SPIN@J-PARC PROPOSAL

2007 DECEMBER 28

Analyzing Power A_n and A_{nn} in 30-50 GeV Very-High-$P_\perp^2$ Proton-Proton Elastic Scattering

A.W. CHAO, F.Z. KHIARI [§], A.D. KRISCH [*], M.A. LEONOVA, V.G. LUPPOV, V.S. MOROZOV, R.S. RAYMOND, D.W. SIVERS, and V.K. WONG	UNIVERSITY OF MICHIGAN, ANN ARBOR, USA
D.G. CRABB	UNIVERSITY OF VIRGINIA, CHARLOTTESVILLE, USA
J. R. O'FALLON [#]	U.S. DEPARTMENT OF ENERGY, USA
Y.S. DERBENEV	JEFFERSON LABORATORY, USA
K. YONEHARA	FERMILAB, USA
S. ISHIMOTO	KEK, TSUKUBA, JAPAN
K. HATANAKA and STUDENTS	RCNP, OSAKA, JAPAN
T.-A. SHIBATA	TOKYO INSTITUTE OF TECHNOLOGY, TOKYO, JAPAN
Y. SAKEMI	TOHOKU UNIVERSITY, JAPAN
G. FIDECARO [#] and M. FIDECARO [#]	CERN, SWITZERLAND
A. I. MYSNIK, A.F. PRUDKOGLYAD, S.M. TROSHIN, and M.N. UKHANOV	INSTITUTE FOR HIGH ENERGY PHYSICS, PROTVINO, RUSSIA
A.M. KONDRATENKO	GOO ZARYAD, NOVOSIBIRSK, RUSSIA
W.T.H. VAN OERS	TRIUMF, VANCOUVER, CANADA

* SPOKESPERSON, [#] RETIRED, [§] NOT YET CONFIRMED

UNPOLARIZED BEAM and TARGET

$$\left\langle \frac{d\sigma}{dt} \right\rangle \propto \left(N_{\uparrow\uparrow} + N_{\uparrow\downarrow} + N_{\downarrow\uparrow} + N_{\downarrow\downarrow}\right)$$

EITHER BEAM or TARGET POLARIZED (ONE-SPIN)

$$A_n = \frac{A_{meas}}{P_T} = \frac{\left(N_{\uparrow} - N_{\downarrow}\right)}{P_T\left(N_{\uparrow} + N_{\downarrow}\right)}$$

BOTH BEAM and TARGET POLARIZED (TWO-SPIN)

$$A_{nn} = \frac{A_{meas}}{P_T P_B} = \frac{\left(N_{\uparrow\uparrow} - N_{\uparrow\downarrow} - N_{\downarrow\uparrow} + N_{\downarrow\downarrow}\right)}{P_T P_B\left(N_{\uparrow\uparrow} + N_{\uparrow\downarrow} + N_{\downarrow\uparrow} + N_{\downarrow\downarrow}\right)}$$

A_{meas} = MEASURED ASYMMETRY

P_T and P_B = TARGET and BEAM POLARIZATIONS

N_i and N_{ij} = NORMALIZED ELASTIC EVENT RATES

PERTURBATIVE QCD $\Rightarrow$

$A_n = 0$ at HIGH $P_\perp^2$ and HIGH ENERGY

$A_n \neq 0 \Rightarrow$

PROBLEM with PQCD?

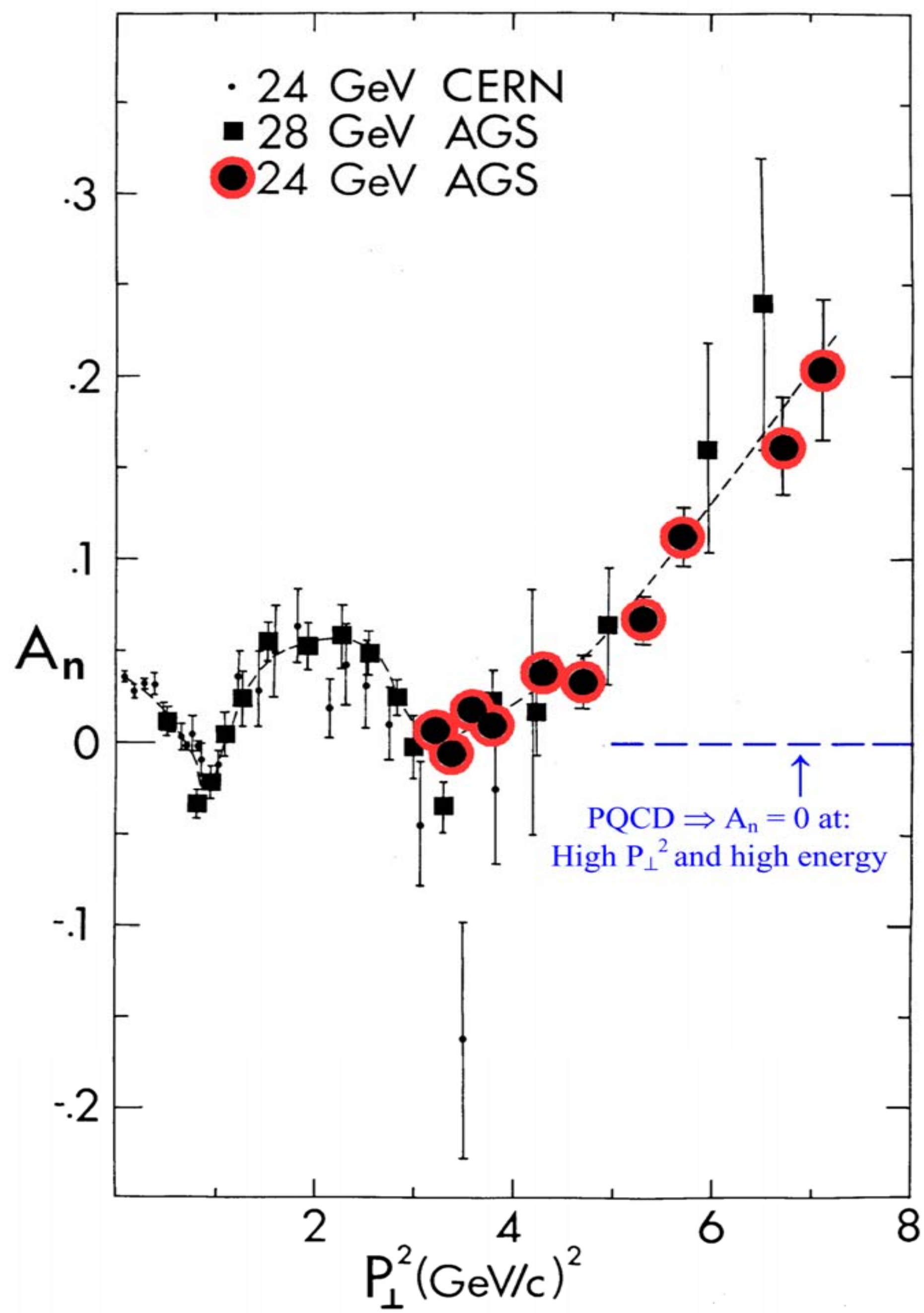
NO MODEL can EXPLAIN ALL

HIGH-$P_\perp^2$ SPIN EFFECTS (A_n & A_{nn})

GOAL

MEASURE A_n (and A_{nn})

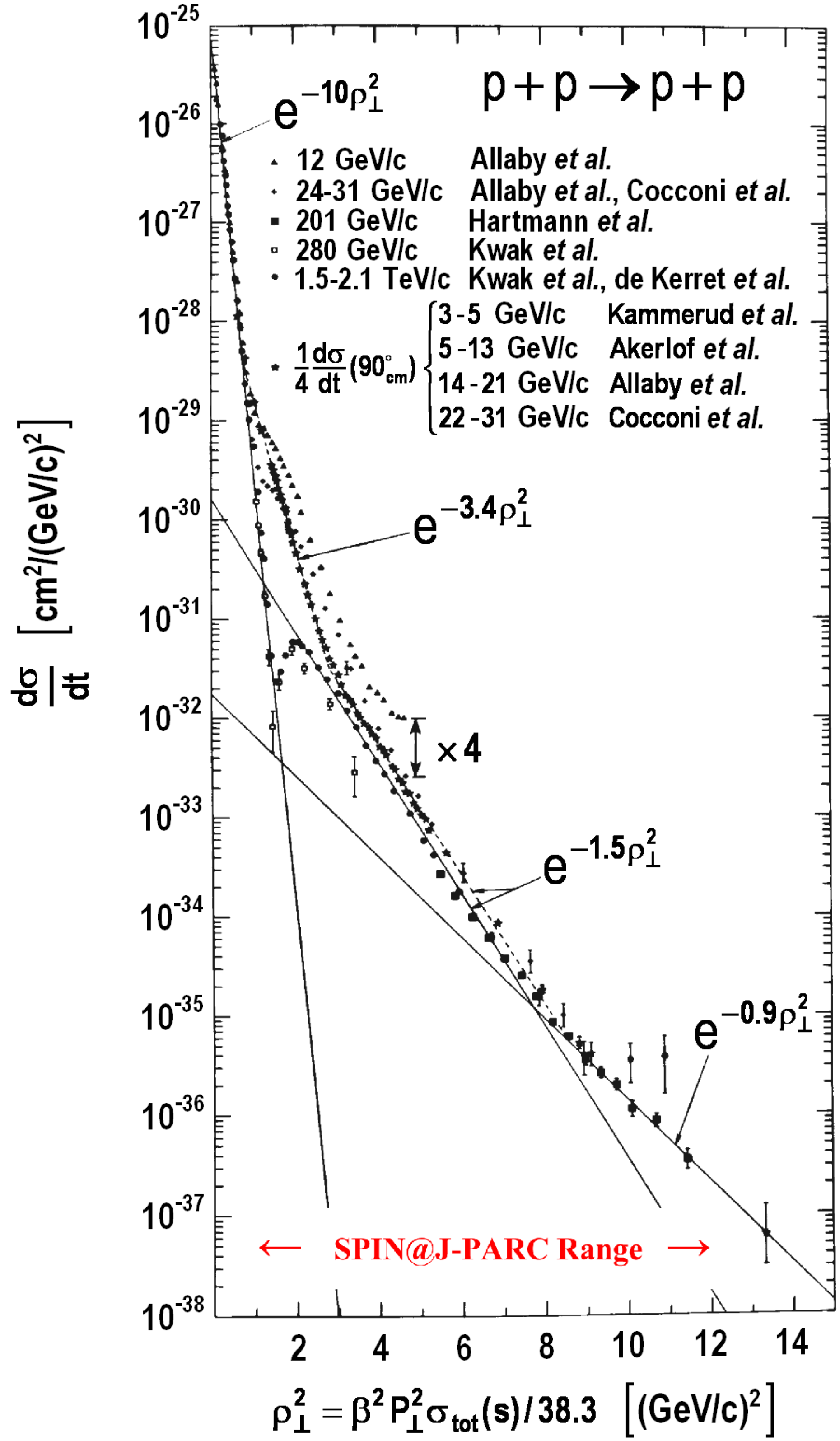
up to $P_\perp^2 = 12\ (GeV/c)^2$



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

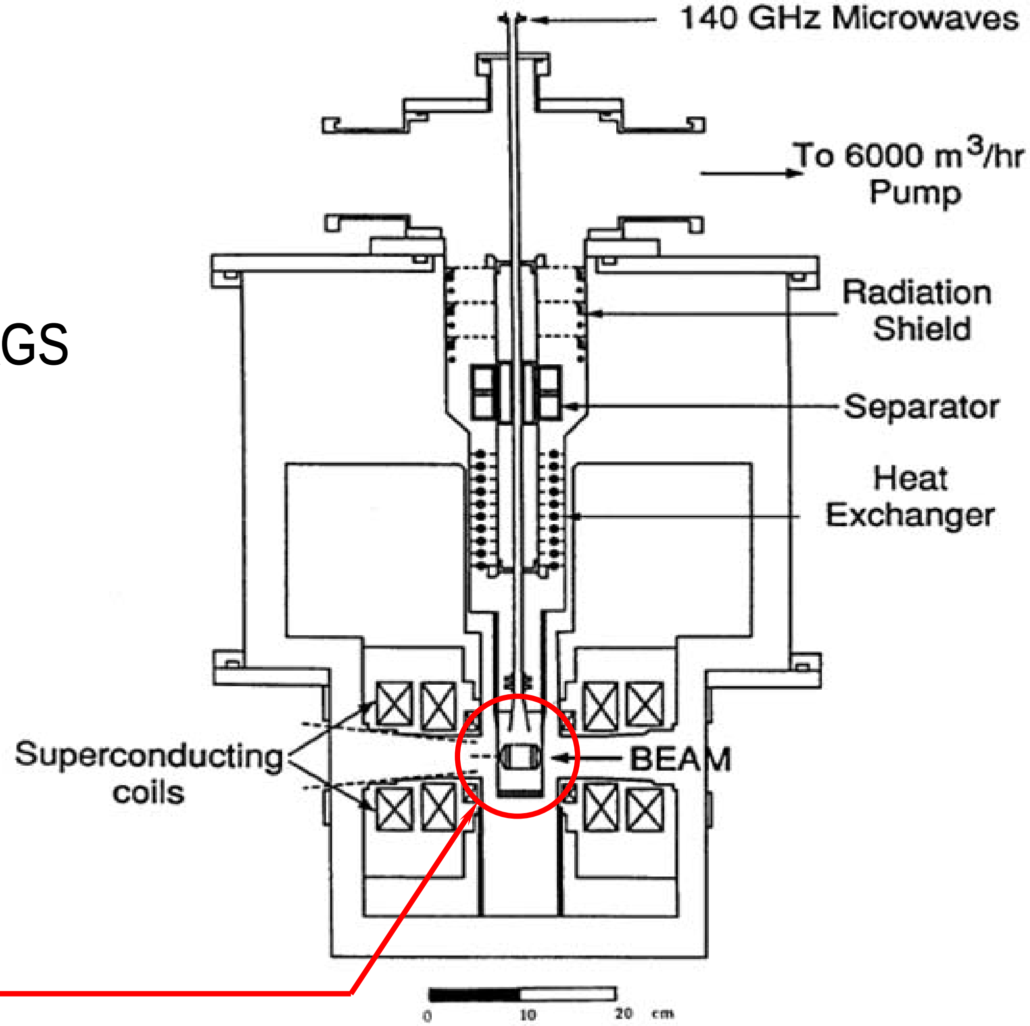
NOTE 4 DIFFERENT SLOPES
FIRST EVIDENCE for STRUCTURE
inside PROTON (Akerlof *et al.* 1966)

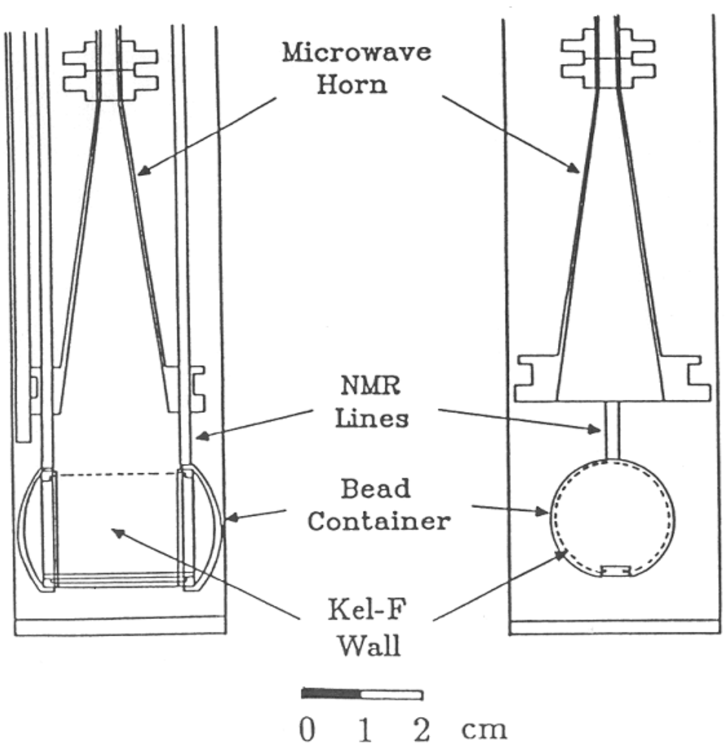


MICHIGAN SOLID POLARIZED PROTON TARGET

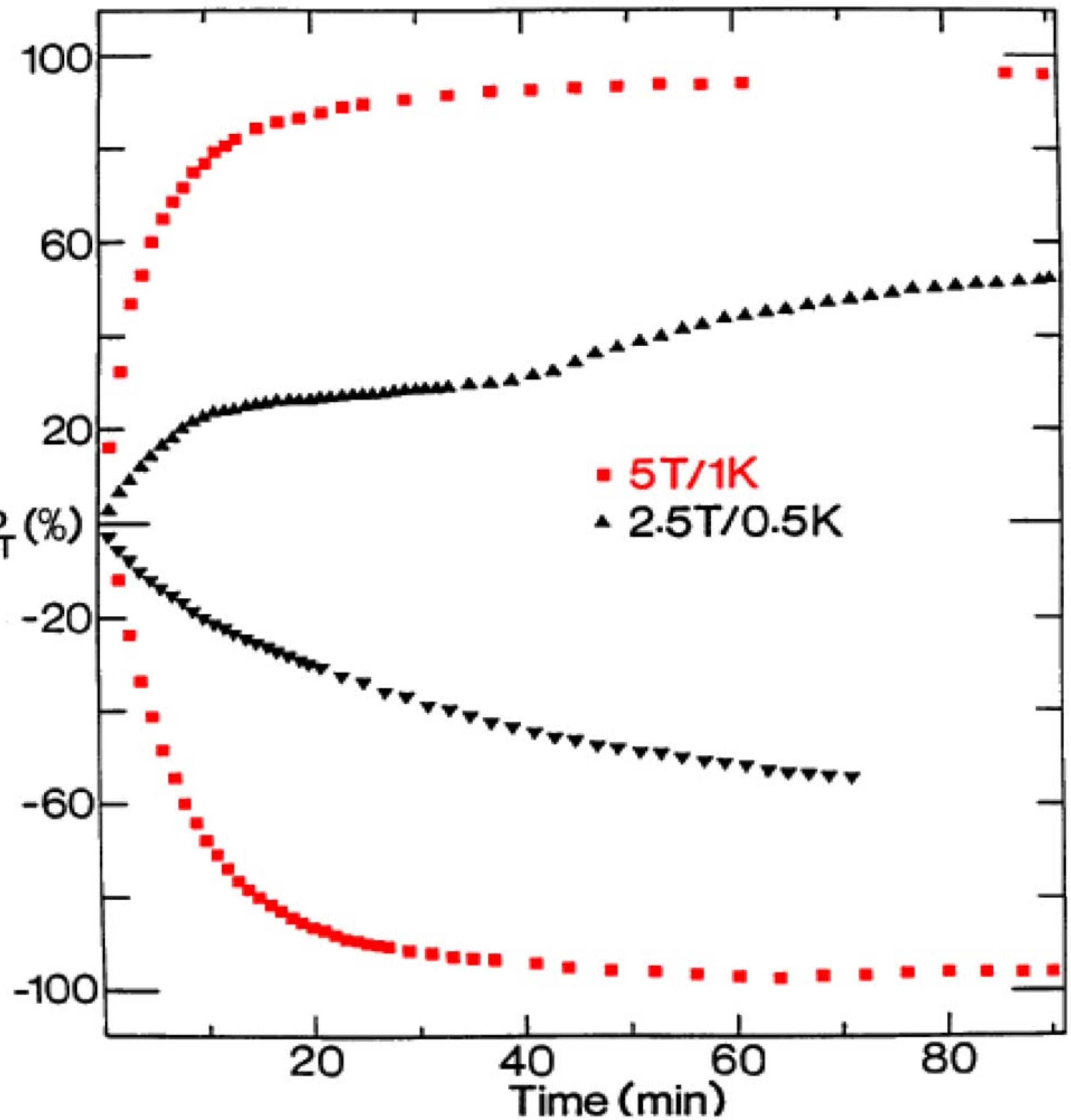
NOW at KEK

- Highly uniform 5 T field
- 0.9 W of cooling power at 1 K
- Target cavity filled with NH_3
- 96% proton polarization in NH_3
- 85% average over 3-month at AGS





POLARIZING TIME FOR IRRADIATED NH_3



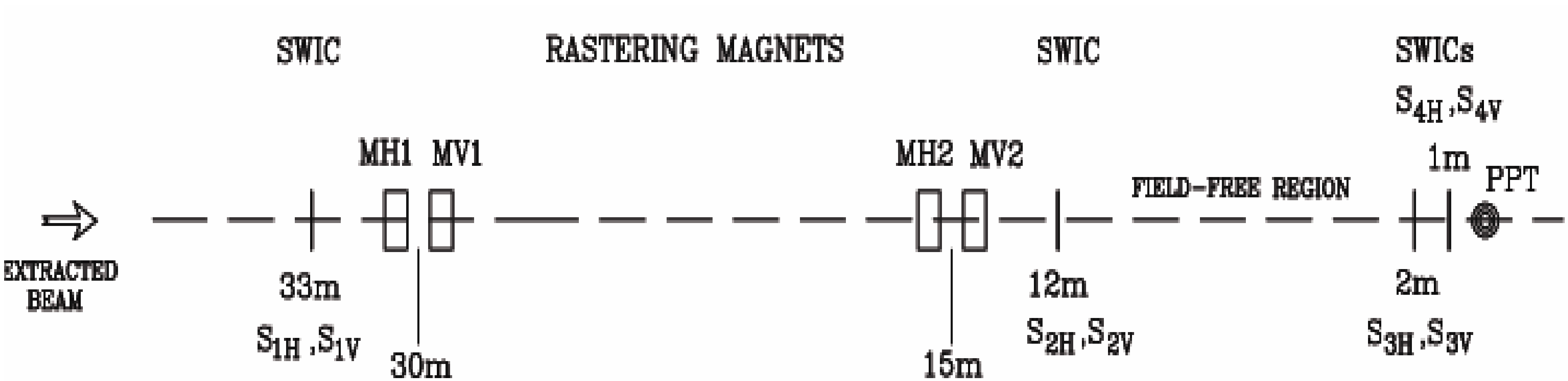
BEAM STABILITY

RELIABLE DATA and NO QUENCHING of SUPERCONDUCTING PPT MAGNET

- ~85% OF BEAM INSIDE 3 mm DIAMETER CIRCLE
- STABLE INTENSITY, POSITION and SPOT SIZE

BEAM CONTROL SYSTEM

- WEAK UPSTREAM CORRECTOR and POSITION-CONTROL FEEDBACK SYSTEM
- DOWNSTREAM CORRECTOR to REALIGN BEAM for DOWNSTREAM USERS

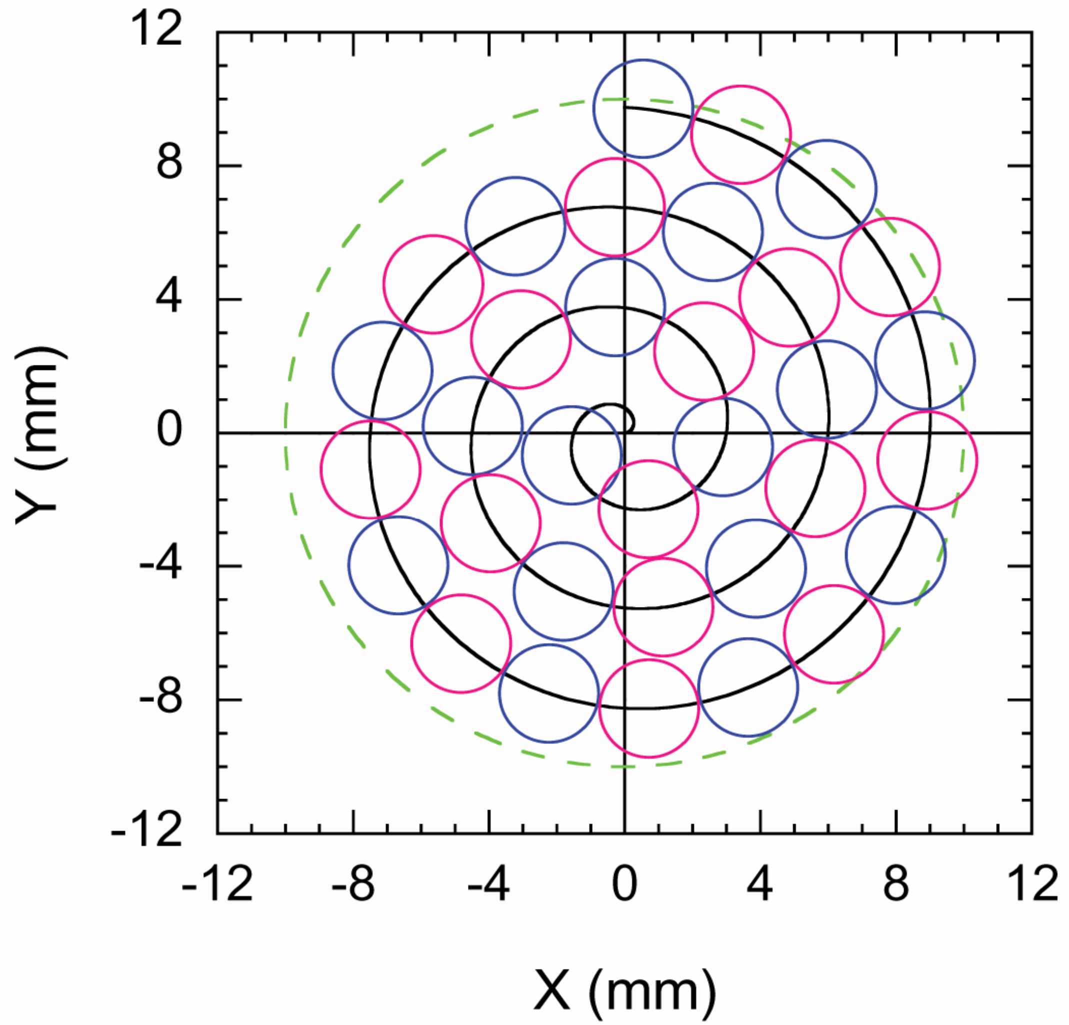


SPIRAL BEAM RASTERING

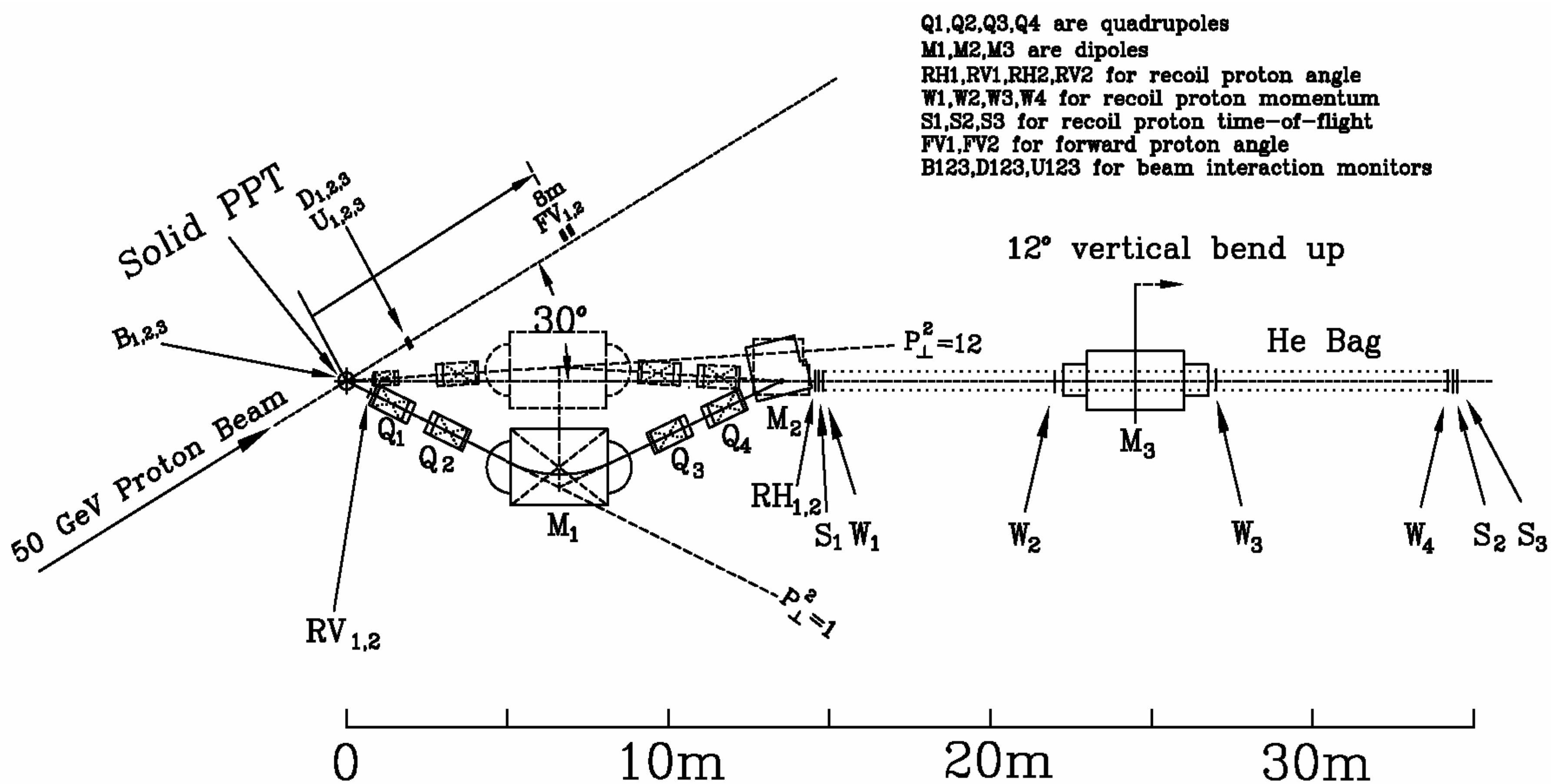
UNIFORM IRRADIATION of TARGET

RUN HORIZONTAL and VERTICAL
CORRECTORS ~90° OUT of PHASE

USED AT SLAC and J-LAB
Crabb *et al.*



PROPOSED SPIN@J-PARC SPECTROMETER



MAGNET PARAMETERS

MAGNET	LENGTH (m)	DIAMETER OR GAP (cm)	B'_{MAX} (T/m)	B_{MAX} (T)
Q_1,Q_2,Q_3,Q_4	1.00	20	14.8	
Q_1^{SUPER}	0.60	10x16	60.8	
M_1,M_3	3.00	20		1.8
M_2	1.50	20		1.8

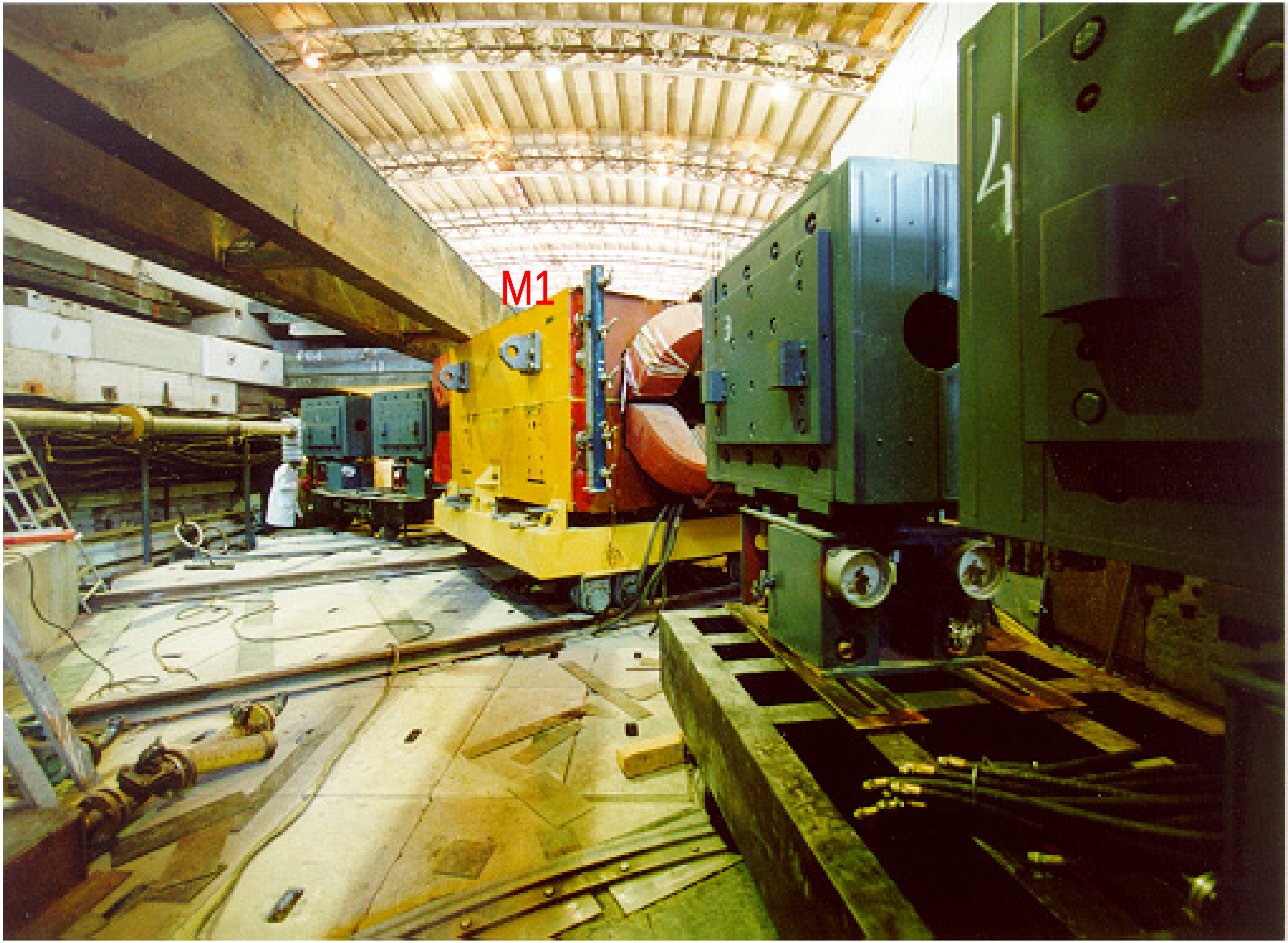
ANGLES and MOMENTA of ELASTIC PROTONS and MAGNET STRENGTHS

$P_\perp^2$ (GeV/c)^2	θ_F degrees	P_F GeV/c	θ_R degrees	P_R GeV/c	$\int B \cdot dl^{EFF}$ PPT T·m	θ_R' degrees	$\int B \cdot dl^{EFF}$ M1 T·m	$\int B \cdot dl^{EFF}$ M2 T·m	$\int B \cdot dl^{EFF}$ M3 T·m
1	1.16	49.5	61.2	1.14	0.445	54.7	3.15	-1.58	0.79
2	1.66	48.9	51.9	1.80	0.451	47.7	3.63	-1.81	1.25
3	2.05	48.4	45.8	2.42	0.456	42.7	3.57	-1.76	1.67
4	2.40	47.8	41.3	3.03	0.461	38.9	3.21	-1.57	2.09
5	2.72	47.2	37.8	3.65	0.467	35.8	2.64	-1.29	2.51
6	3.02	46.6	35.0	4.28	0.472	33.2	1.91	-0.94	2.93
7	3.30	45.9	32.6	4.92	-0.478	34.1	2.68	-1.31	3.35
8	3.58	45.3	30.5	5.58	-0.484	31.8	1.70	-0.83	3.78
9	3.86	44.6	28.7	6.26	-0.490	29.8	0.62	-0.30	4.22
10	4.13	43.9	27.0	6.96	-0.496	28.0	-0.57	0.28	4.67
12	4.68	42.4	24.2	8.45	-0.509	25.1	-3.21	1.57	5.59

SPIN@J-PARC DETECTORS

DETECTOR TYPE	LOCATION	SIZE (H X V) [mm]	CH.	RESOLUTION [mm]	THICKNESS [mm]
RV_1 Scintillator	R-0.8 m	60 x 160	8	10.7 V	10
RV_2 Scintillator	R-0.8 m	60 x 160	8	10.7 V	10
RH_1 Scintillator	R-14.2 m	200 x 200	8	13.3 H	10
RH_2 Scintillator	R-14.2 m	200 x 200	8	13.3 H	10
S_1 Scintillator	R-14.6 m	200 x 200	4	50 V	10
S_2 Scintillator	R-34.3 m	305 x 438	4	62.5 V	10
S_3 Scintillator	R-34.5 m	305 x 438	4	62.5 V	10
W_1 MWPC	R-15 m	200 x 200	192	1 V	20
W_2 Drift Chamber	R-22 m	300 x 500	2 x 32	1 V	20
W_3 Drift Chamber	R-26 m	300 x 500	2 x 32	1 V	20
W_4 Drift Chamber	R-33 m	300 x 500	2 x 32	1 V	20
FV_1 Scintillator	F-8 m	15 x 80*	8	1 V	10
FV_2 Scintillator	F-8 m	15 x 80*	8	1 V	10
U_{123} Scintillators	F-2 m 20°up	10 x 10	3	--	32
D_{123} Scintillators	F-2 m 20°down	10 x 10	3	--	32
B_{123} Scintillators	1 m below	12 x 8.5	3	--	40

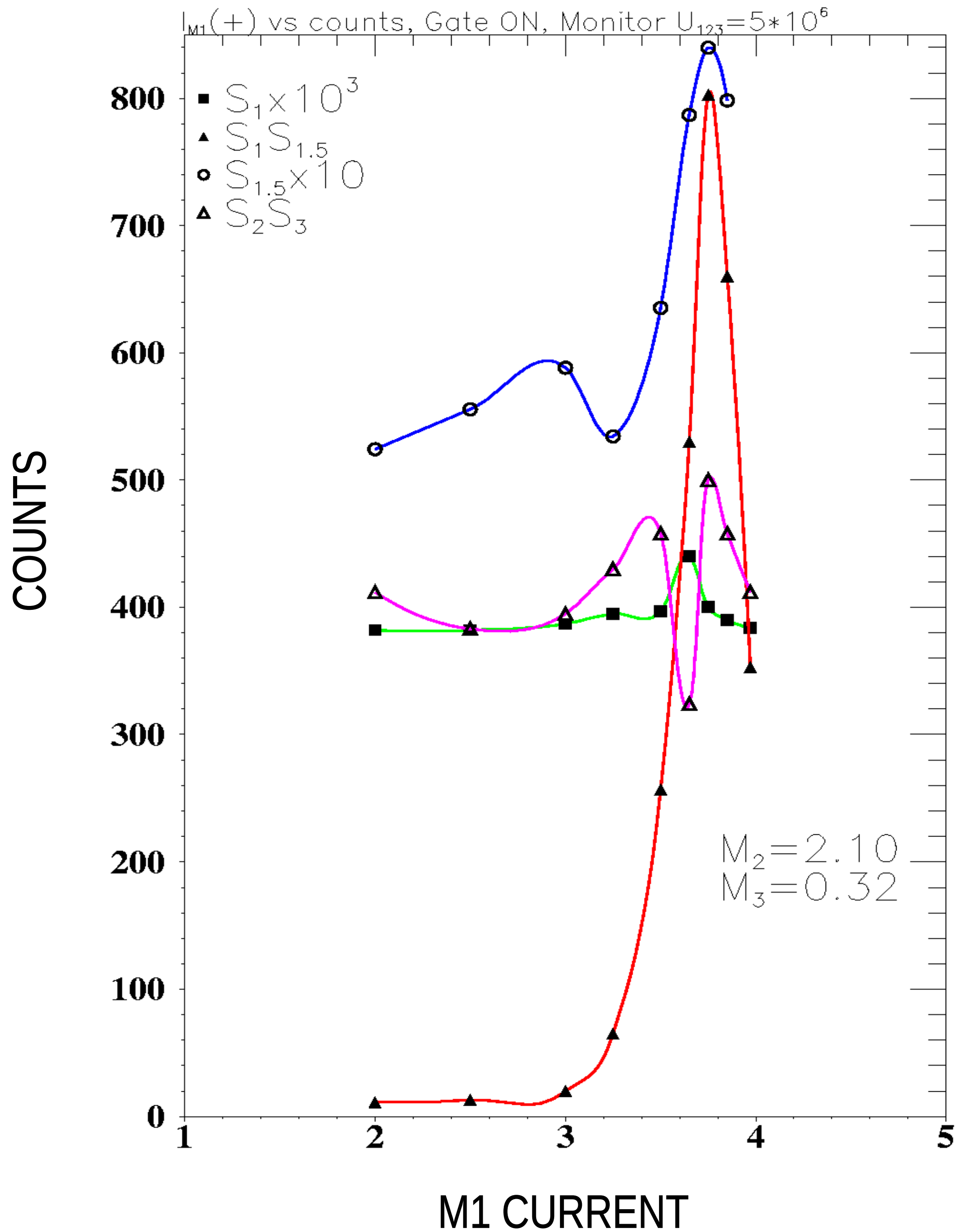
SPIN@U-70 SPECTROMETER



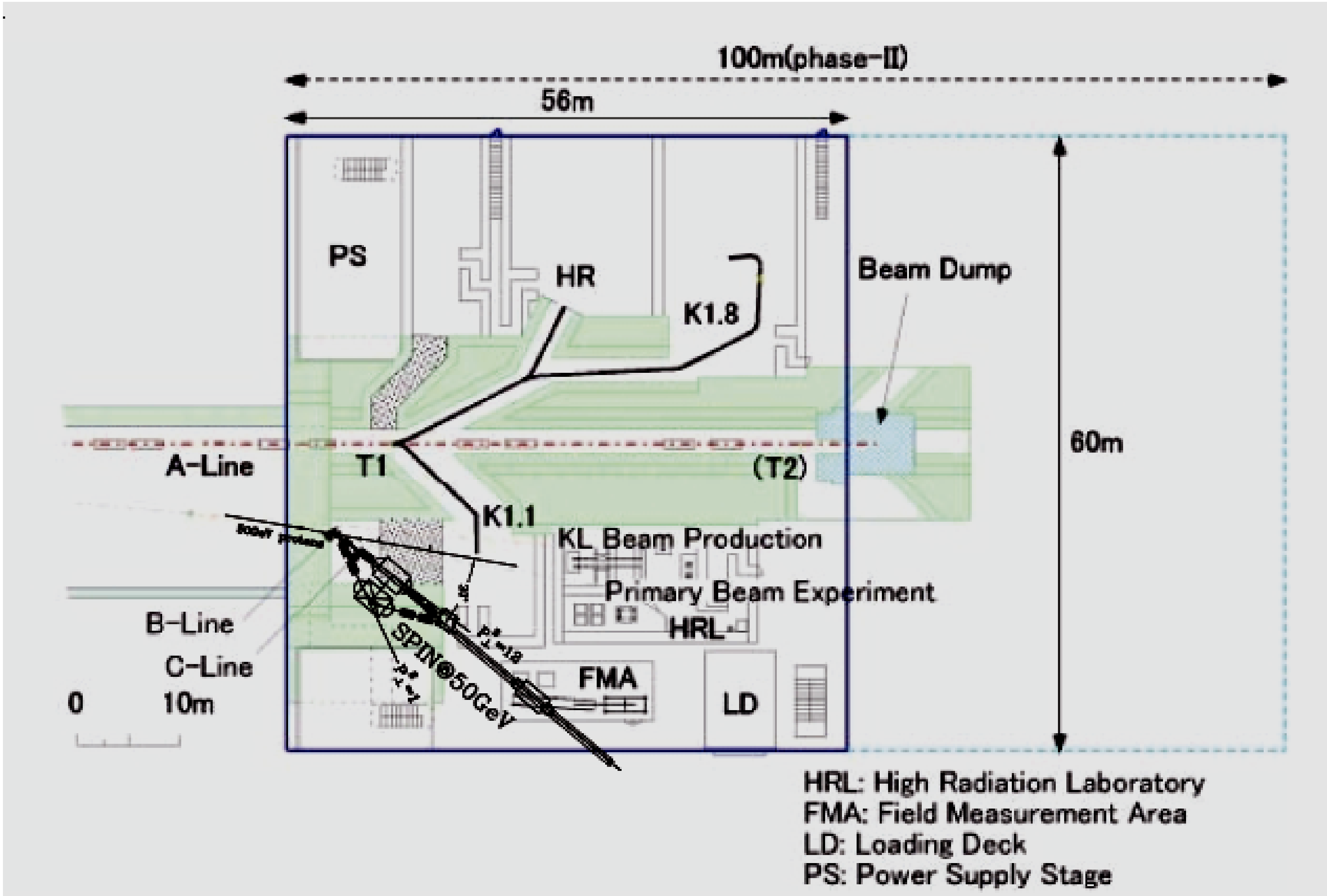
SPIN@U70 TEST RUN

FIRST HALF of RECOIL SPECTROMETER ONLY

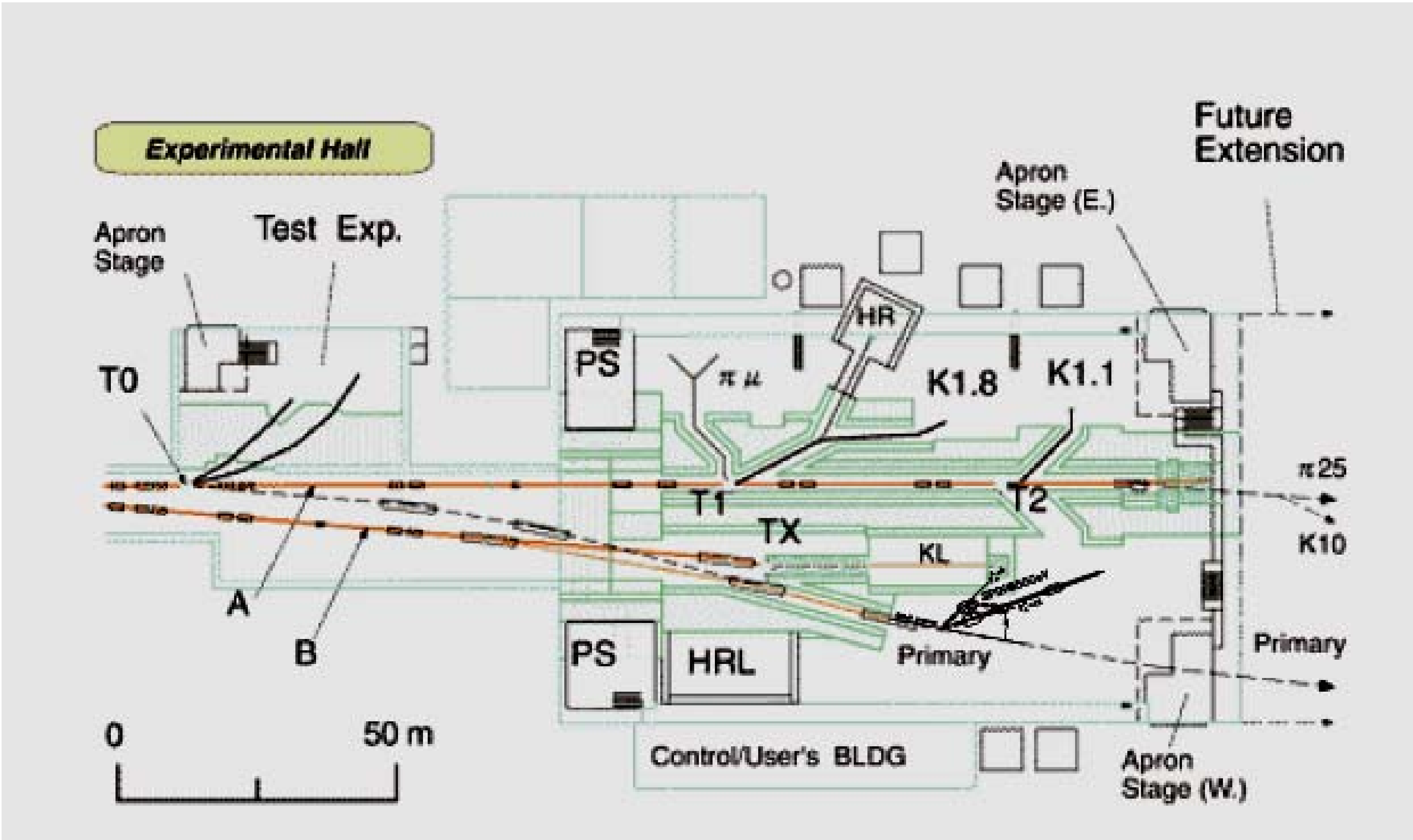
SIGNAL : BACKGROUND ~ 80 : 1



POSSIBLE SPIN@J-PARC PLACEMENT



2nd POSSIBLE SPIN@J-PARC PLACEMENT



PROTON-PROTON ELASTIC CROSS-SECTIONS

PPT THICKNESS:

$$T = N_0 \cdot \rho \cdot 3.2\ \text{cm} \cong 2\ 10^{23}\ \text{protons cm}^{-2}$$

BEAM INTENSITY:

$$I_B = 10^{11}\ \text{protons / s}$$

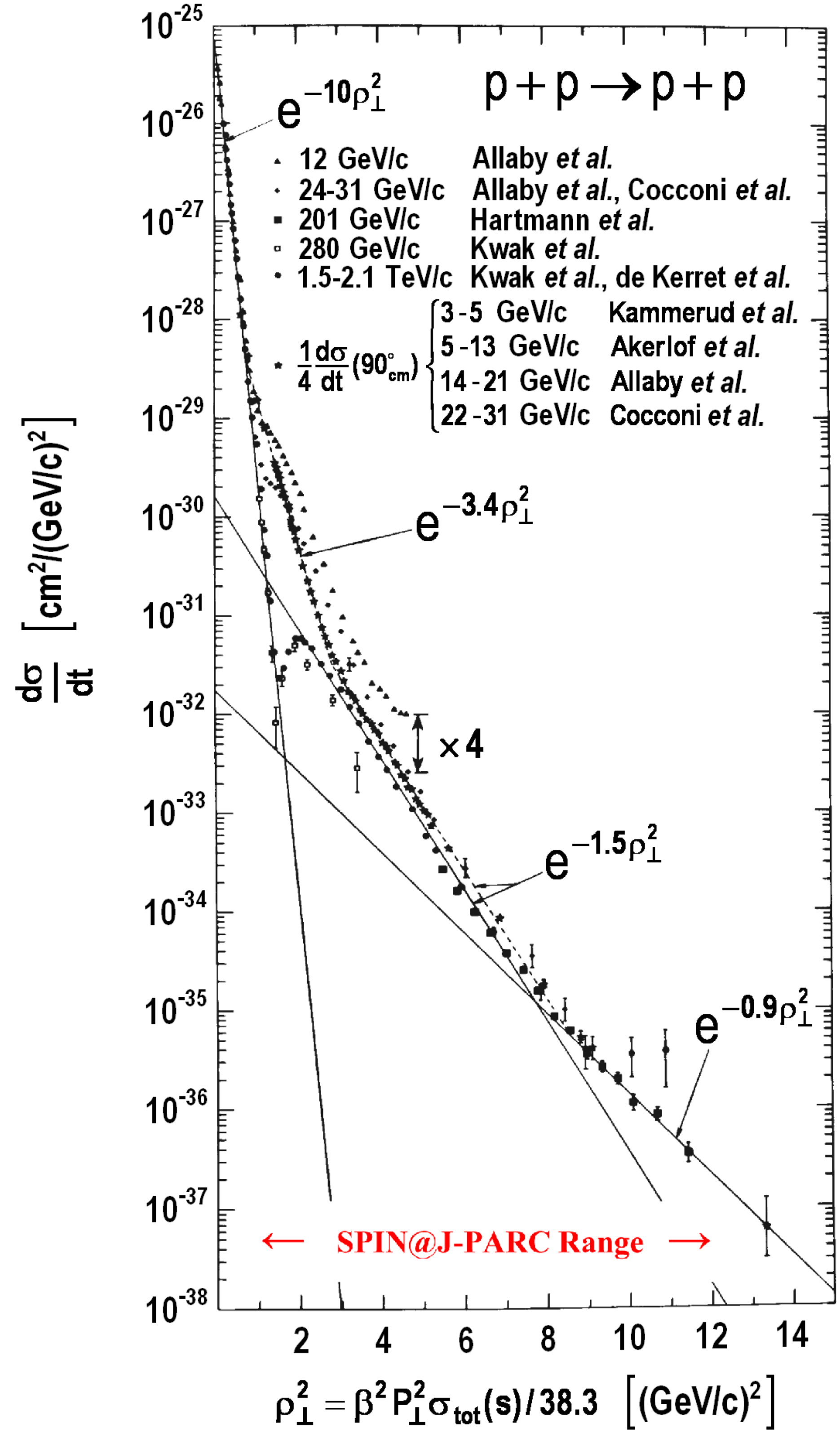
TIME-AVERAGED LUMINOSITY:

$$L = I_B \cdot T \cong 2\ 10^{34}\ \text{s}^{-1}\ \text{cm}^{-2} \Rightarrow$$

SPIN@J-PARC Events/hour

$$= L \left({d\sigma}/{dt}\right)\left(\frac{\Delta t \cdot \Delta\phi \cdot \varepsilon}{2\pi}\right) 3600\ {s}/{hr}$$

$$= 6\left({d\sigma}/{dt}\ [\text{nb}]\right)\cdot\left(\Delta t\ [(\text{GeV/c})^2] \cdot \Delta\phi\ [\text{mr}]\right)$$



EVENT RATES and ERRORS in A_n

$P_\perp^2$ $(GeV/c)^2$	Δt $(GeV/c)^2$	$\Delta\phi$ mr	$d\sigma/dt$ $nb/(GeV/c)^2$	EVENTS per hour	HOURS	EVENTS	$\Delta A_n = [.85\sqrt{N}]^{-1}$ (%)	
1.0	0.06	159	4000	230000	100	$2.3\cdot10^7$	0.03	
2.0	0.09	177	90	8600	100	$8.6\cdot10^5$	0.1	
3.0	0.25	194	19	5500	100	$5.5\cdot10^5$	0.2	
4.0	0.35	210	4.0	1800	100	$1.8\cdot10^5$	0.3	
5.0	0.45	225	0.9	550	100	$5.5\cdot10^4$	0.5	
6.0	0.56	240	0.22	180	200	$3.6\cdot10^4$	0.6	
7.0	0.67	254	0.055	56	200	$1.1\cdot10^4$	1.1	Super Q_1
8.0	0.79	268	0.016	20	300	$6.0\cdot10^3$	1.5	"
9.0	0.92	282	0.0047	7.3	400	$2.9\cdot10^3$	2.2	"
10.0	1.06	296	0.0017	3.2	600	$1.9\cdot10^3$	2.7	"
12.0	1.25	324	0.0003	0.73	800	$4.4\cdot10^2$	4.9	"

TOTAL HOURS: 3000 + 500 (TUNE-UP)

WITH 10^{11} PROTONS/sec

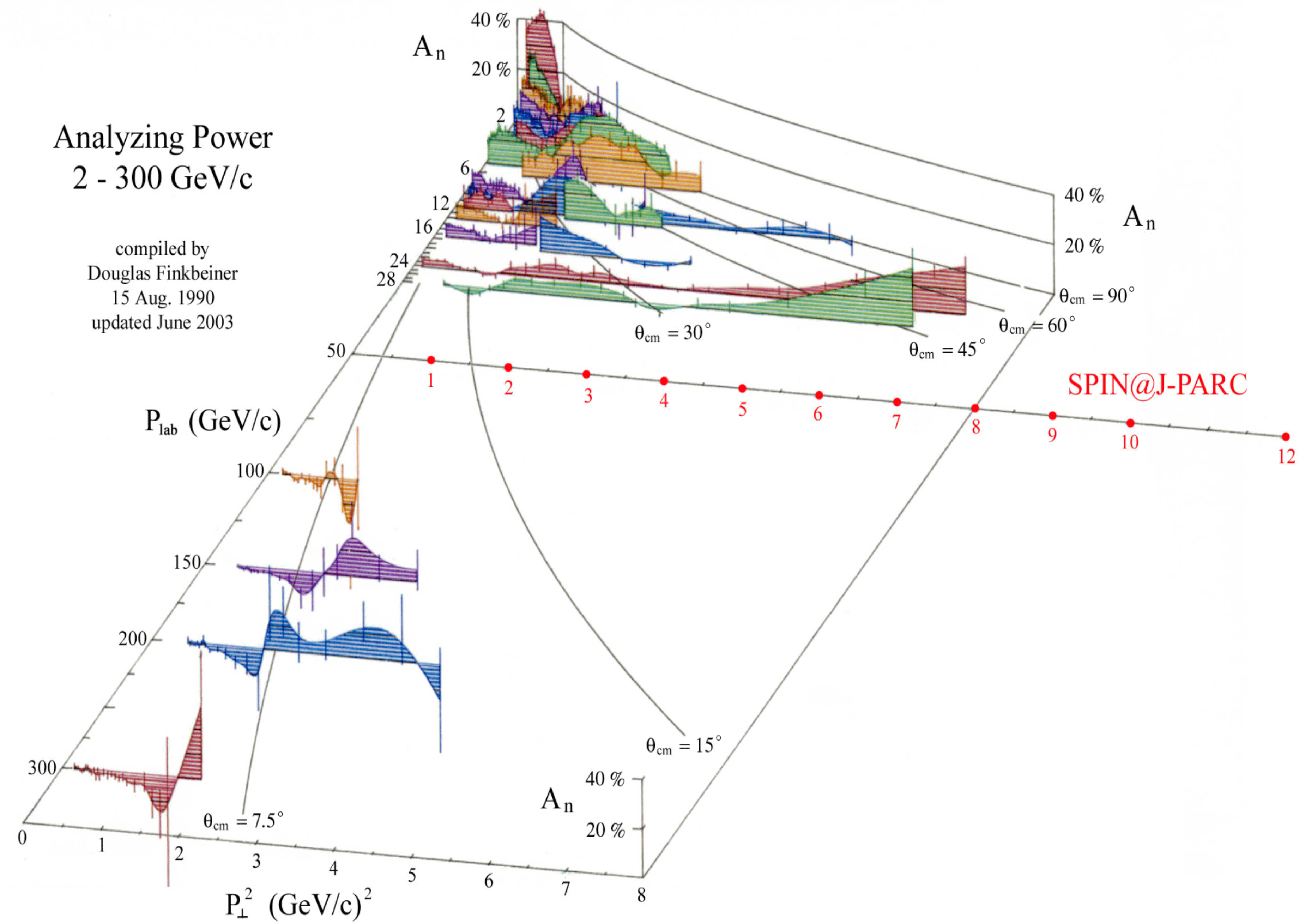
With POLARIZED BEAM (P_B) and POLARIZED TARGET (P_T)

$\Delta A_{nB} = (P_B\sqrt{N})^{-1}$; $\Delta A_{nT} = (P_T\sqrt{N})^{-1}$; $\Delta A_{nn} = (P_B P_T \sqrt{N})^{-1}$; $\Delta d\sigma/dt = (\sqrt{N})^{-1}$

STATUS of EQUIPMENT

#	ITEM	STATUS	SUGGESTED ACTION	TIME NEEDED
1.	SOLID PPT, NMR, MICROWAVES	AT KEK	ASSEMBLE AND TEST	6 MONTHS
2.	PPT PUMPS	NEED	ACQUIRE IN JAPAN	6 MONTHS
3.	PPT STAND + HARDWARE	AT KEK	ASSEMBLE AND TEST	3 MONTHS
4.	QUADRUPOLES Q_1, Q_2, Q_3, Q_4	J-PARC PROVIDE		2 YEARS
5.	DIPOLES M_1, M_2, M_3	J-PARC PROVIDE		2 YEARS
6.	STANDS FOR: Q_1-Q_4 & M_1-M_3	J-PARC PROVIDE		1 YEAR
7.	MAGNETS' POWER SUPPLIES	J-PARC PROVIDE		1 YEAR
8.	SCINTILLATORS: FV_1,FV_2,S_1,S_2,S_3 RH_1,RV_1,RH_2,RV_2	SOME AT MICHIGAN	MAKE OTHERS, THEN SHIP	6 MONTHS
9.	WIRE CHAMB: W_1,W_2 W_3, W_4	NEED	MAKE AND SHIP	9 MONTHS
10.	DETECTOR STANDS	J-PARC PROVIDE		6 MONTHS
11.	CABLES, CONNECTORS, ENDS	NEED	MAKE AND SHIP	3 MONTHS
12.	ELECTRONICS	MOSTLY AT KEK	ACQUIRE REST, SHIP	3 MONTHS
13.	COMPUTERS	AT MICHIGAN	SHIP	3 MONTHS
14.	MONITORS D_{123}, U_{123}, B_{123}	SOME AT MICHIGAN	MAKE OTHERS, THEN SHIP	3 MONTHS
15.	BEAM STABILIZER SYSTEM	J-PARC PROVIDE		1 YEAR
16.	RASTERING SYSTEM	J-PARC PROVIDE		1 YEAR
17.	EXPERIMENT CONTROL ROOM	J-PARC PROVIDE ?		1 YEAR
18.	SHIELDING BLOCKS	J-PARC PROVIDE	PLAN, REARRANGE	1 YEAR
19.	MAGNETS' MOVEMENT PLATES	J-PARC PROVIDE	DESIGN, BUILD AT J-PARC	1 YEAR
20.	LIQUID HELIUM AND NITROGEN	J-PARC PROVIDE	PURCHASE OR LIQUIFY	??
21.	SUPERCONDUCTING Q_1	J-PARC OR MICHIGAN	WILL NEED LATER	2 YEARS

ANALYZING POWER for PROTON-PROTON ELASTIC SCATTERING



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