1 Nov 2010

SANTA FE

POLARIZED PROTON BEAMS: PAST, PRESENT & FUTURE

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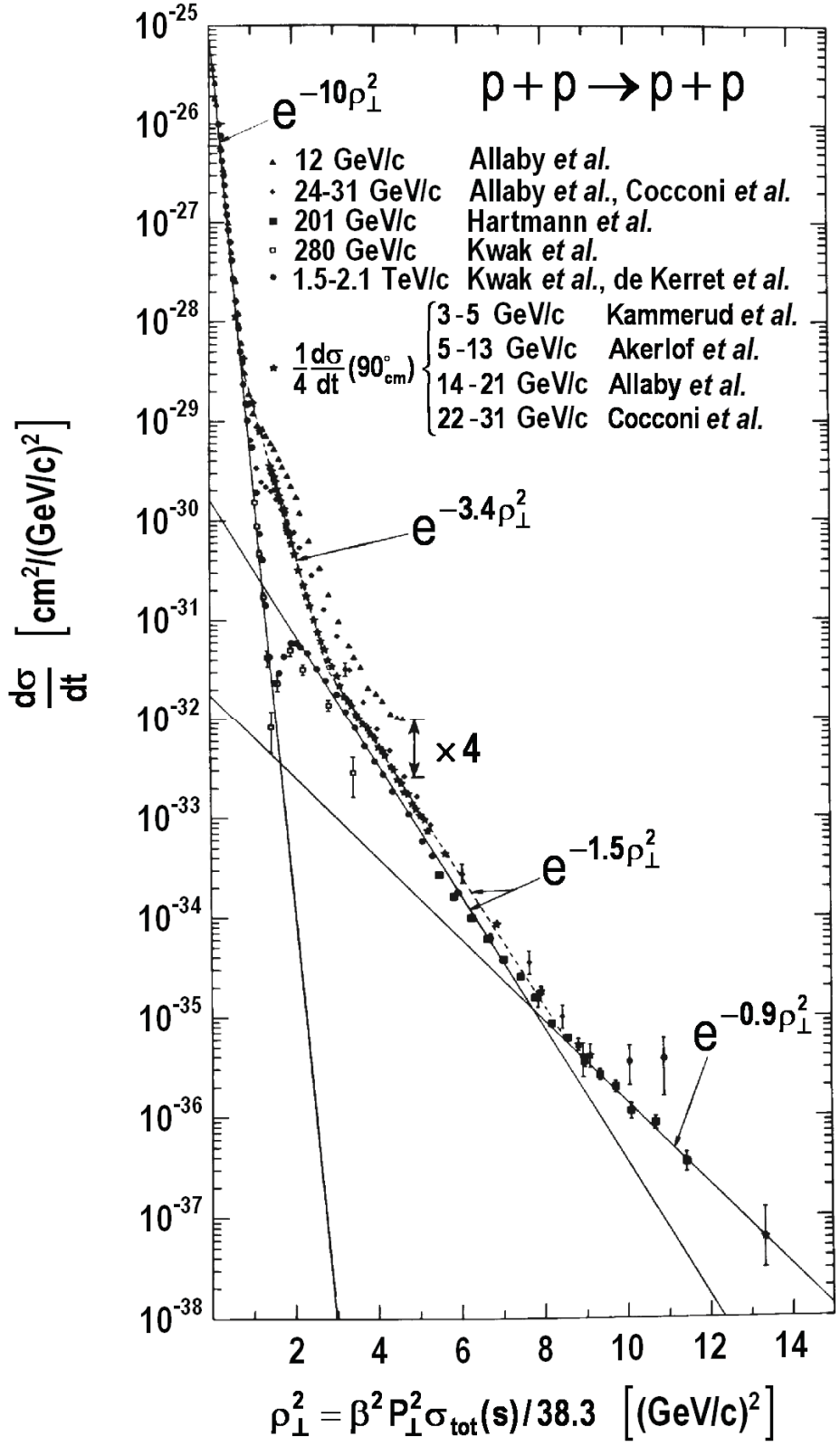
PROTON-PROTON ELASTIC CROSS-SECTION

UNPOLARIZED $d\sigma/dt$ for all
$p + p \rightarrow p + p$ data above 3 GeV
PLOTTED vs. SCALED $P_\perp^2$ VARIABLE

NOTE 4 DIFFERENT SLOPES
FIRST EVIDENCE for STRUCTURE
inside PROTON (Akerlof *et al.* 1966)

1968 Comment by Prof. Serber on x4 at 90°_{cm}
led to interest in spin & polarized beams



ARGONNE 12 GeV ZGS WORLD'S FIRST HIGH ENERGY POLARIZED PROTON BEAM

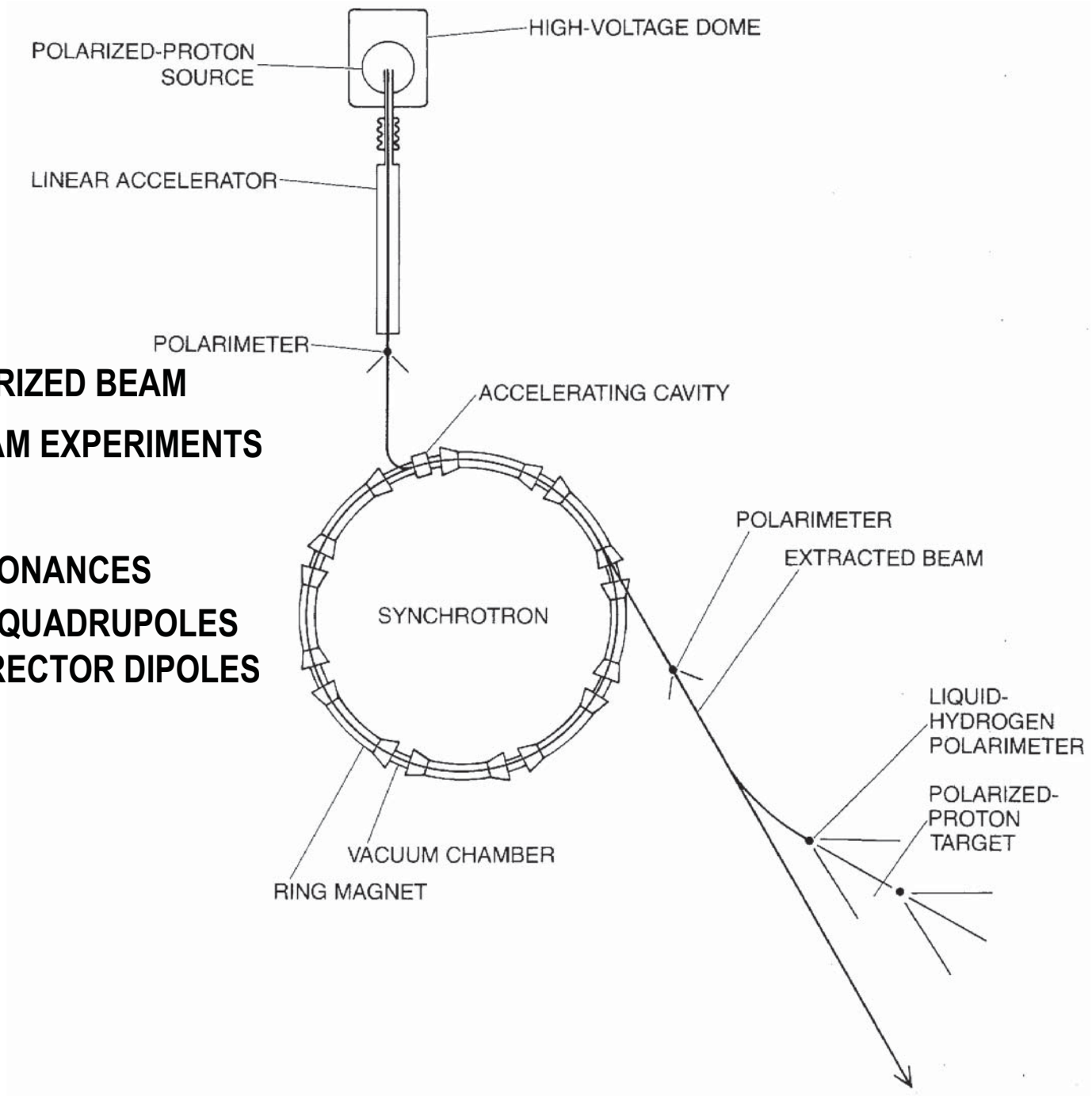
1969-1973 DEVELOP POLARIZED BEAM

1973-1979 POLARIZED BEAM EXPERIMENTS

DEPOLARIZING RESONANCES

INTRINSIC: PULSED QUADRUPOLES

IMPERFECTION: CORRECTOR DIPOLES



2-SPIN PROTON-PROTON ELASTIC CROSS SECTIONS

12 GeV ZGS

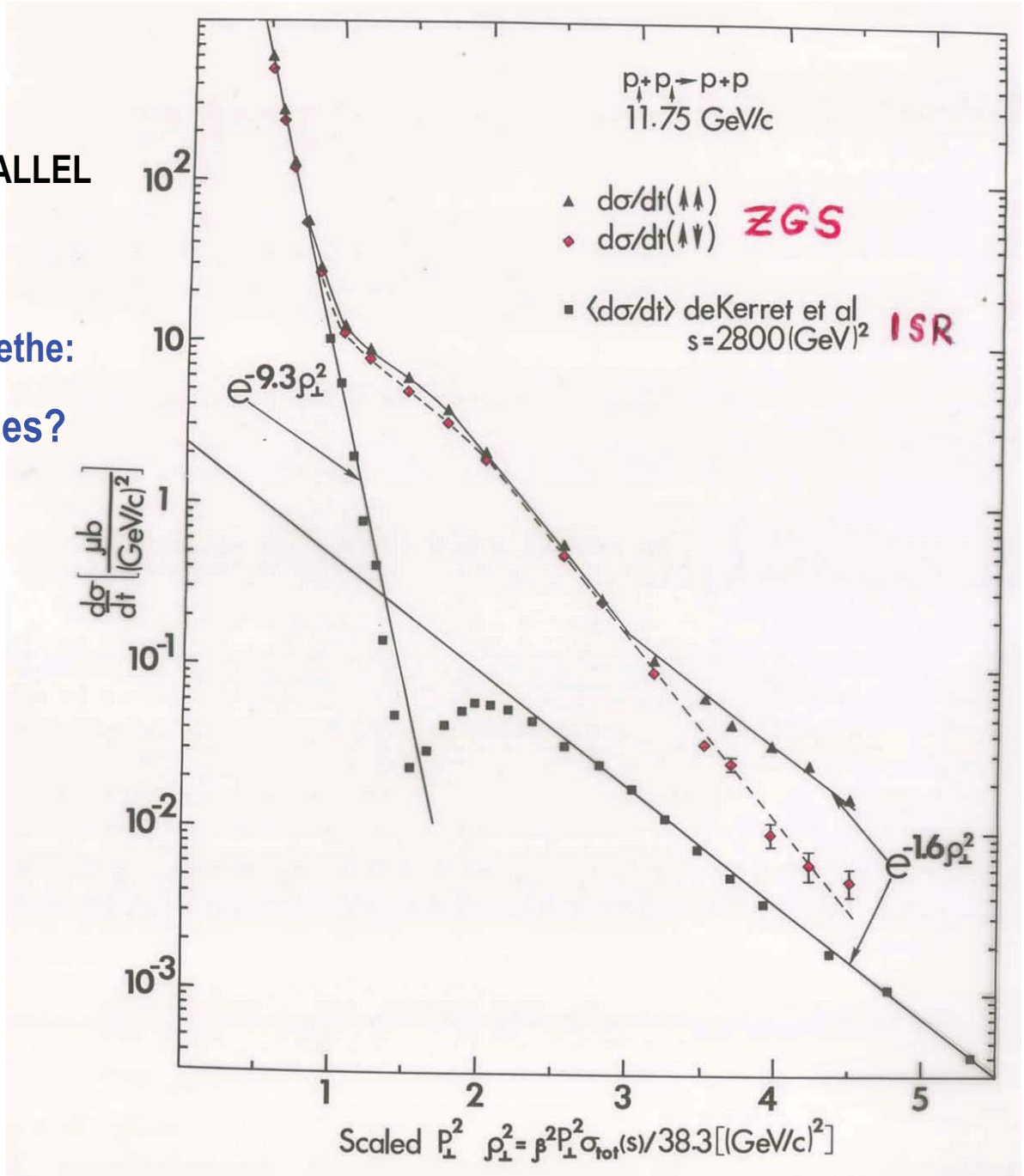
1977-1978

SPINS PARALLEL 4x SPINS ANTIPARALLEL

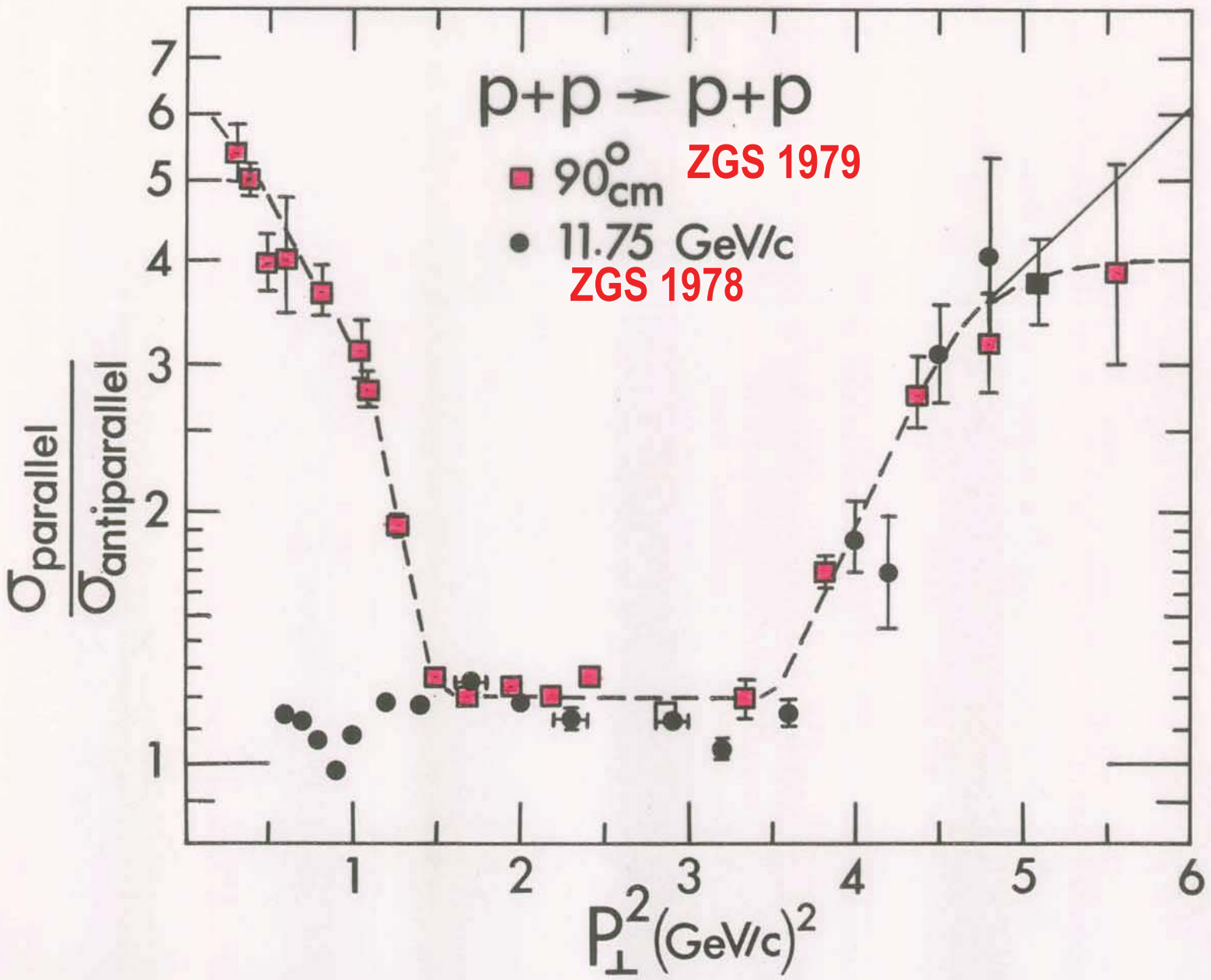
TOTALLY UNEXPECTED

Questions by Profs. Weisskopf & Bethe:

High P_T or 90°_{cm} Identical Particles?



Answer to Questions by Profs. Weisskopf & Bethe



BNL AGS: First Strong Focusing Polarized Proton Beam

1977- 84 Polarized Beam Development

1984-now Experiments & RHIC Injector

VERY DIFFICULT PROJECT

Hardware: $10 Million 1980$

45 Depol. Resonances:

INTRINSIC IMPERFECTION

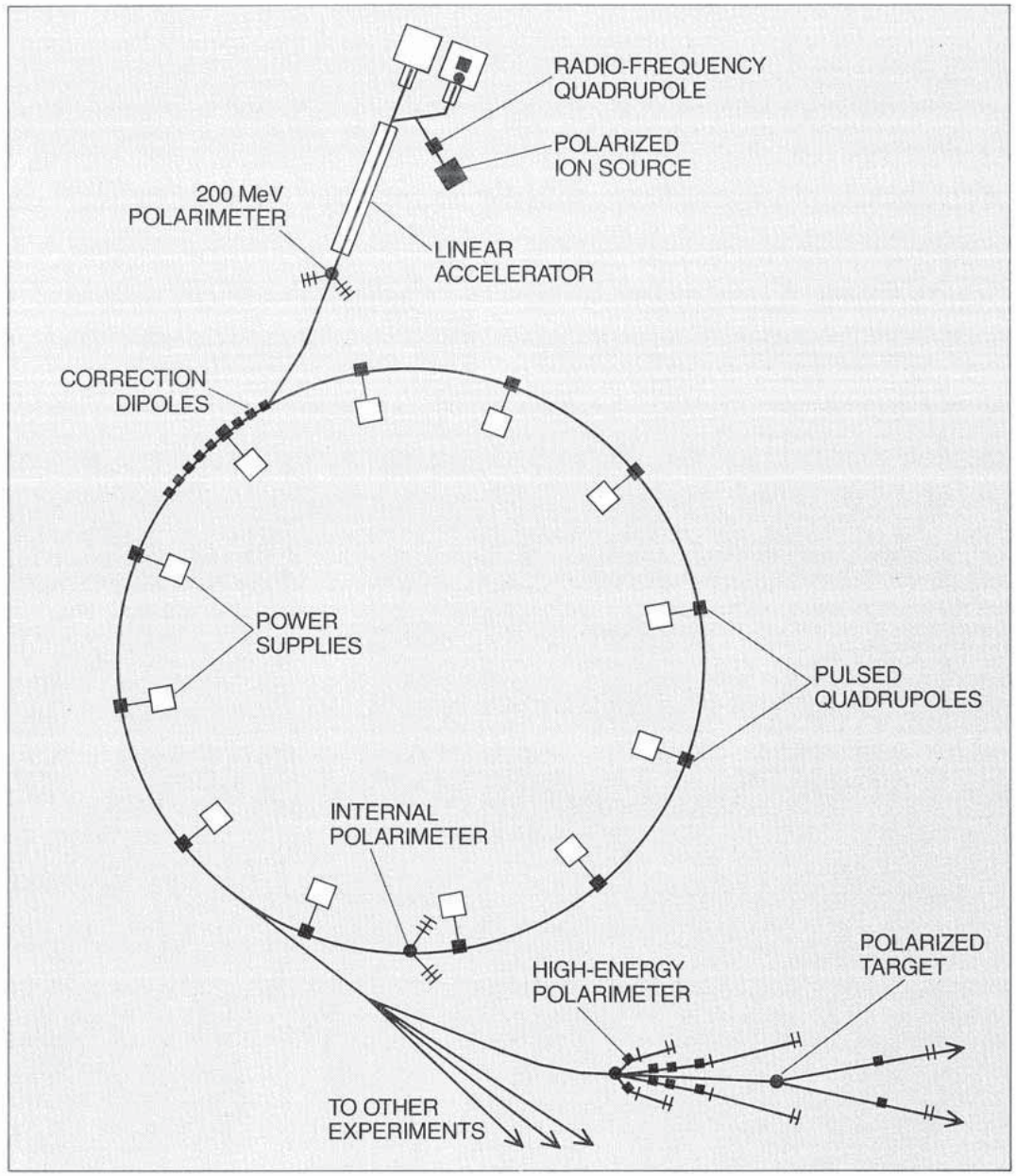
12 Pulsed Quads 96 Correction Dipoles

AGS Tune-up Time:

1984-88: 3-7 weeks each year

1988: 22 GeV/c Polarization 42%

2000-now: Better with new ideas; but still hard



POLARIZED BEAMS at SSC 1983

POLARIZED PROTONS at 20-20 TeV

INDIVIDUALLY OVERCOME EACH RESONANCE
- **Worked very well at 12 GeV Weak Focusing ZGS**
- **Worked painfully at 28 GeV Strong Focusing AGS**
- **Impossible at 20 TeV Strong Focusing SSC**

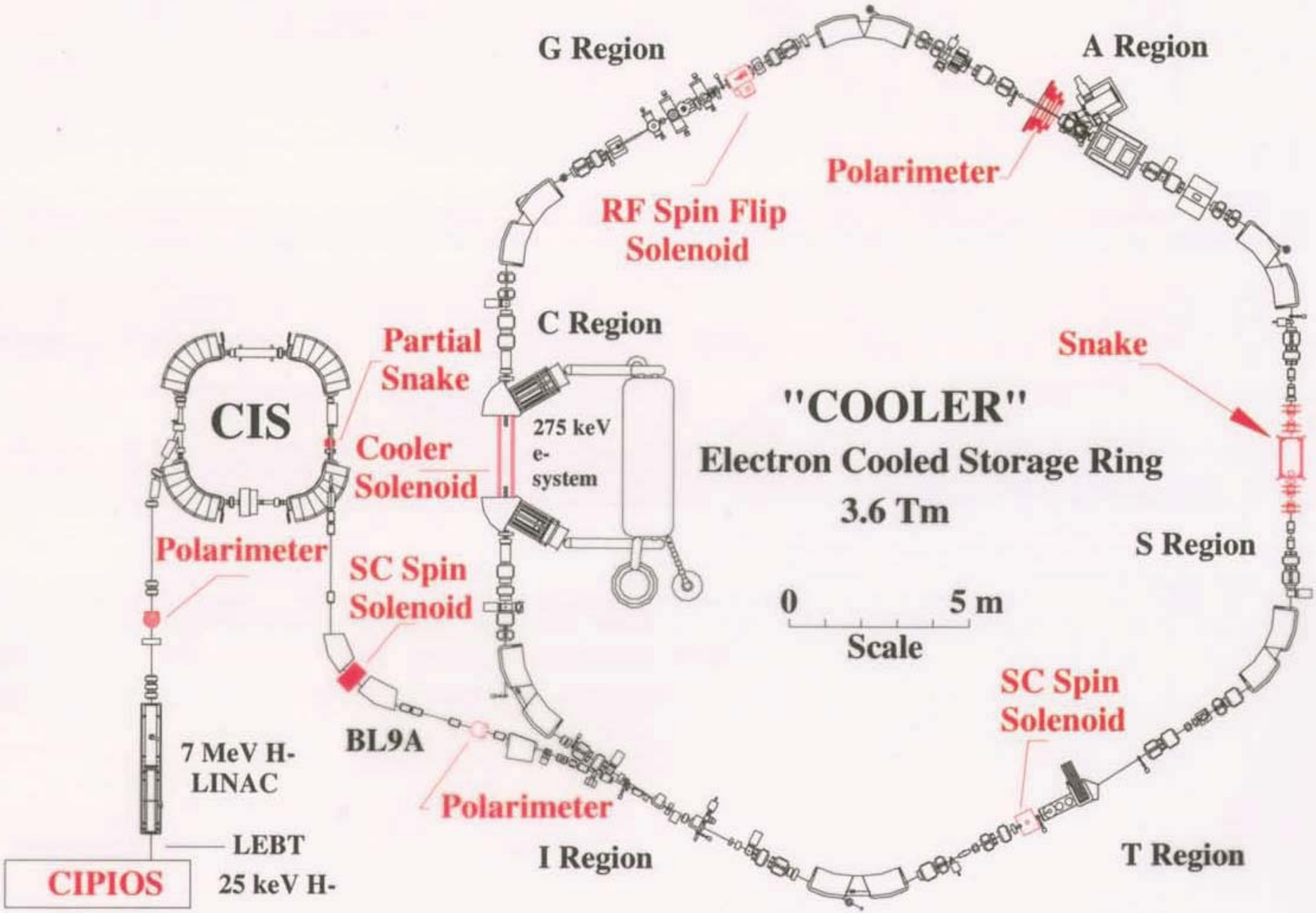
SIBERIAN SNAKES DERBENEV & KONDRATENKO ~1977

CHAMBERLAIN, COURANT, TERWILLIGER, ADK
1985 ANN ARBOR WORKSHOP on PPB in SSC:
CONCLUSIONS:

1. 20 TeV PPB POSSIBLE with 26 SNAKES / RING
BUT SEEMS: "TOO GOOD TO BE TRUE"

2. MUST TEST SIBERIAN SNAKE EXPERIMENTALLY

TEST SIBERIAN SNAKE IUCF COOLER RING: 1985-2002



FIRST SIBERIAN SNAKE TEST 1989

ROTATES SPIN by 180° per TURN

SIBERIAN SNAKE TEST

PRL 1989

First Test of the Siberian Snake Magnet Arrangement to Overcome Depolarizing Resonances in a Circular Accelerator

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Randall Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan 48109

J. E. Goodwin, H-O. Meyer, M. G. Minty, P. V. Pancella, R. E. Pollock, T. Rinckel, M. A. Ross, F. Sperisen, and E. J. Stephenson
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

E. D. Courant, S. Y. Lee, and L. G. Ratner
Brookhaven National Laboratory, Upton, New York 11973
(Received 25 July 1989)

We studied the $G\gamma=2$ imperfection depolarizing resonance at 108 MeV, both with and without a Siberian snake, by varying the resonance strength while storing beams of 104- and 120-MeV polarized protons at the Indiana University Cooler Ring. We used a cylindrically symmetric polarimeter to simultaneously study the effect of a depolarizing resonance on both the vertical and radial components of the polarization. At 104 MeV we found that the Siberian snake eliminated the effect of the nearby $G\gamma=2$ depolarizing resonance.

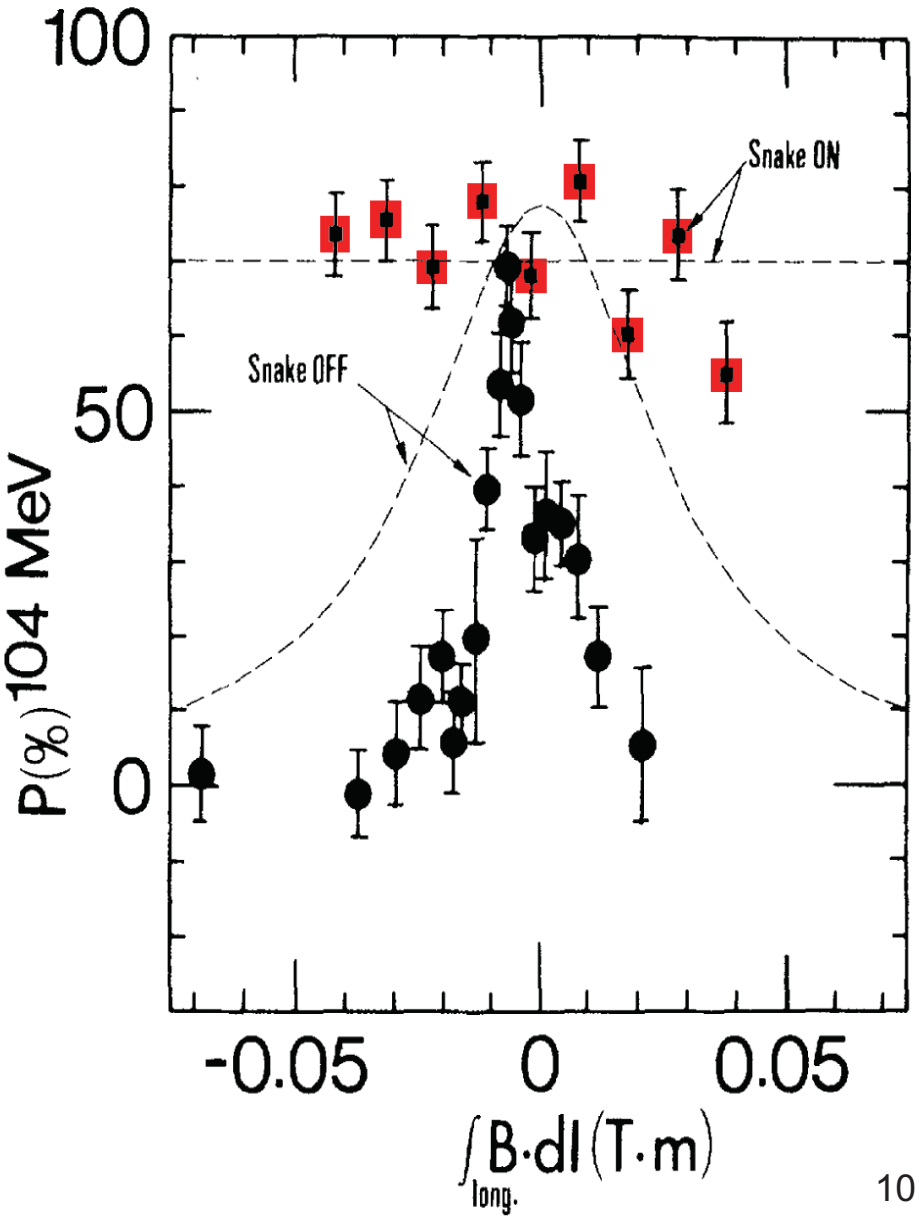


FIG. 4. The beam polarization in each stable polarization direction at 104 MeV is plotted against the longitudinal magnetic field integral in the Cooler Ring solenoids. The circles are the vertical polarization with the snake off and the injection of vertically polarized protons. The squares are the radial polarization with the snake on and the injection of horizontally polarized protons. We combined all data into bins of width 0.00115 Tm. There is a systematic normalization uncertainty of about ±5%. The dashed curve is the predicted behavior. The straight dashed line is a fit.

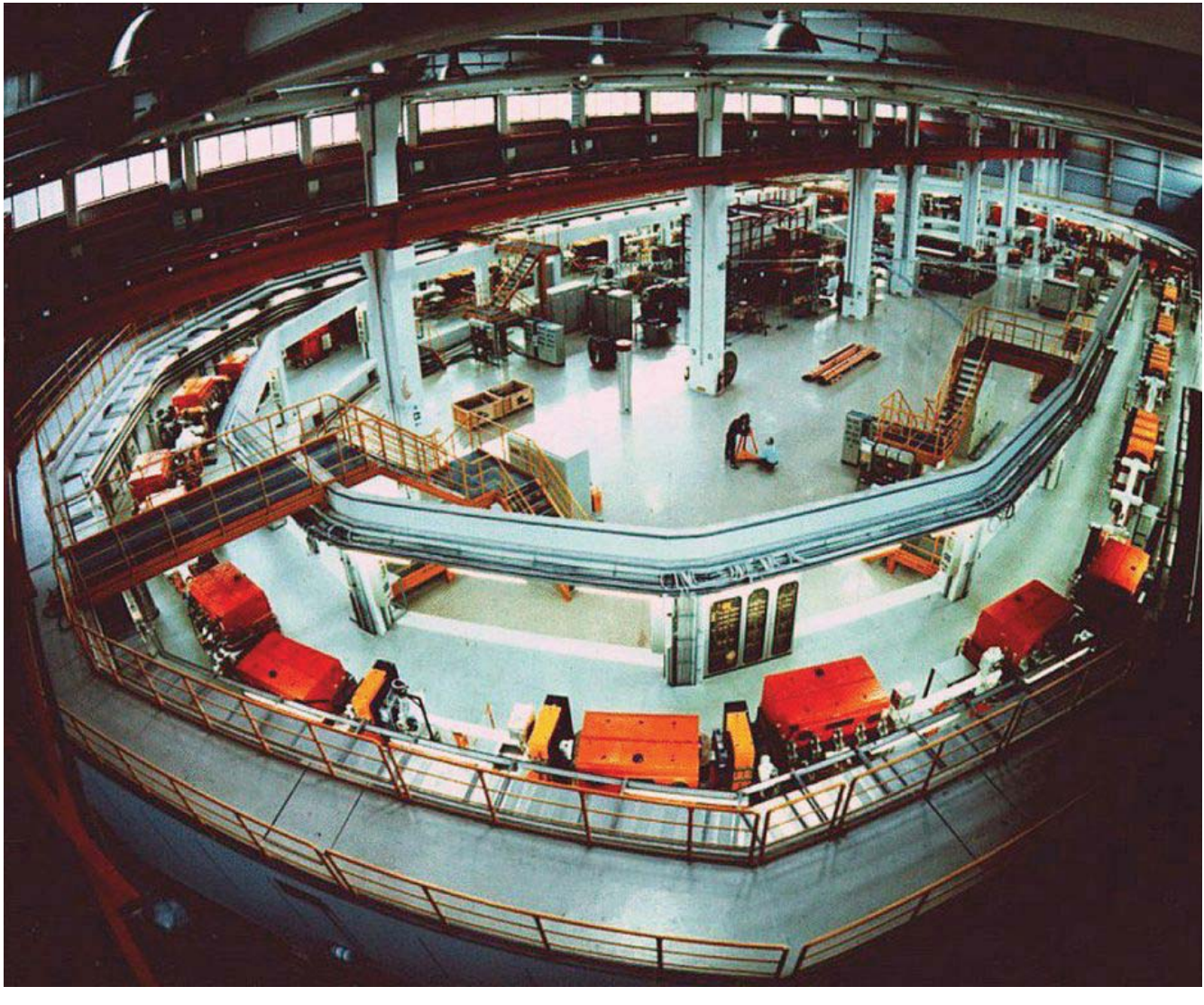
SPIN@COSY 2002-2009

CERN COURIER

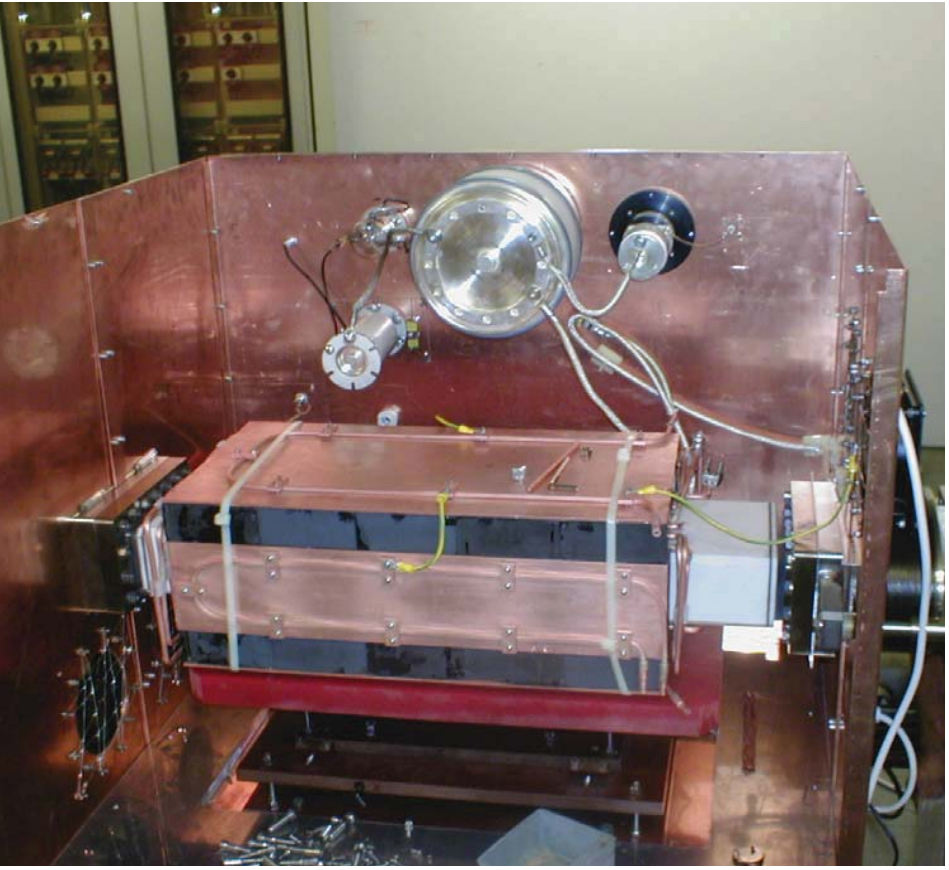
Nov 24, 2004

Spin-flipping crosses the Atlantic

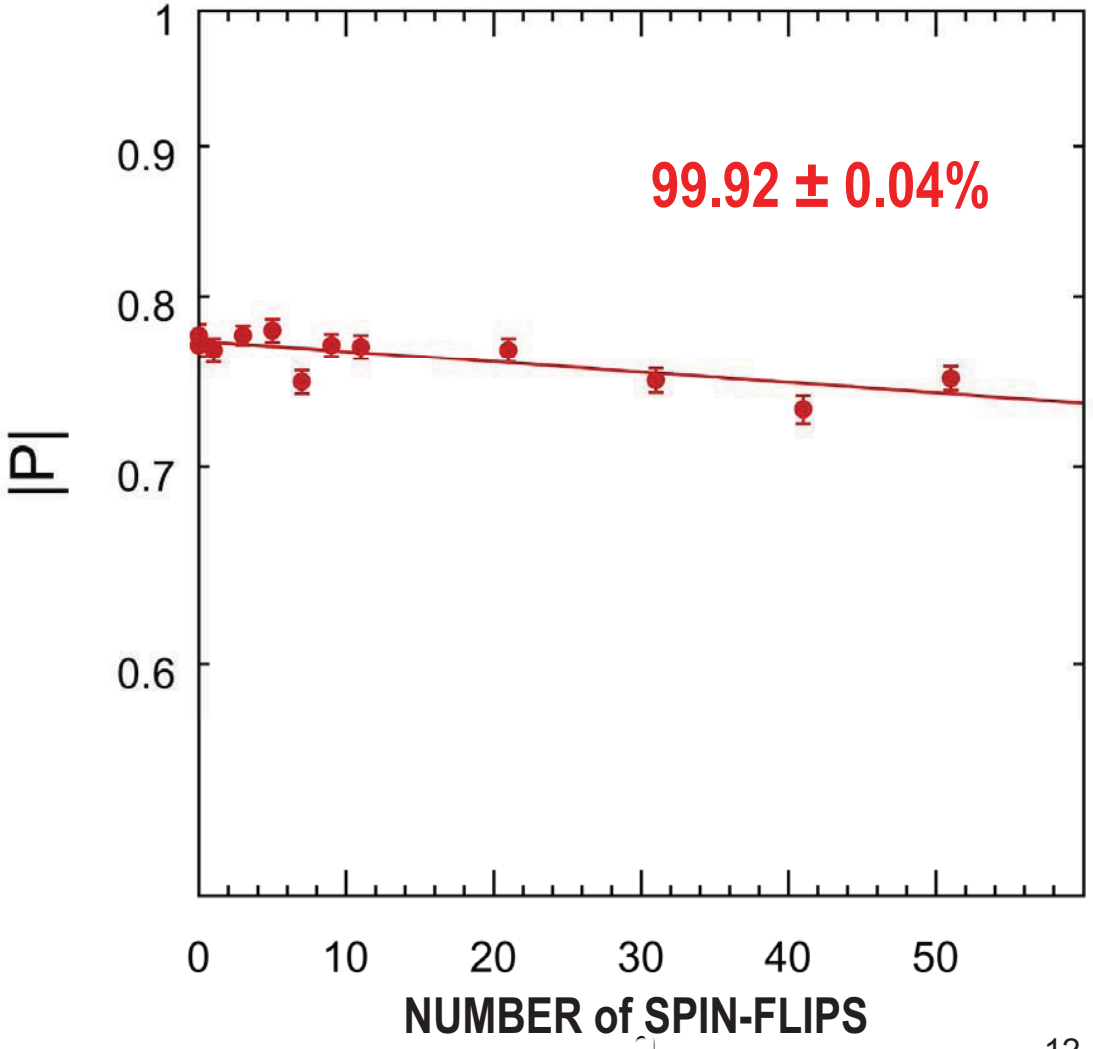
After the venerable Cooler Ring at the Indiana University Cyclotron Facility (IUCF) passed on to accelerator heaven in autumn 2002, the polarized beam team, led by Alan Krisch, crossed the Atlantic to continue their spin-manipulation work at COSY, the cooler synchrotron at the Forschungszentrum in Jülich (figure 1). As part of the SPIN@COSY collaboration, they have been improving the polarization capabilities of the 3.5 GeV/c proton and deuteron storage ring. Recently, the collaboration - from Michigan and Brookhaven in America, COSY, Bonn and Hamburg in Germany, and KEK and J-PARC in Japan - has used a new ferrite RF-dipole magnet to flip the spins of stored 2.1 GeV/c protons with almost no polarization loss.



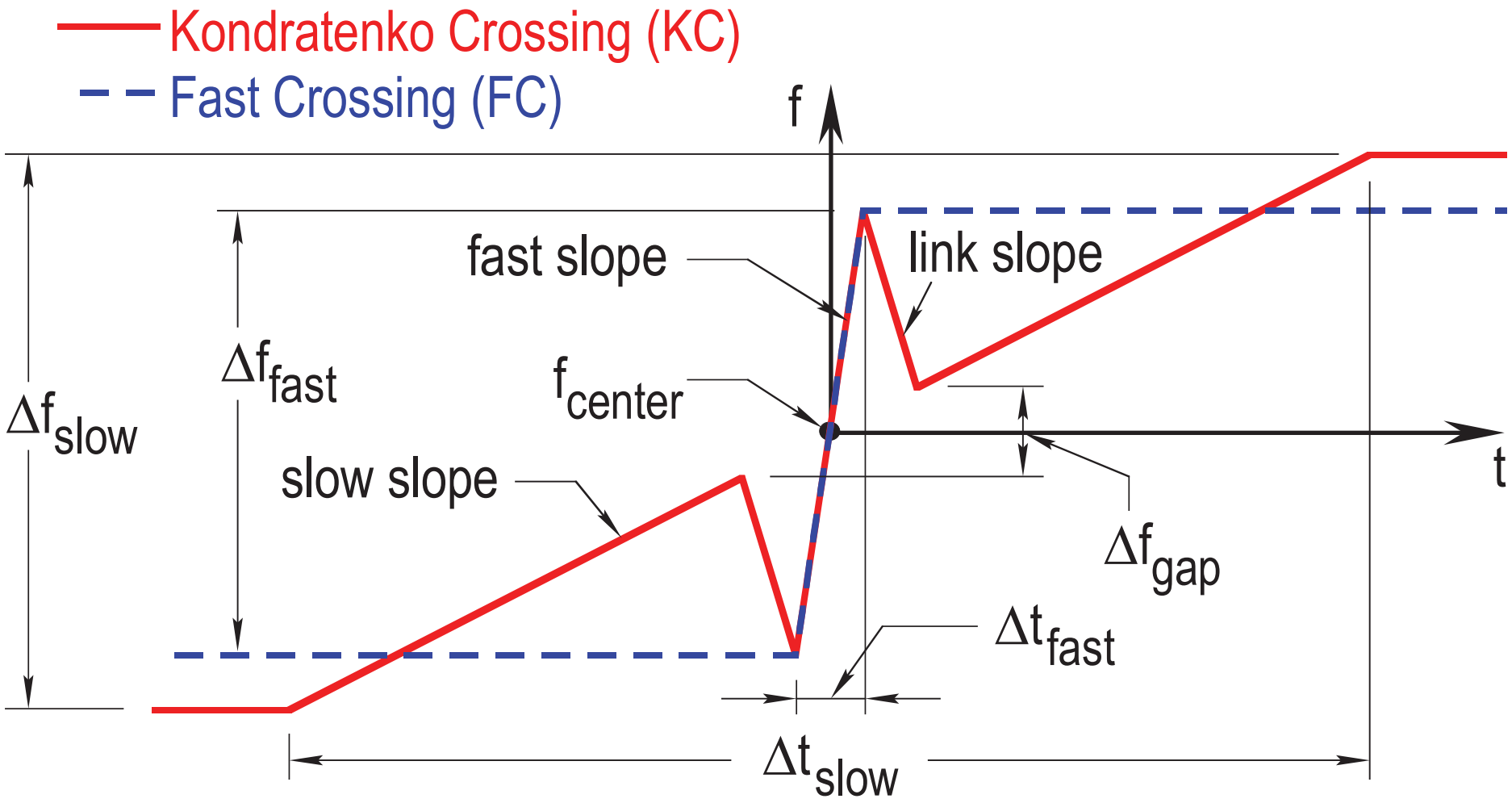
VERY HIGH SPIN-FLIP EFFICIENCY with SMALL RF DIPOLE



$\int B_{rms} \cdot dl$ = 0.54 T·mm at ~917 kHz

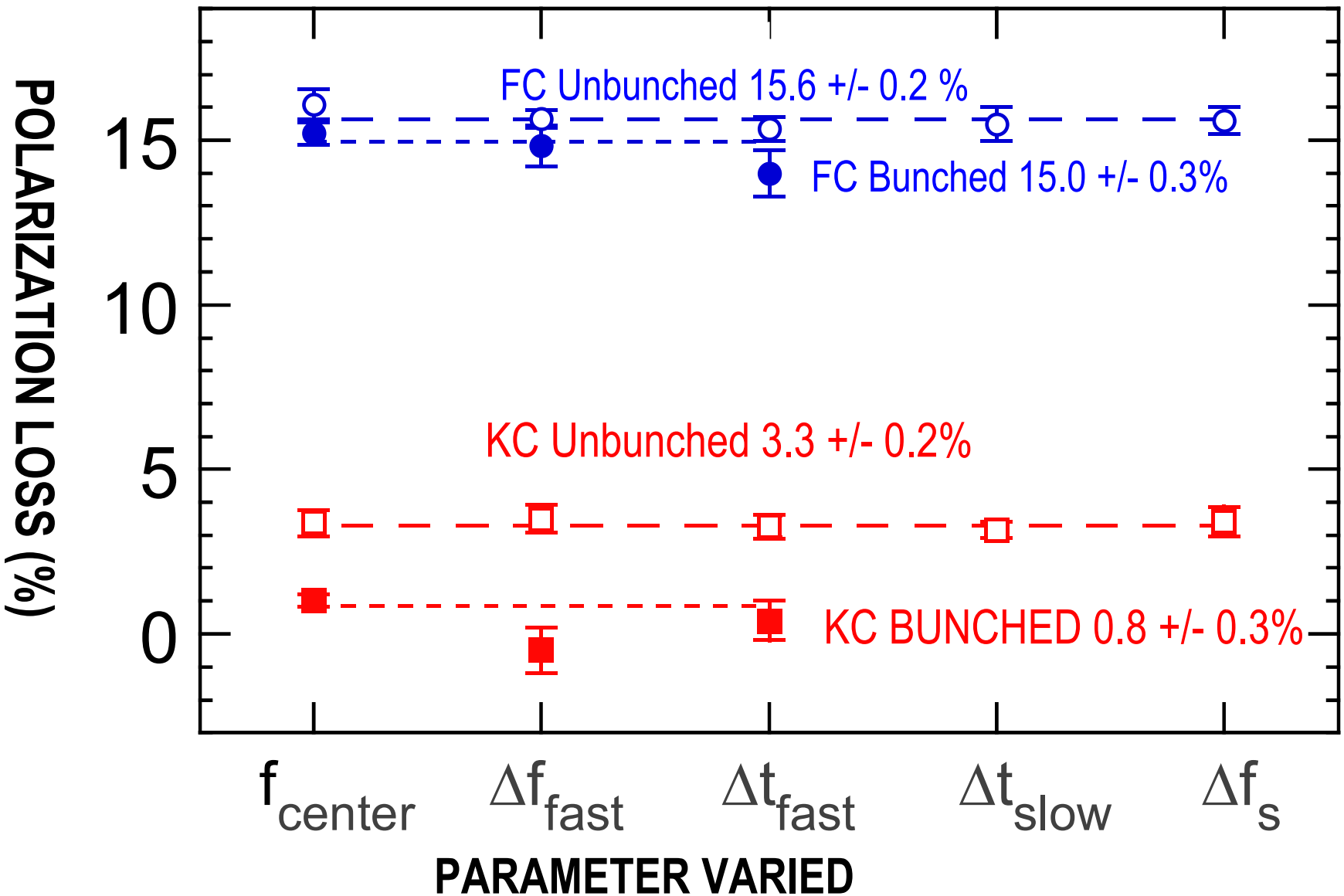


KONDRATENKO CROSSING SHAPE



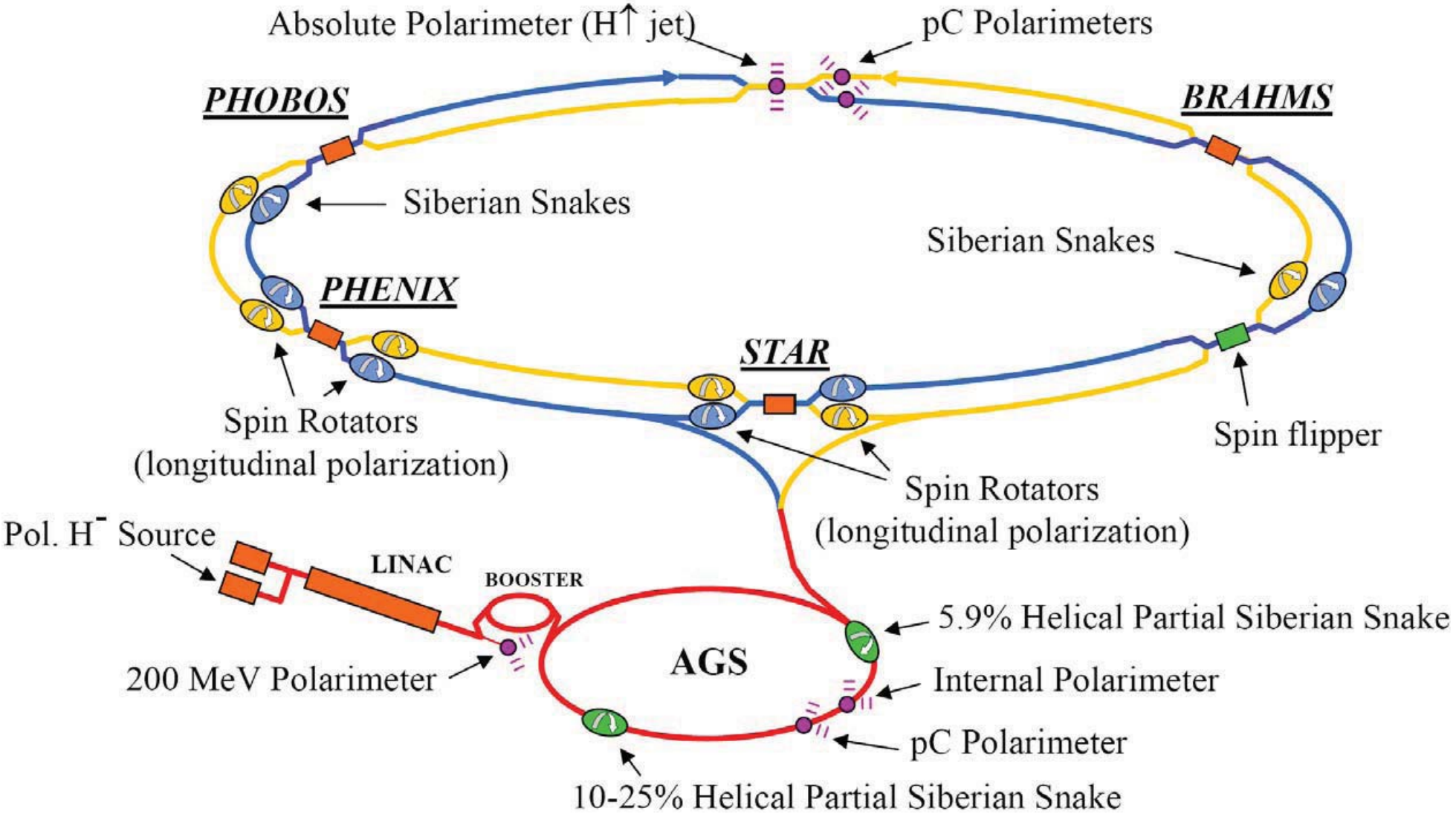
KONDRATENKO CROSSING (KC) vs. FAST CROSSING (FC)

At KC Polarization Peak At EQUAL KC and FC Crossing Speeds MAY 2008



V.S. Morozov *et al*. PRL **102**, 244801 (2009)

RHIC POLARIZED BEAM COMPLEX



UM HE 95-09
July 24, 1995

Acceleration of Polarized Protons to 120 GeV and 1 TeV at Fermilab

SPIN Collaboration

Michigan, Indiana, Fermilab,

IHEP-Protvino, JINR-Dubna, Moscow, INR-Moscow, BINP-Novosibirsk

KEK

TRIUMF

The SPIN collaboration has studied the acceleration of a polarized proton beam in the Fermilab Main Injector and Tevatron. The first section of this Report summarizes some physics goals for a polarized proton beam near 120 GeV and 1 TeV; it also contains a schedule and budget for the Polarized Main Injector and Polarized Tevatron-Collider projects. The rest of the Report describes the detailed plan to accelerate polarized protons and to perform polarized proton experiments in the Main Injector, the Tevatron and the Tevatron-Collider. Some highlights are:

- Nine Siberian snakes and some other minor hardware should allow 75% polarization to be maintained and manipulated in the Booster, Main Injector, and Tevatron.
- Recent progress in ABS and OPPIS polarized ion sources (0.6 mA and 1.6 mA) should allow a polarized Collider luminosity of about $7 \cdot 10^{31}$ cm^{-2}s^{-1}. We are supporting R & D for both source types to reach an even higher polarized luminosity.
- The source's 30-month preparation time makes it a critical-path item. A decision is required by *mid-August 1995* to allow installation of a polarized source and other polarized hardware during the 1998 Main Injector installation shutdown.
- To make empty spaces in the Tevatron for six Siberian snakes and four Collider-detector spin rotators, twenty new 6 T superconducting dipoles would replace thirty-six existing 4.4 T Tevatron ring dipoles. Since an *immediate* decision on the 6 T dipoles would be needed to install them and the Tevatron snakes during the 1998 Main Injector installation shutdown, we instead recommend a *phased* commissioning of the Polarized Main Injector and Polarized Tevatron.

1.2 SPIN collaboration list

July 20, 1995

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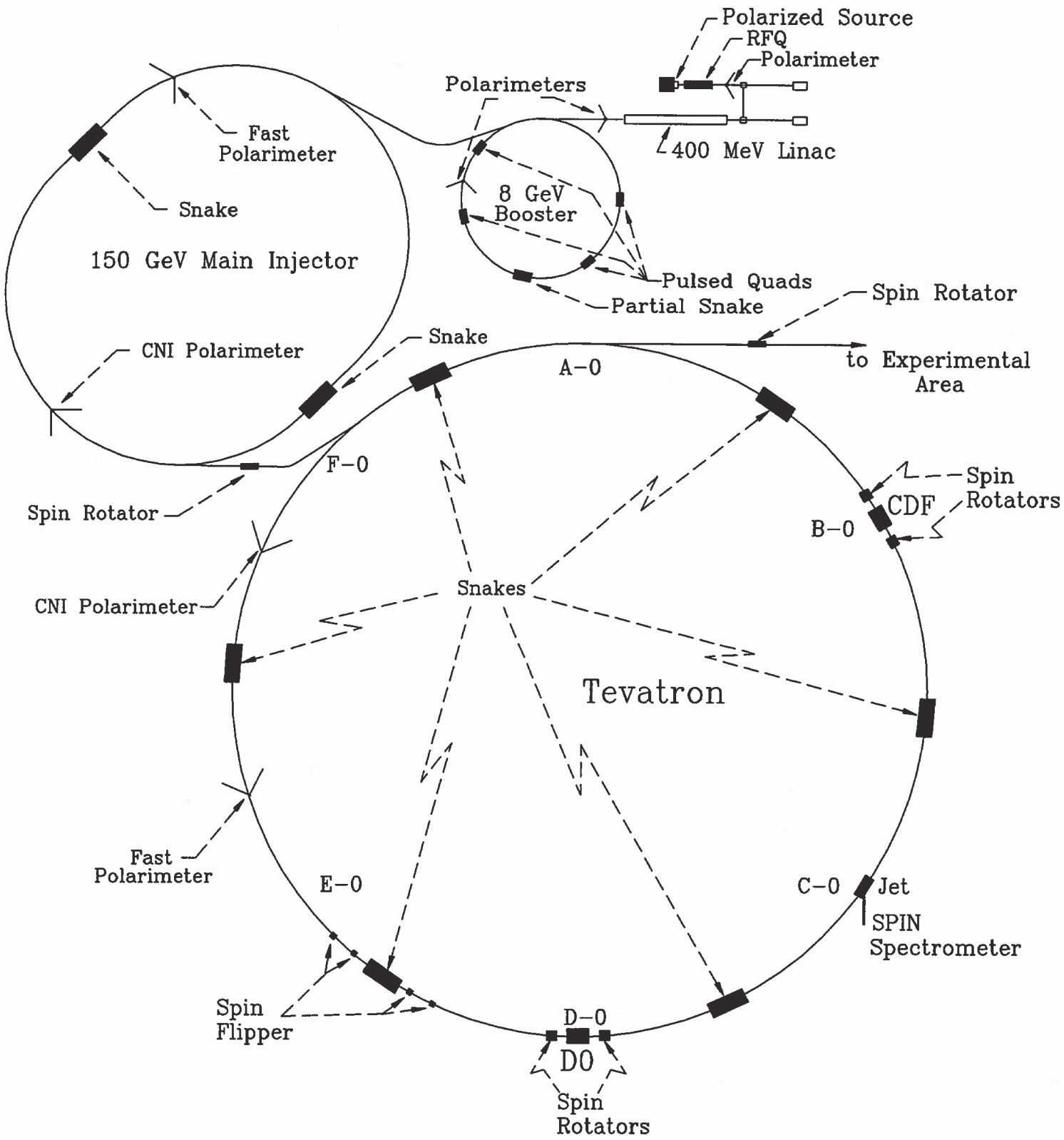
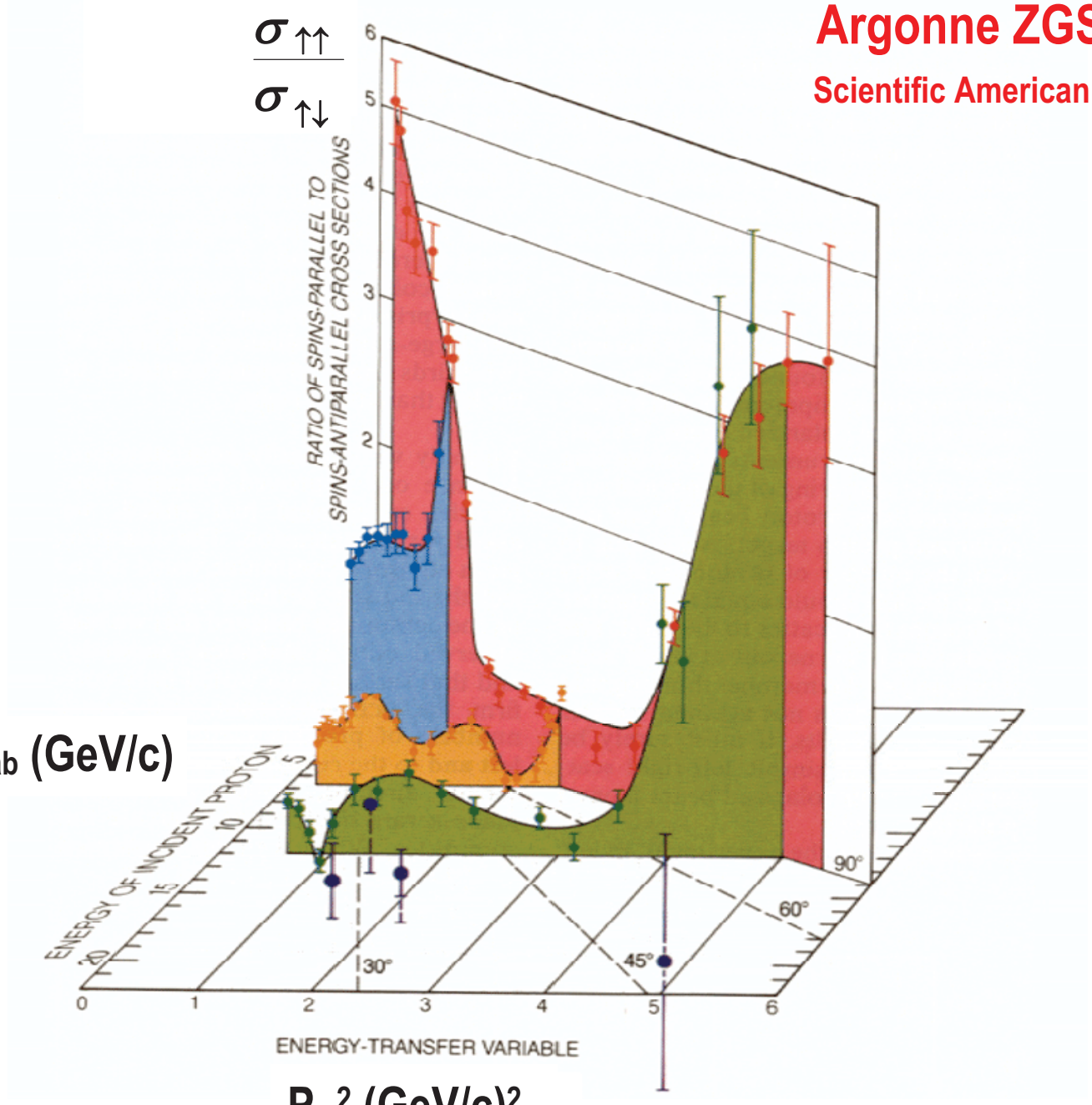
i SLAC
j Tokyo Univ.
k Univ. of Alberta
l Kyushu Univ.
m INR-Moscow


Polarized Source
RFQ
Polarimeter
Polarimeters
400 MeV Linac
Fast
Polarimeter
Snake
150 GeV Main Injector
8 GeV
Booster
Pulsed Quads
Partial Snake
Spin Rotator
to Experimental
Area
CNI Polarimeter
Snake
A-0
F-0
Spin Rotator
Spin
Rotators
CDF
B-0
CNI Polarimeter
Snakes
Tevatron
Fast
Polarimeter
E-0
C-0
Jet
SPIN
Spectrometer
Spin
Flipper
D-0
D0
Spin
Rotators

Ratio Spin-Parallel: Spin-Antiparallel p-p Elastic Cross-Sections

Argonne ZGS 1977-79

Scientific American 1979 & 1987

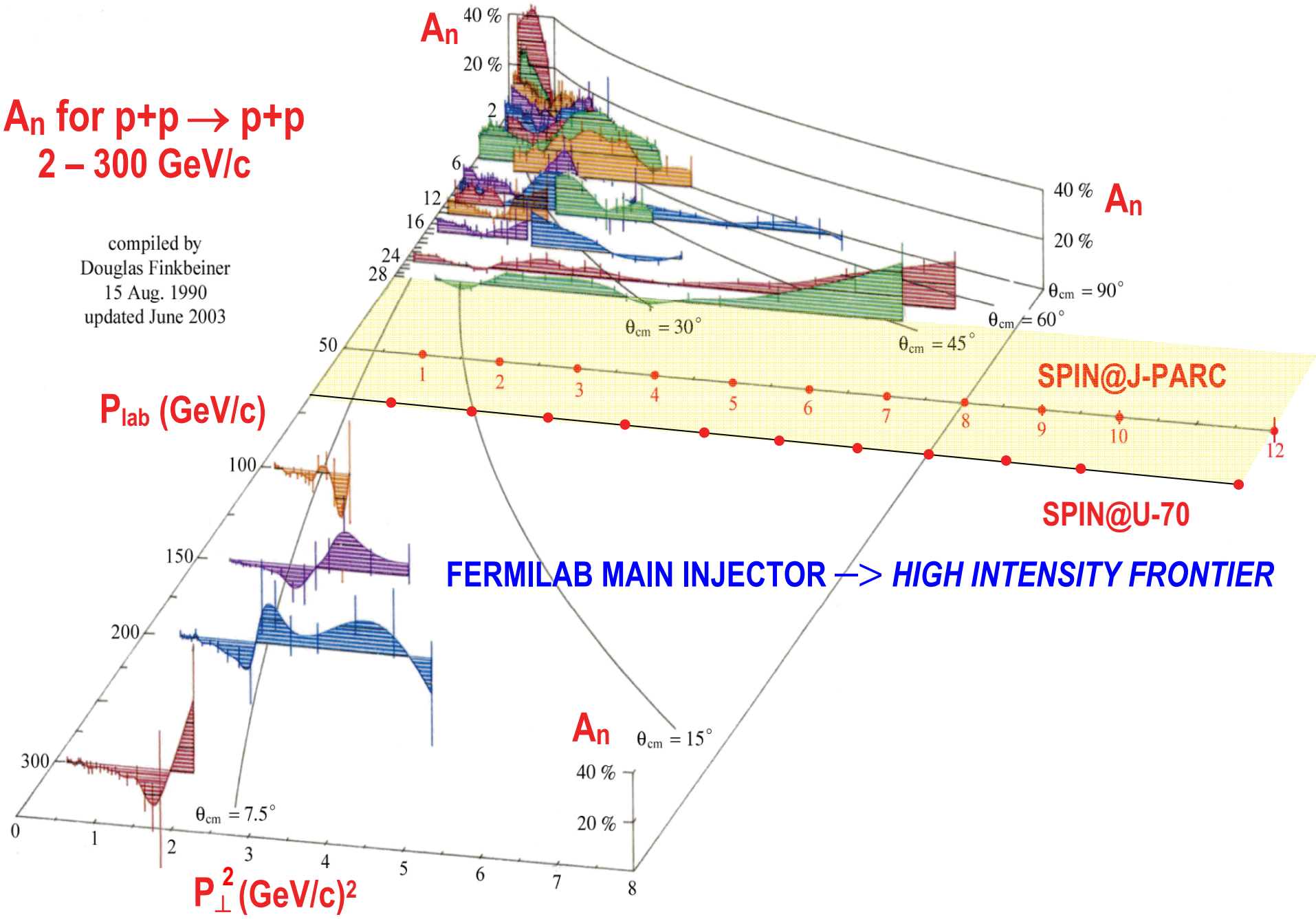


P_{Lab} (GeV/c)

$P_{\perp}^2$ (GeV/c)^2

A_n for p+p → p+p
2 – 300 GeV/c

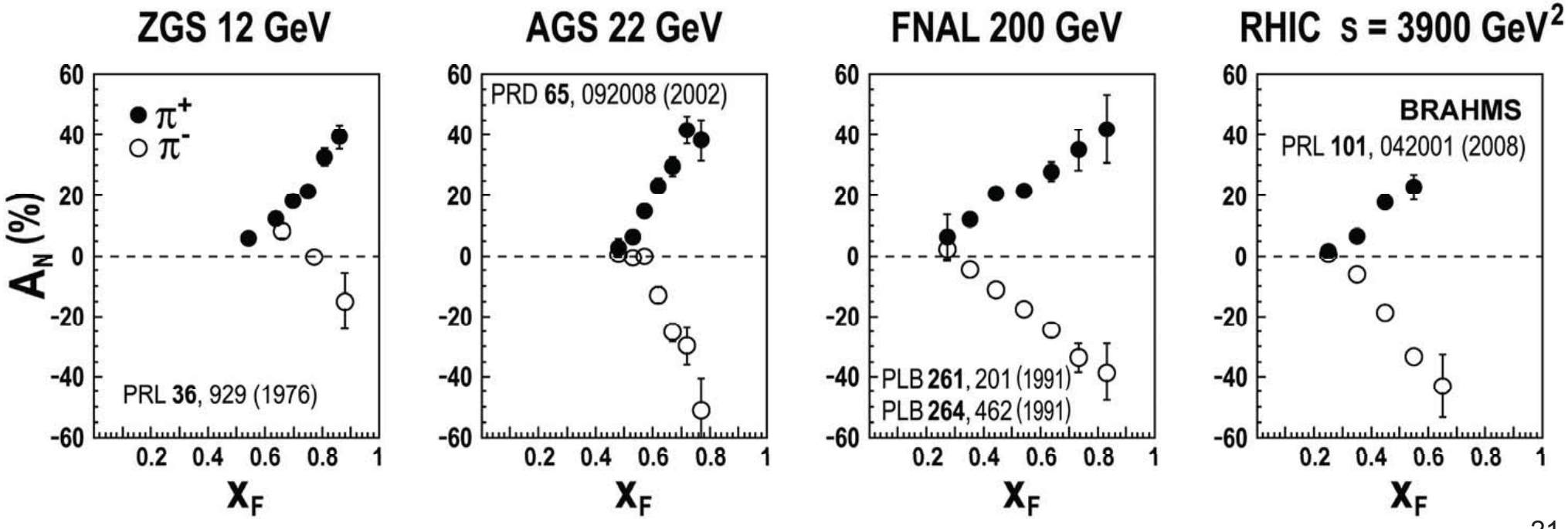
compiled by
Douglas Finkbeiner
15 Aug. 1990
updated June 2003



FERMILAB MAIN INJECTOR —> *HIGH INTENSITY FRONTIER*

INCLUSIVE PION ASYMMETRY IN PROTON-PROTON COLLISIONS

C. Aidala SPIN 2008 Proceeding and CERN Courier June 2009



SUMMARY

For 30+ years QCD-based calculations could not explain large transverse spin effects:

- **ZGS 2-spin & AGS 1-spin p-p elastic data;**
- **Fermilab large hyperon polarization**
- **ZGS, AGS, Fermilab & RHIC p-p inclusive spin data.**

★ **Large spin effects do not go to zero at high-energy or high-$P_\perp$ as earlier predicted.**

★ **Resulted in modifications of QCD that unpolarized experiments could not see.**

BASIC PRINCIPLE OF SCIENCE:

If theory does not agree with reproducible experimental data,
then theory must be modified.

★ **High energy proton spin data → experimental guidance for further QCD modification.**