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A Jet-Target for Polarimetry at RHIC

(Proposal and Project Status)

1. - Jet-Targets (J-T) fit Colliders :

- Low density → negligible beam perturbation
- Luminosity as high as colliding- beams (C-B)

2. - Practical aspects :

- Design criteria ↘
- Construction → ENGINEERING
- Install./operation ↗
- **Costs**

3. - Additional advantages for polarimetry :

* Fixed-target (F-T): $\sqrt{s}$ overlaps present data ($pp \to pp$, $pp \to \pi X$)

** Recoil-particle accessible $[P_R \equiv A_N^{(B)}]$ ↘
($pp \to pp$) → SELF-CALIBRATION
*** Pol.Gas-Targets (PG-T) $[A_N^{(T)} \equiv A_N^{(B)}]$ ↗

4. - Status of project :

✔ 3- year R&D prototype studies done (MC /PJ-T)

✔ Setup design (integrated with PP2PP: forward+ recoil detectors)

✔ Molecular cluster(MC) assembly available (ADONE/NIKHEF)

- Polarized J-T components existing; assembly in progress
- Funding request to complete vacuum parts in progress
- **Need to finalize installation plans and schedule (target year 2000)**

1. - Successful & dependable experience with MC J-T :

Laboratory	Experiment (Accelerator)				
CERN	UA6 (SPS)	R704 (ISR)	PS202 (LEAR)		
FNAL	E760 (AAR)				M
TSL	(CELSIUS)	[Light-heavy (A=1-131) gases]			C
LNF	BTPB (ADONE)	" "	(A=1-40)	"	J
NIKHEF	⇓	" "	"	"	T
⋮					
DESY	HERMES (HERA)	H↑/D↑ storage cell			
BINP	(VEPP-2/3)	" "	"	"	P
IUCF	(Cooler Ring)	" "	"	"	G
⋮					T

1.1 - Typical parameters for J-T systems

Target Type	Target Material [A]	Target Thickness [g/cm^2; at/cm^2]	Pressure Bump [mbar]	Beam Aperture [Ø, cm]	Detection Clearance [$\Delta\Omega/4\pi$]	Recoil Detection [MeV/c]
MC J-T	1-131	0.2-4 10^{-9}; $\geq 10^{14}$	$\leq 10^{-7}$	≥ 10	≈ 0.7	≥ 30 (p)
AB PJ-T	1-2	0.02 10^{-9}; $\approx 10^{12}$	$\leq 10^{-8}$	≥ 10	≈ 0.7	≥ 30 (p)
SC PG-T	1-3	0.2 10^{-9} ; $\approx 10^{14}$	$\leq 10^{-7}$	≤ 2	≈ 0.7	≥ 200 (p)
Fiber (*)	12,95,184	$\approx 5\ 10^{-4}$; $\approx 10^{17}$	10^{-9}	≈ 5	≈ 1	≥ 240 (C)
Ribbon(*)	12, 197	$\approx 5\ 10^{-6}$; $\approx 10^{15}$	10^{-9}	≈ 5	≈ 1	≥ 50 (C)

(*) Shown for comparison; average thickness sweeping through beam.

1.2 - Luminosity: $L = N_B \times n_B \times n_T \times l_T \times q \times f_o$

RHIC Parameters for p-p (polarized)	
Energy (Injection - Top)	28 - 250 GeV
Number of bunches (n_B)	120
Number of protons/bunch (N_B)	$2\ 10^{11}$
Revolution frequency (f_o)	$78\ 10^3$ Hz
Beta at crossing point (β^*)	10 m
(low beta)	2 m
Normalized emittance (ε)	20 π mm mrad
Circumference	3834 m
Beam pipe diameter (Ø)	80 mm
Vacuum (warm regions)	$7\ 10^{-10}$ mbar
Beam store time (T_S)	5-10 hours
Beam polarization (P_B)	≈ 70%

Typical MCJ-T parameters (UA6)	
Total gas input (@ 1 bar)	20 mbar . l/s
Nozzle diameter	0.1 mm
Nozzle temperature	28 K
Distance nozzle - beam	25 cm
Jet density (n_T)	$2\ 10^{14}$ atoms/cm^3 ($3.4\ 10^{-10}$ g/cm^3)
Jet sectional area ($w \times l_T$)	6x8 mm^2
B -T overlap factor (q)	typically ≈ 1
Target thickness (t_T)	$1.6\ 10^{14}$ atoms/cm^2
Background gas (n_b)	$< 2\ 10^9$ atoms/cm^3
Residual pressure bump	$6\ 10^{-8}$ mbar (≈ 5 m)

$$L = 2\ 10^{11} \times 120 \times 1.6\ 10^{14} \times 79\ 10^3 = 3\ 10^{32}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$$

1.3 - Effects on the beams: losses and emittance growth

Order of magnitude estimate:

- Compare effects of J-T and associated pressure bump with the effects of residual gas in the rings;

- Ignore specific (nuclear) effects [$\approx A^{\alpha}$]: they might be significant in the overall rings, but not relevant for the J-T region (H gas).

	Influence on beam lifetime and emittance					
	Pressure P [mbar]	Length L [cm]	n [at./cm^3]	n . L [at./cm^2]	L_S/L_I	L_S/L_R
RHIC average	$1.8\ 10^{-10}$	$3.8\ 10^{5}$	$\approx 2\ 10^{7}$	$0.8\ 10^{13}$	$8\ 10^{-4}$	$6.2\ 10^{-4}$
Target region	$\leq 2\ 10^{-7}$	≈ 500	$\leq 5\ 10^{9}$	$\leq 2.5\ 10^{12}$	$\leq 3\ 10^{-4}$	$\leq 2.2\ 10^{-4}$
Jet	$4\ 10^{-3}$	0.8	$2\ 10^{14}$	$1.6\ 10^{14}$	$1.8\ 10^{-2}$	$1.5\ 10^{-2}$

Assuming $4\ 10^4$ sec store time (T_S):

$L_S = f_o \times L \times T_S$ effective integrated path length of beam particles

$L_I = 1/n\,\sigma$ effective interaction length

$L_R = X_o/\rho$ effective radiation length

The two parameters L_T/L_I and L_T/L_R , control the lifetime of the beams and the rate of emittance growth during a store:

$\tau^{-1} = f_o \times n \times L \times \sigma$ represents the beam lifetime [$N_B(t) = N_B\ e^{-t/\tau}$]

Emittance growth is given by

$$d\varepsilon/dt = \beta^* \Theta_{ms}^2/2,$$

with $\Theta_{ms}^2 = (15/p)^2 (L/L_R)$ and p in MeV/c. Lifetime is given by $\tau = T_S/(L_T/L_I)$ and $\Delta\varepsilon = \beta^* (15/p)^2 (L_S/L_R)\, T_S$, measures the total emittance growth during one store. The region surrounding the target, although with sizable pressure, does not introduce appreciable deterioration of the beams; the jet target (at $\approx 2\ 10^{14}$ at./cm^3 density) affects significantly, but not catastrophically the losses and emittance of the beams; at $\approx 10^{13}$ at./cm^3 the effects are quite tolerable.

2. - Engineering and cost

The jet-target system should provide

- jet density ≥ 10^{12} atoms/cm^3
- free standing pure H jet unobstructed over 8 cm Ø
- mantain machine vacuum of 10^{-10} torr away from immediate vicinity of jet by differential pumping
- design and construction criteria appropriate for easy installation, reliable operation and simple maintenance

Objectives: Providing a target assembly with MC and PAB sources easily interchangeable. In combination with PP2PP a suitable J-T should provide absolute polarization measurements in times shorter than one colliding-beam fill with 5% precision.

2.1 - Cost estimate

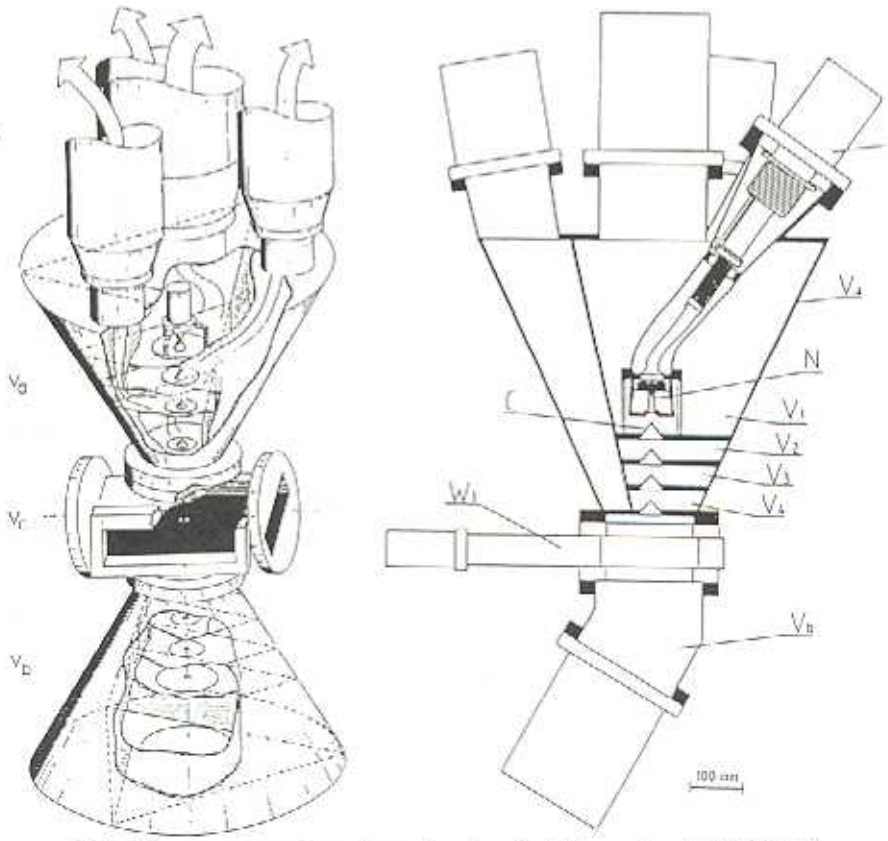
Jet production stage:		381 k$
chamber	20. k$	
nozzle/skimmer	8. k$	
cold head+compressor	36. k$	
turbo pumps	246. k$	
primary pumps	39. k$	
vacuum gauges	32. k$	
Target Stage:		41 k$
Chamber	11. k$	
Valves	30. k$	
Dump Stage:		24 k$
Chamber	6. k$	
Cold head+compressor	18. k$	
Infrastructure		51 k$
Cables, pipes	23. k$	
Support structure	8. k$	
Controls	20. k$	
Polarized jet (additional cost)		200 k$
Dissociator	15 k$	
Extra pumps	120 k$	
RF transitions	20 k$	
Polarimeter	45 k$	
Total (with overhead and contingency)		697 k$

2.2 Cheap Scheme

Recover existing equipment (Genova) of MC J-T used at ADONE

Net cost of supplementary parts to reforbish and commission the system, divided by item:

Pumps and vacuum equipment	44 + 38 + 25 = 107 k$
Polarized source	15 + 29 = 44 k$
Mechanical parts	6 + 8 = 14 k$
Controls	20 k$
Total	175 k$



The Genova molecular -cluster Jet-Target at ADONE

For the polarized atomic beam source the basic components (dissociator and sextupole magnets) exist already; a design to integrate the source into the Genova assembly is in progress.

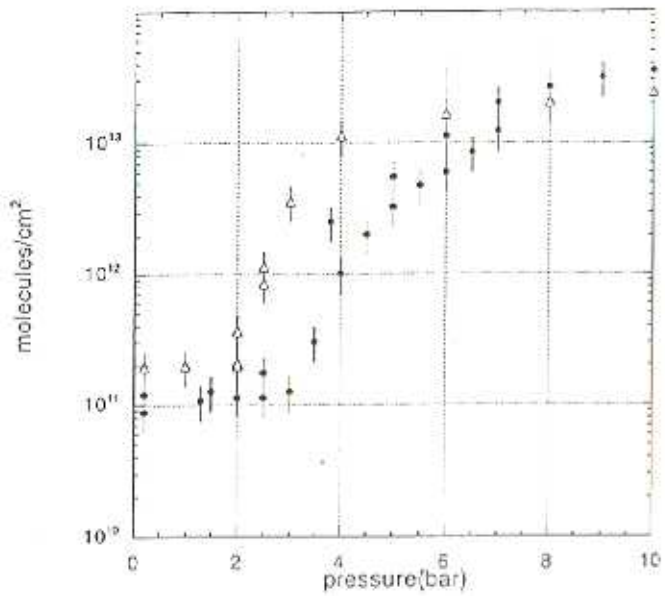


Fig. 3. Target thickness in molecules/cm² vs. inlet pressure deduced from the residual vacuum measured in the dump volume V_b. Full dots: N_2 at 130 K nozzle temperature, open triangles: O_2 at 160 K.

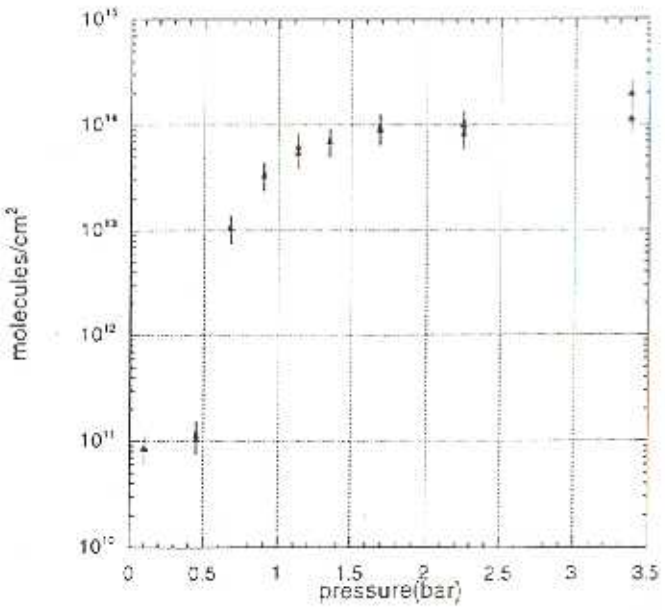


Fig. 4. Same measurement as Fig. 4 with H_2 gas at nozzle temperature of 40 K.

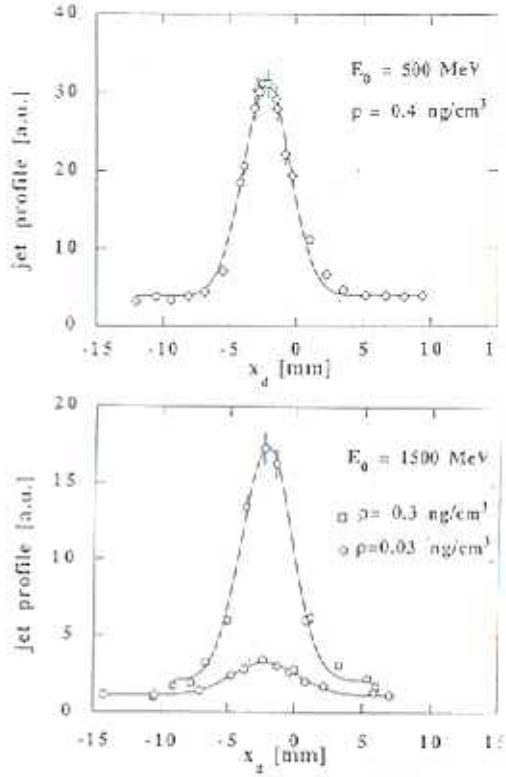
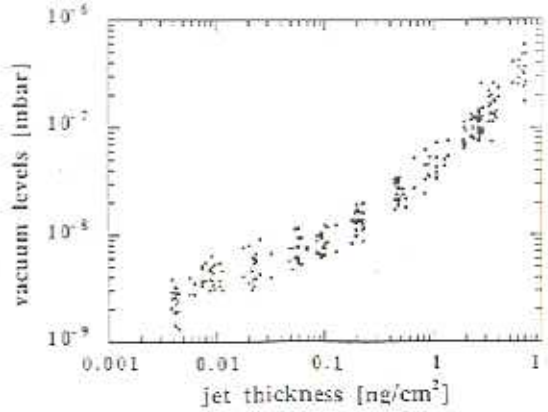


Fig. 6. Jet profiles measured at the given electron energies and jet thicknesses. The solid line curve are the convolutions obtained from eq. (15) with $d_0 = 5.4$ mm.



Conclusions

- significant progress in securing a suitable gas jet-target for polarimetry at RHIC

- possibility of performing absolute polarization measurements at the required 5% level in the conceptually cleanest way:

  - pure hydrogen target
  - unbiased detection of pp → pp
  - self-calibrating by recoil analysis

- polarized jet option included

- integration with PP2PP

  - cost effective
  - forward-recoil detection
  - infrastructure

- unpolarized jet can be rapidly implemented

  - feedback needed to focus plans