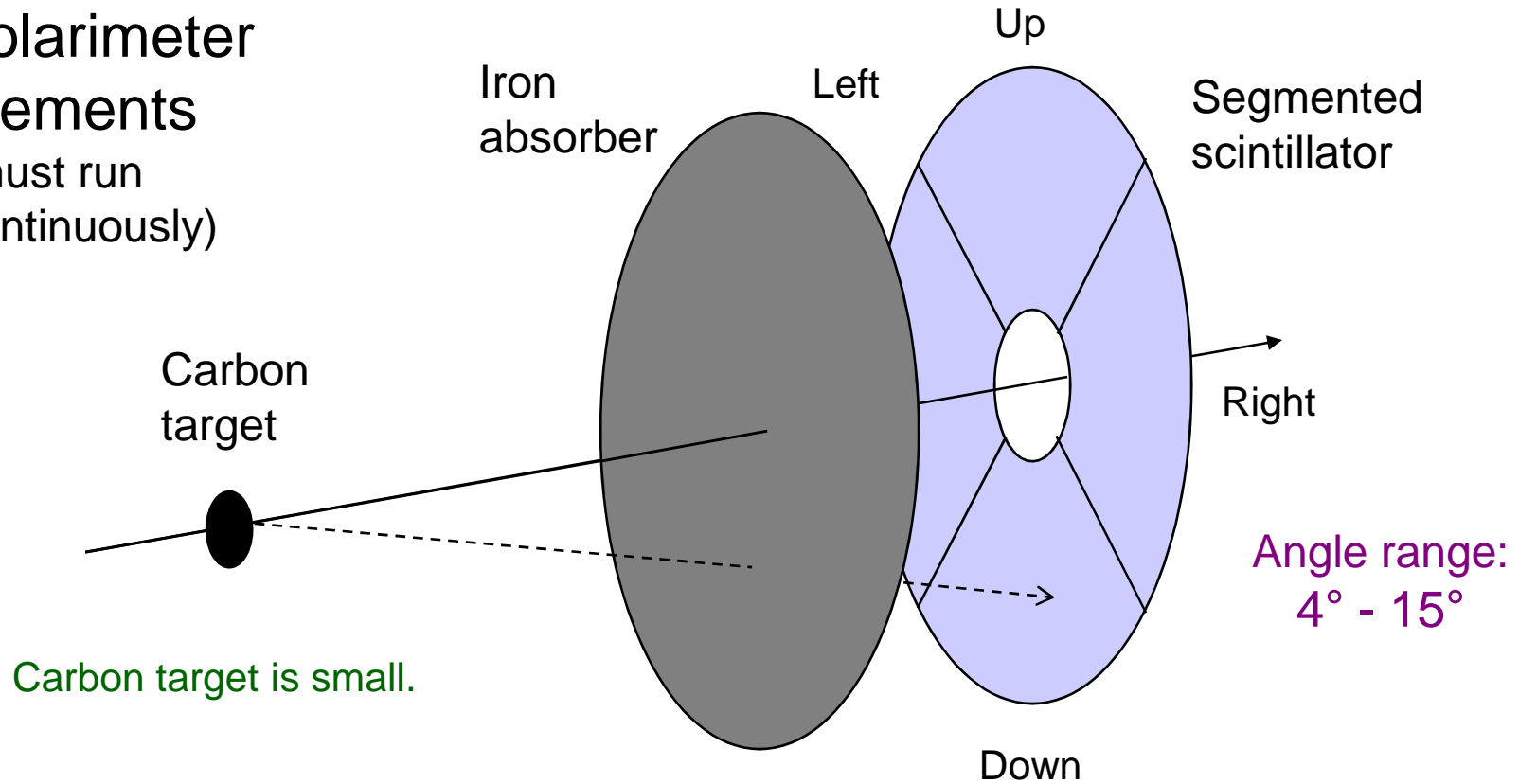


## Changes for EDM application:

- eliminate wire chambers (high rates) and segment final scintillator
- adjust carbon thickness to maximize efficiency (FOM)
- adjust iron thickness to favor elastic over breakup events

# Functional polarimeter elements

(must run continuously)



Carbon target is small.

$$\epsilon_{LR} = \frac{L - R}{L + R}$$

Left-right asymmetry carries EDM information.

$$\epsilon_{DU} = \frac{D - U}{D + U}$$

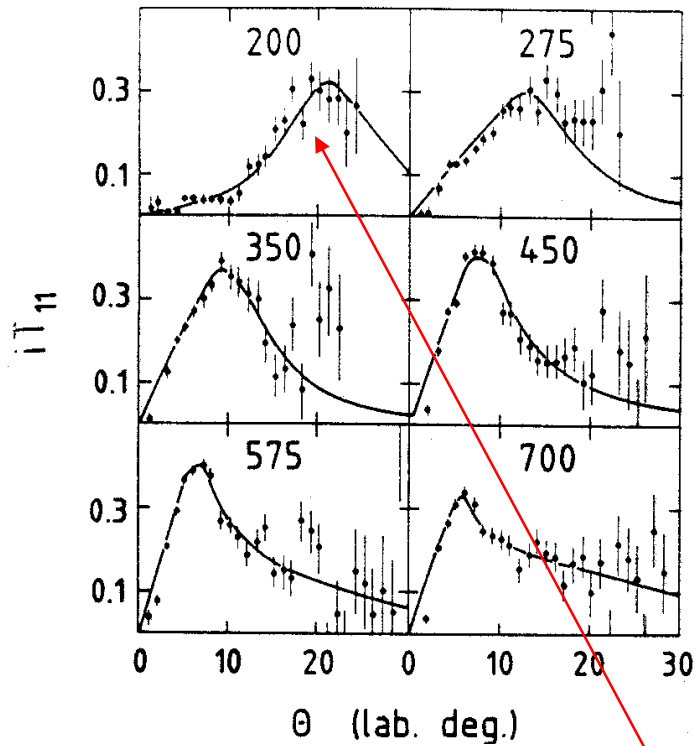
Down-up asymmetry carries information on g-2 precession.

Detailed design awaits decision on bringing beam to polarimeter:  
 slow extraction into second beam  
 extract using jet in ring onto annular target  
 tune beam onto annular target

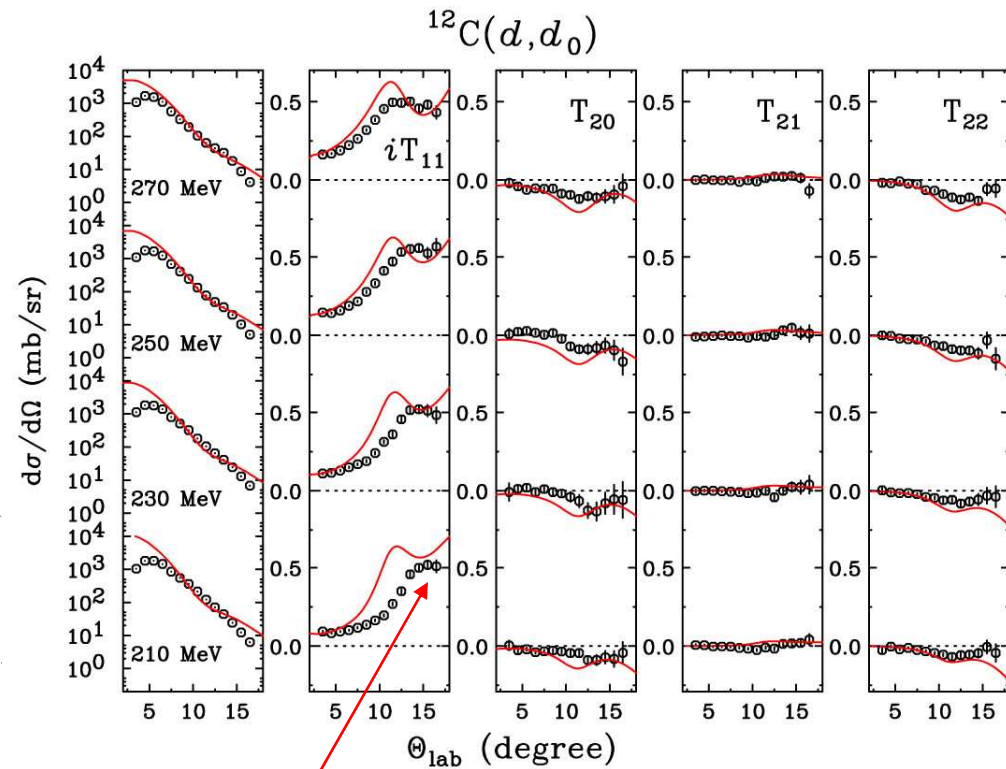


# Sample data:

Bonin

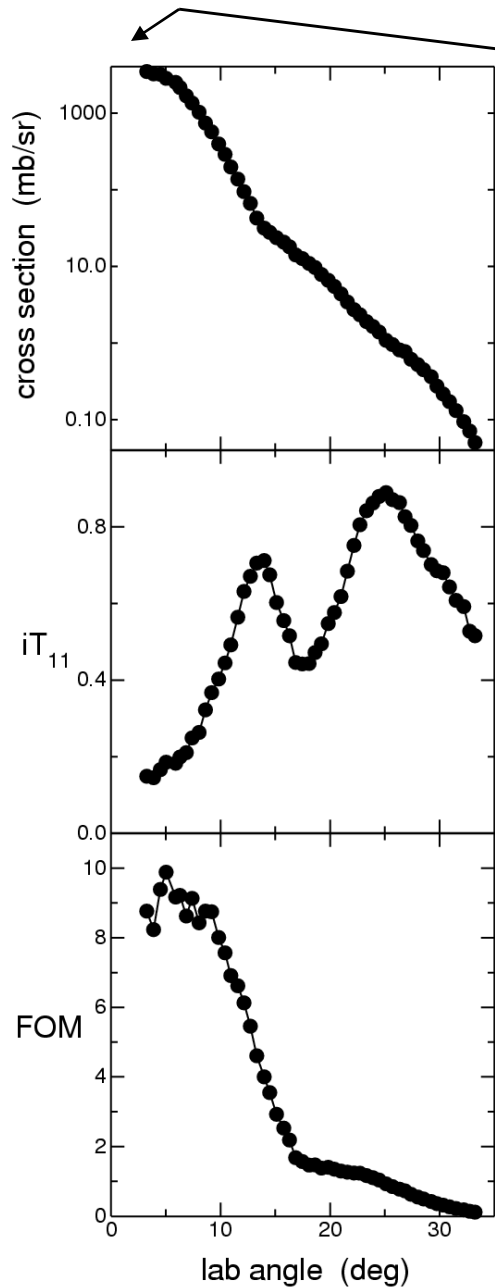


Satou



Note differences in peak analyzing power !!!

Bonin did not eliminate breakup as well.  
Satou did at the expense of efficiency.



At smaller angles  
Coulomb and  
multiple scattering  
dominate, making  
cross section large  
and analyzing  
power zero.

270-MeV deuteron elastic  
scattering – RIKEN  
[data example]  
(errors not shown)

**FIRST TRADE-OFF**

Optimize here:  
favor larger analyzing power,  
leverage against systematics

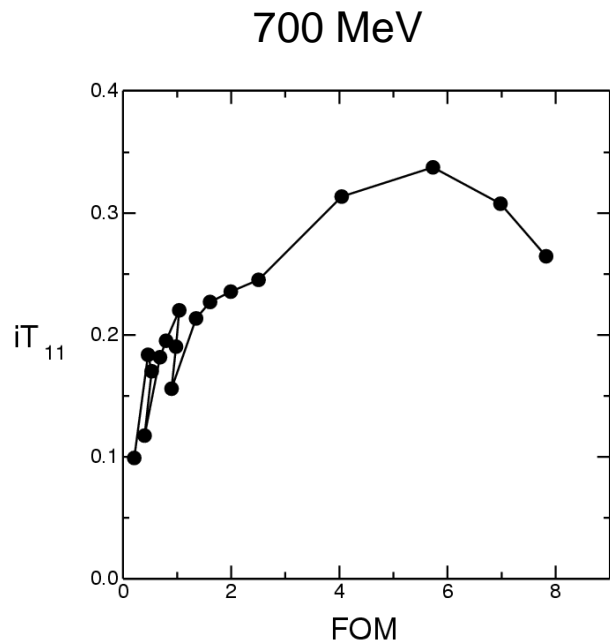
Optimize here:  
favor statistical precision

NEW DEFINITION OF  
FIGURE OF MERIT

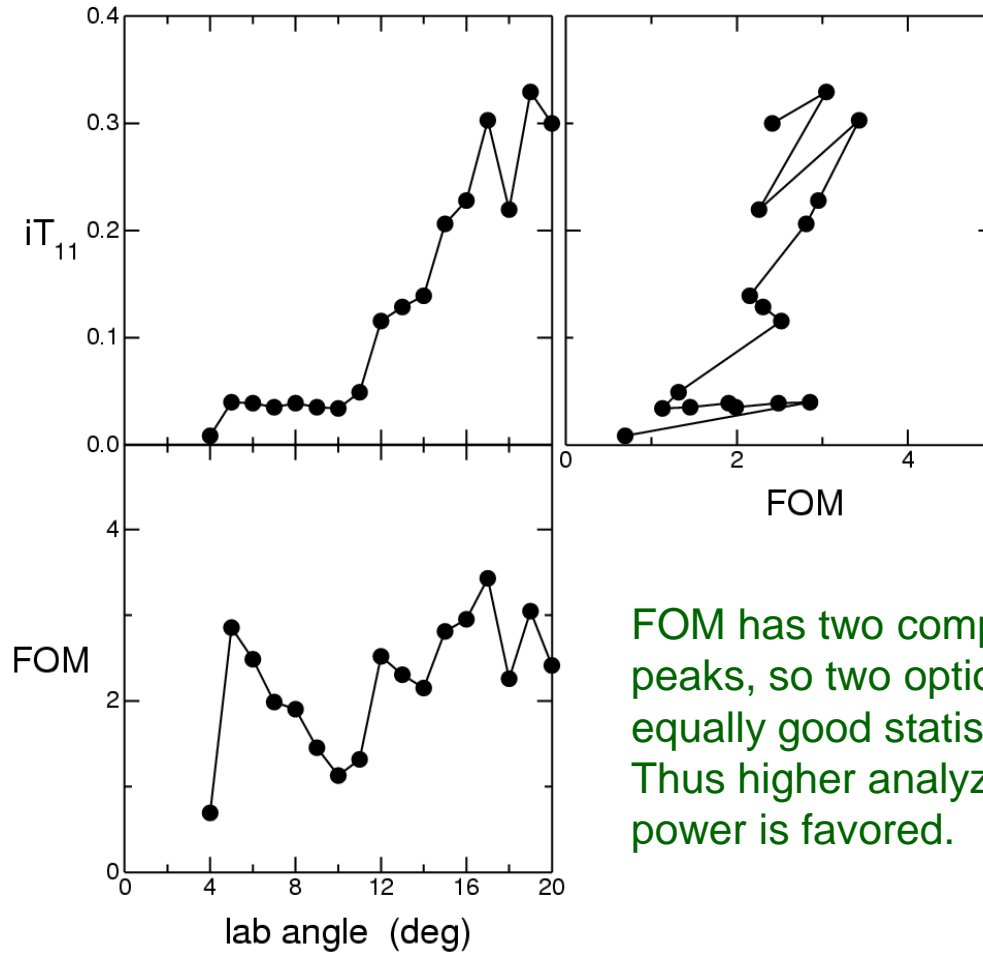
$$FOM = \sqrt{\sigma(\theta)} iT_{11}(\theta) \propto \frac{1}{\delta}$$

# The trade-off at high and low energies:

At the higher energies, FOM and analyzing power peak together. There is no trade-off.



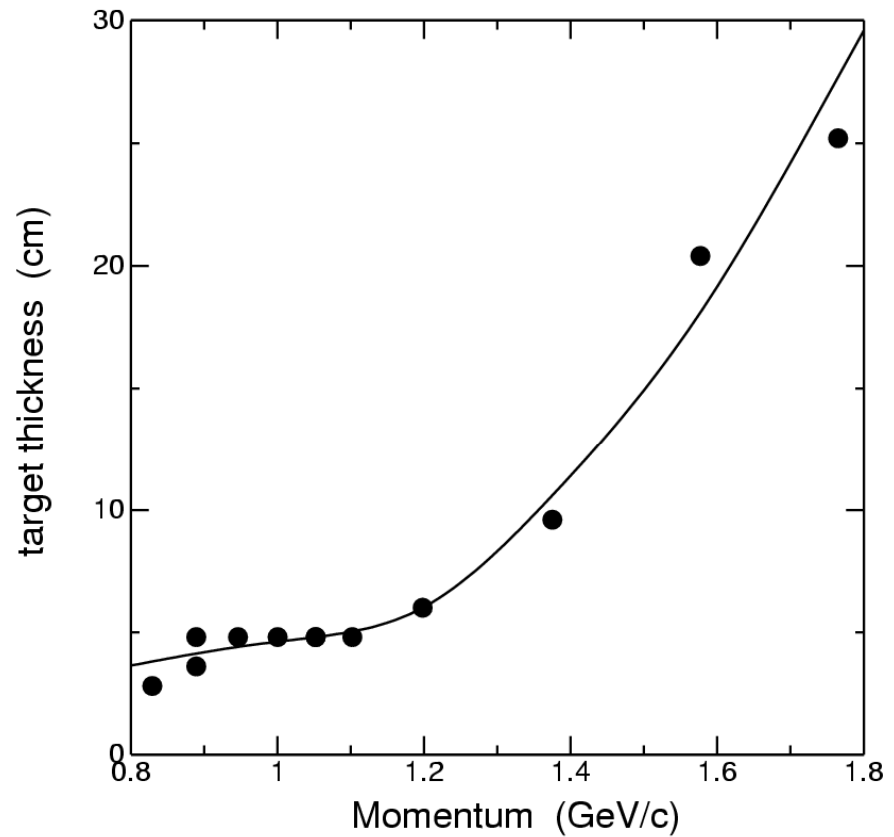
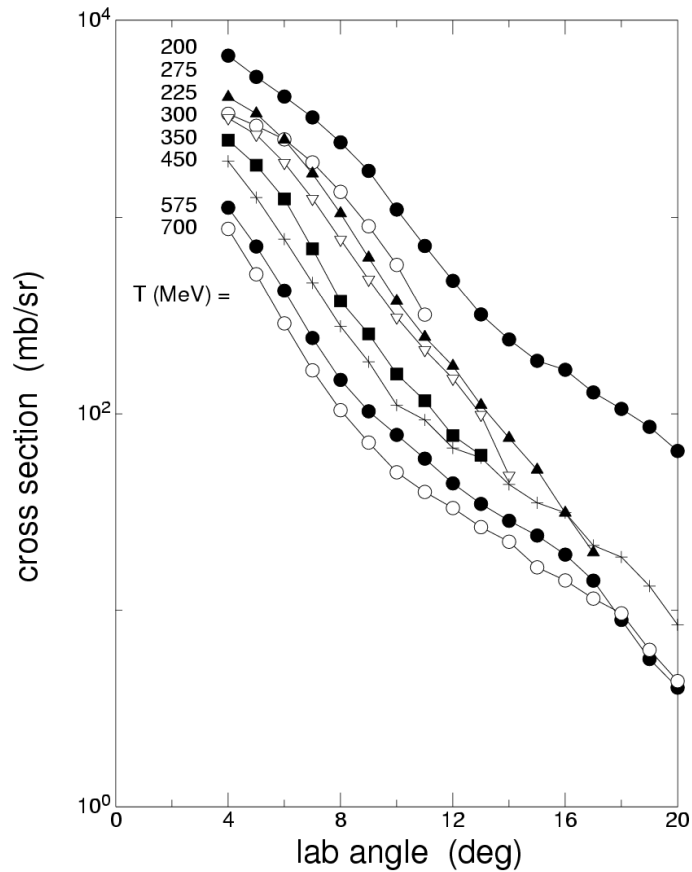
200 MeV



FOM has two comparable peaks, so two options are equally good statistically. Thus higher analyzing power is favored.

Before optimizing the FOM as a function of energy, consider two other energy dependencies:

The cross section is falling.



More energy allows thicker targets.  
Dots = French data  
Line = curve used here

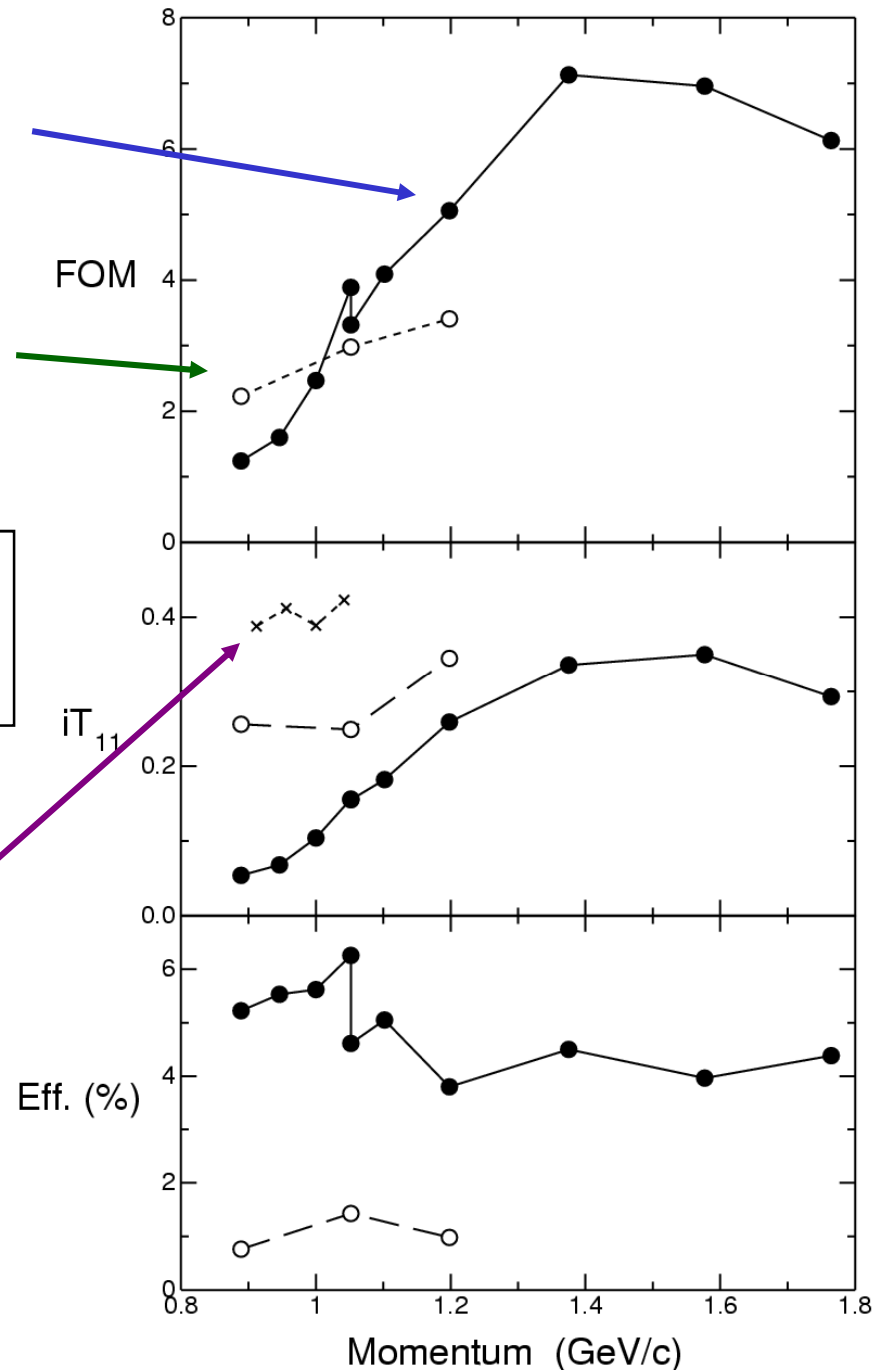
The SOLID dots and lines follow the FORWARD peak in the FOM curve.

The open/dashed dots and lines follow the analyzing power peak (where there is enough data to use).

The AVERAGES shown here integrate over some angle range that covers the relevant feature in FOM or  $iT_{11}$ .

**SECOND TRADE-OFF:**

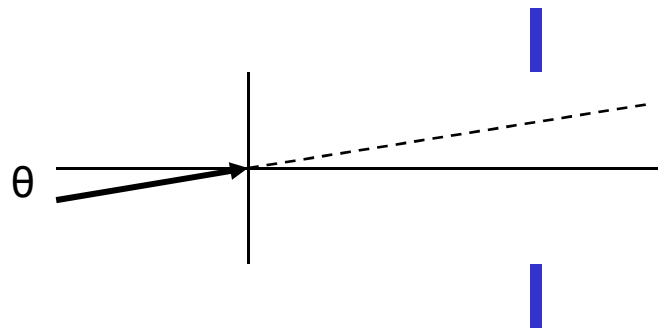
Satou gets even larger analyzing powers by cutting out more protons and losing "efficiency". The FOM is down about 30% from the open dots.



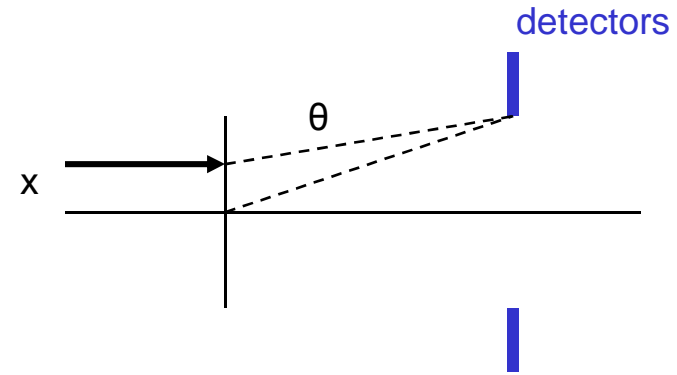
# Polarimeter Systematic Errors

What other sources arise for a left/right asymmetry?

## 1 Displacement / angle errors



angle shift



position shift

Usual remedy:  
 measure on both sides (L/R)  
 flip initial spin  
 use cross ratio formula

$$\varepsilon = pA = \frac{r-1}{r+1}$$

$$r = \sqrt{\frac{C_{L+} C_{R-}}{C_{L-} C_{R+}}}$$

left/right efficiency differences cancel

+/- luminosity differences cancel

spin detector

Errors that are second-order in  $\theta$  and  $u=p_++p_-$

$$\varepsilon_{meas} = \varepsilon + \frac{1}{1-\varepsilon^2} \left[ \varepsilon^3 u^2 + 2\varepsilon^2 \frac{A'}{A} u \theta + \varepsilon \left( \frac{A''}{A} (1-\varepsilon^2) - \left( \frac{A'}{A} \right)^2 \varepsilon^2 \right) \theta^2 \right]$$

logarithmic derivatives of the analyzing power  
as a function of scattering angle

Sizes of logarithmic derivatives need to be evaluated  
for some polarimeter acceptance geometry.

We are helped by the small size of the asymmetry  
and the expected time dependence.