Why we need Liquid Hydrogen data

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MIPP Collaboration Meeting

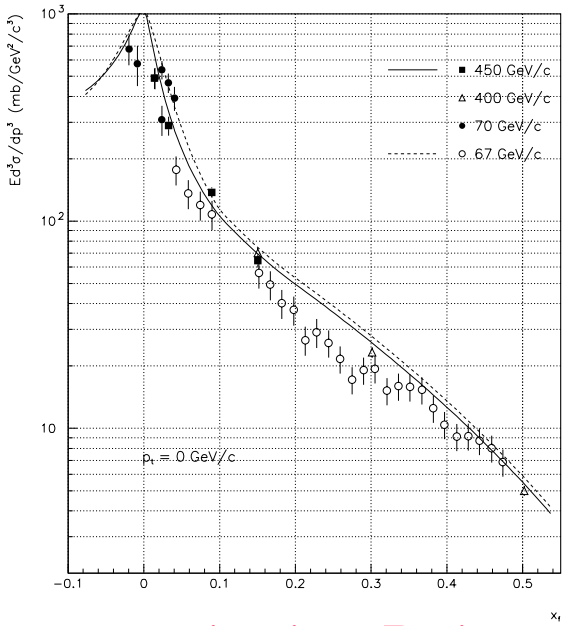
General scaling law of particle fragmentation

- States that the ratio of a semi-inclusive cross section to an inclusive cross section

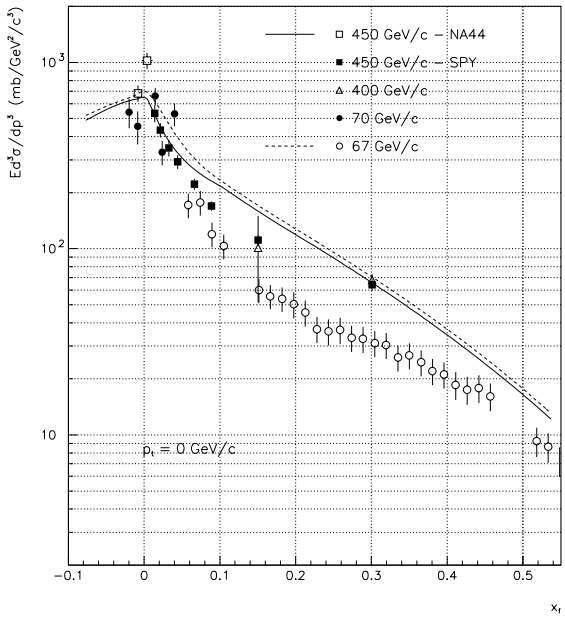
$$\frac{f(a+b\rightarrow c+X_{subset})}{f(a+b\rightarrow c+X)} \equiv \frac{f_{subset}(M^2,s,t)}{f(M^2,s,t)} = \beta_{subset}(M^2)$$

- where M^2,s and t are the Mandelstam variables for the missing mass squared, CMS energy squared and the momentum transfer squared between the particles a and c. PRD18(1978)204.
- Using EHS data, we have tested and verified the law in 12 reactions (DPF92) but only at fixed s.
- The proposed experiment will test the law as a function of s and t for various particle types a ,b and c for beam energies between ~5 GeV/c and 120 GeV/c to unprecedented statistical and systematic accuracy.

Quality of existing data

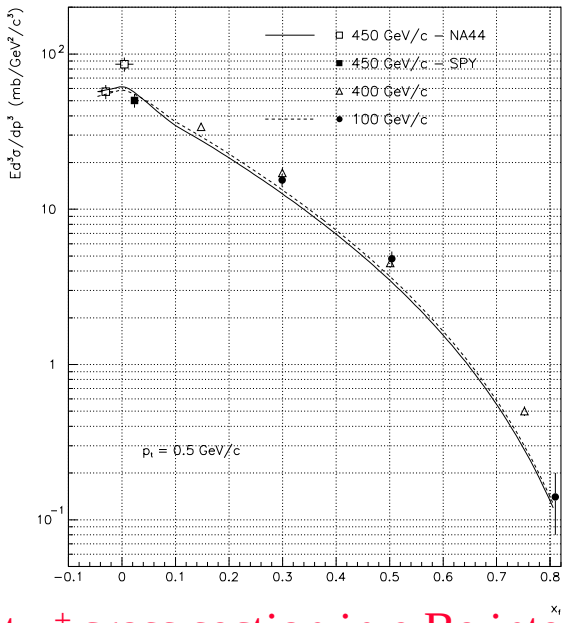


- Invariant π^- cross section in p Be interactions as a function of Feynman x at p_t=0 GeV/c

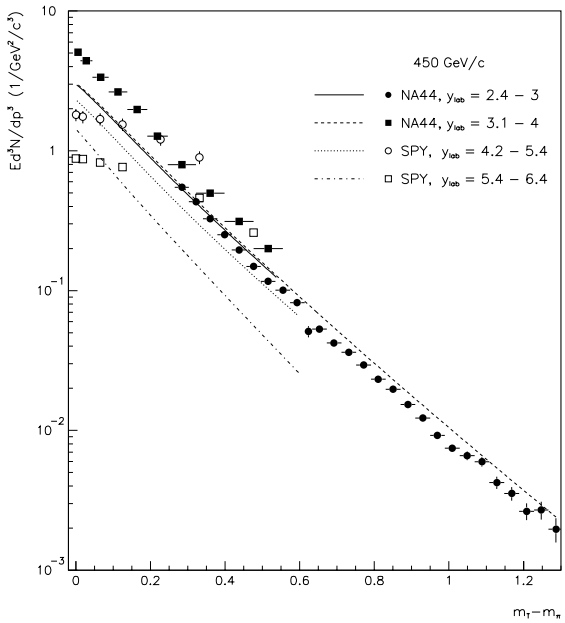


- Invariant π+ cross section in p Be interactions as a function of Feynman x at p_t=0 Gev/c

Quality of existing data



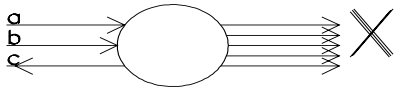
- Invariant π^+ cross section in p Be interactions as a function of Feynman x at p_t=0.5 GeV/c

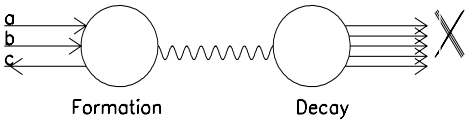


- Invariant π+ cross section in p Be interactions as a function of pion transverse mass.More fitting going on.

Scaling Law

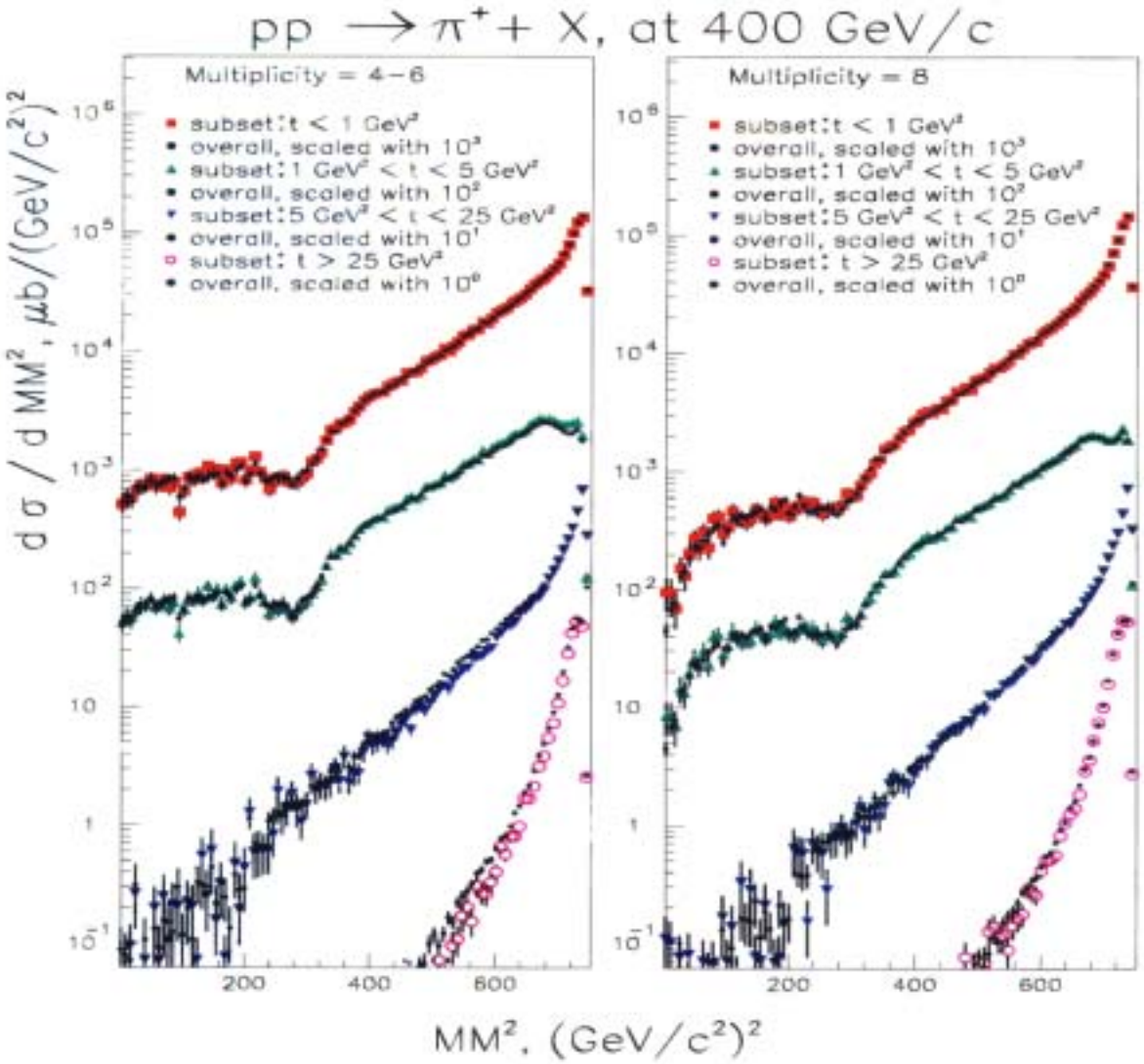
- Physics behind law is the factorization of 3 body scattering cross section.



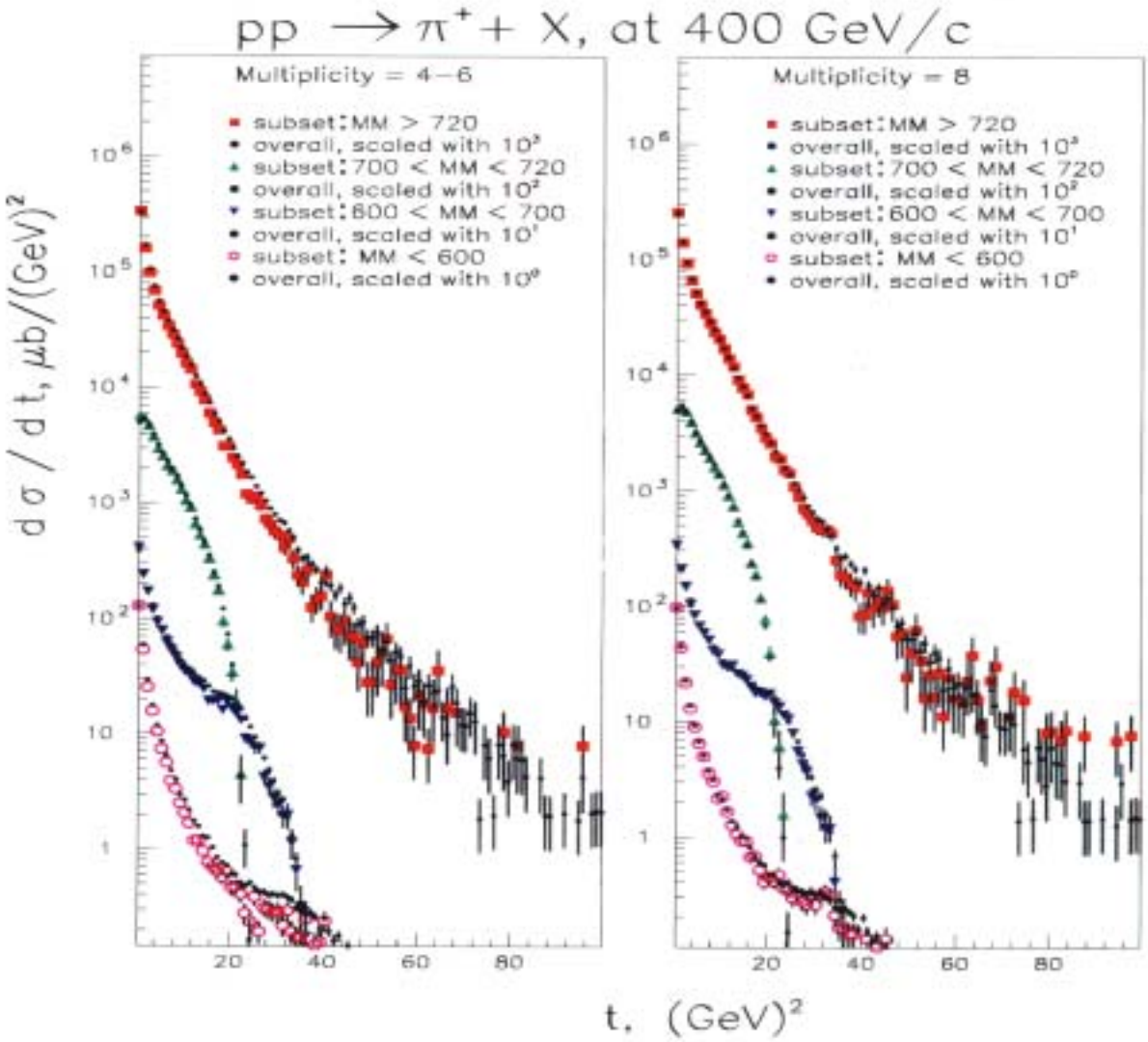


- We will be able to test the scaling law for 36 reactions as a function of s and t for various subsets with unprecedented accuracy.
- For each subset, we will be able to test the equality of the branching function for sets of crossed reactions. E.g $\pi^- p \rightarrow p+X$ and $p^- p \rightarrow \pi^+ + X$ should have the same set of branching functions $\beta_{subset}(M^2)$! One is a diffractive process and the other a central process.

Scaling Law-EHS results



Scaling law -EHS results



Scaling law- inter-relations

$\pi^- p \rightarrow K^+ + X; K^- p \rightarrow \pi^+ + X$

have the same functions $\alpha_n(M^2)$

similiarly,

$pp \rightarrow \pi^+ + X; \pi^- p \rightarrow \ddot{p} + X$

and,

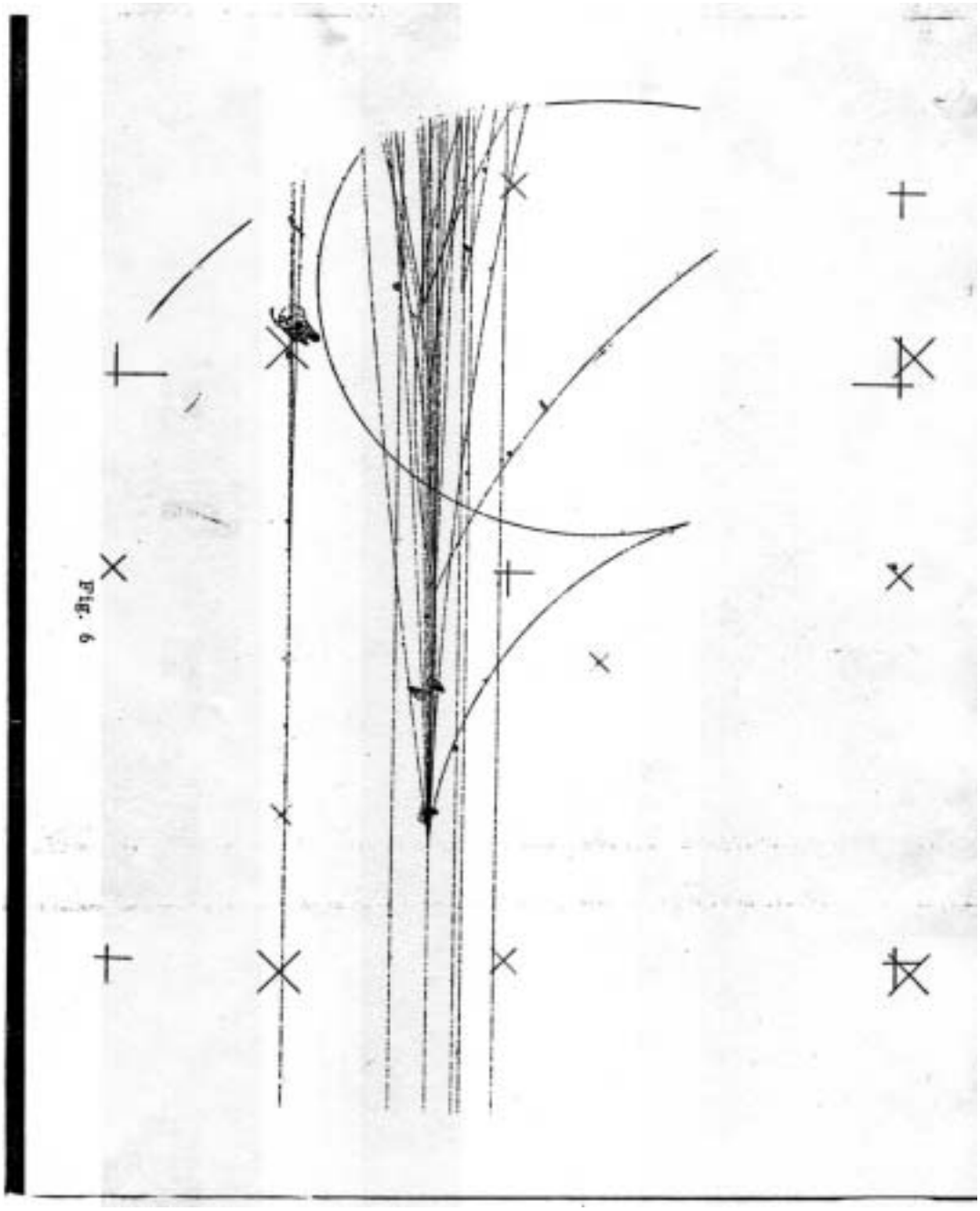
$\pi^- p \rightarrow p + X; \ddot{p}p \rightarrow \pi^+ + X;$

$\pi^+ p \rightarrow p + X; \ddot{p}p \rightarrow \pi^- + X;$

all have the same $\alpha_n(M^2)$; CP symmetry used

Diffractive dissociation is connected to central production

Existing LH2 data- J.Whitmore review 1973



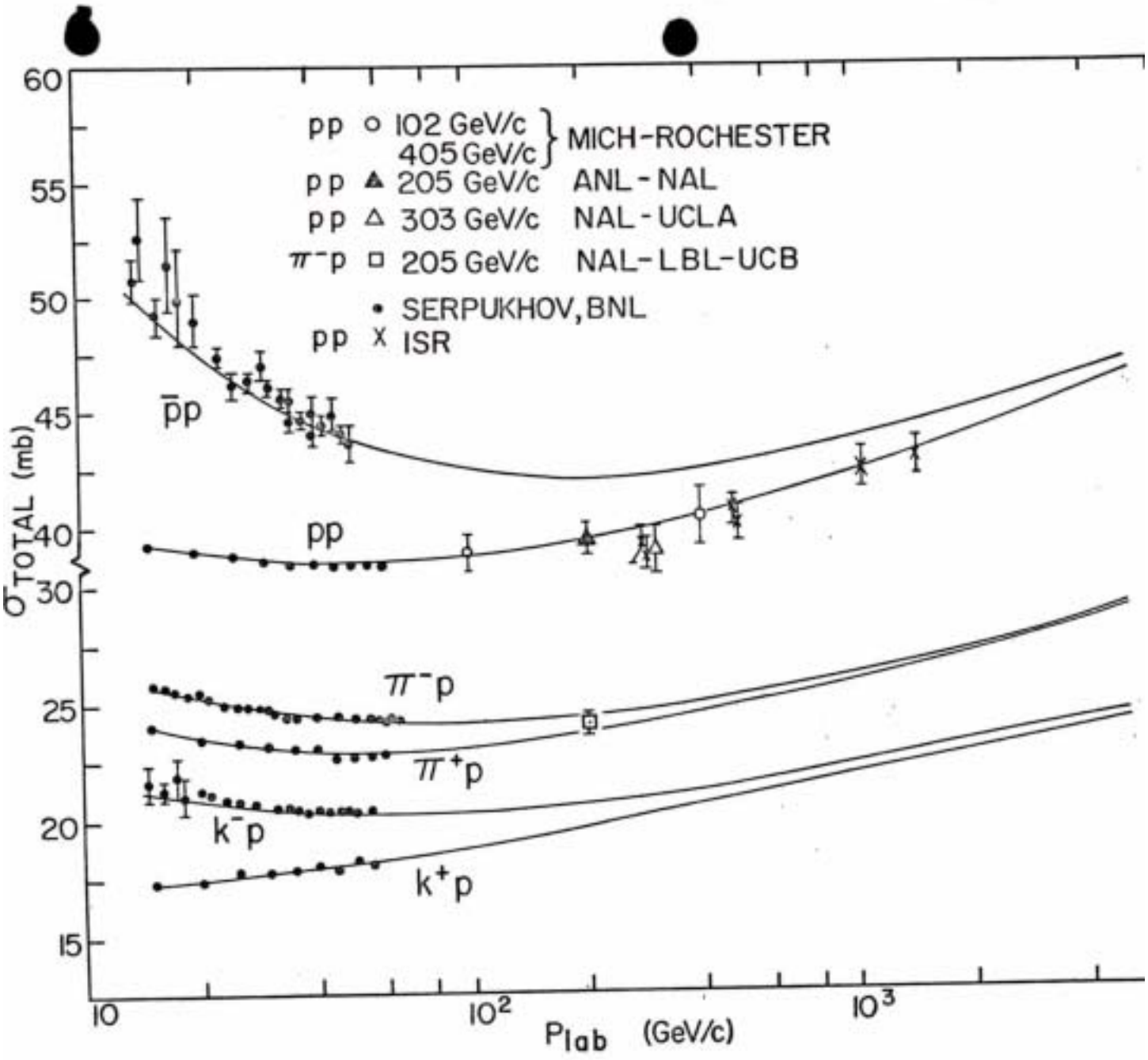

pp ○ 102 GeV/c
405 GeV/c
MICH-ROCHESTER
pp ▲ 205 GeV/c ANL-NAL
pp △ 303 GeV/c NAL-UCLA
π⁻p □ 205 GeV/c NAL-LBL-UCB
• SERPUKHOV, BNL
pp X ISR
p̄p
pp
π⁻p
π⁺p
k⁻p
k⁺p
σTOTAL (mb)
Plab (GeV/c)
60
55
50
45
40
30
25
20
15
10
10²
10³

Fig. 7

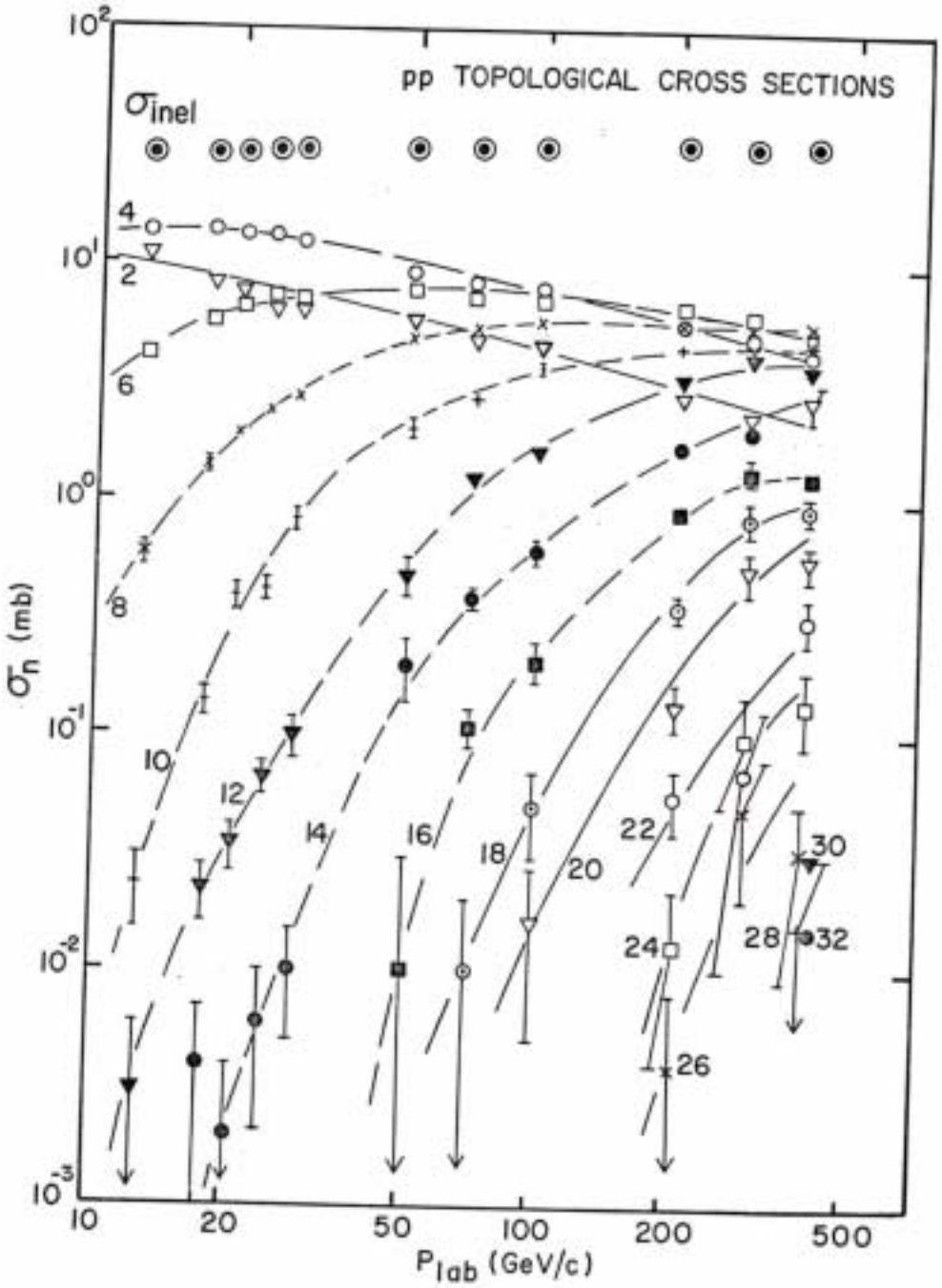

pp TOPOLOGICAL CROSS SECTIONS
σ_{inel}
σ_n (mb)
P_{lab} (GeV/c)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10
20
50
100
200
500
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

Fig. 8

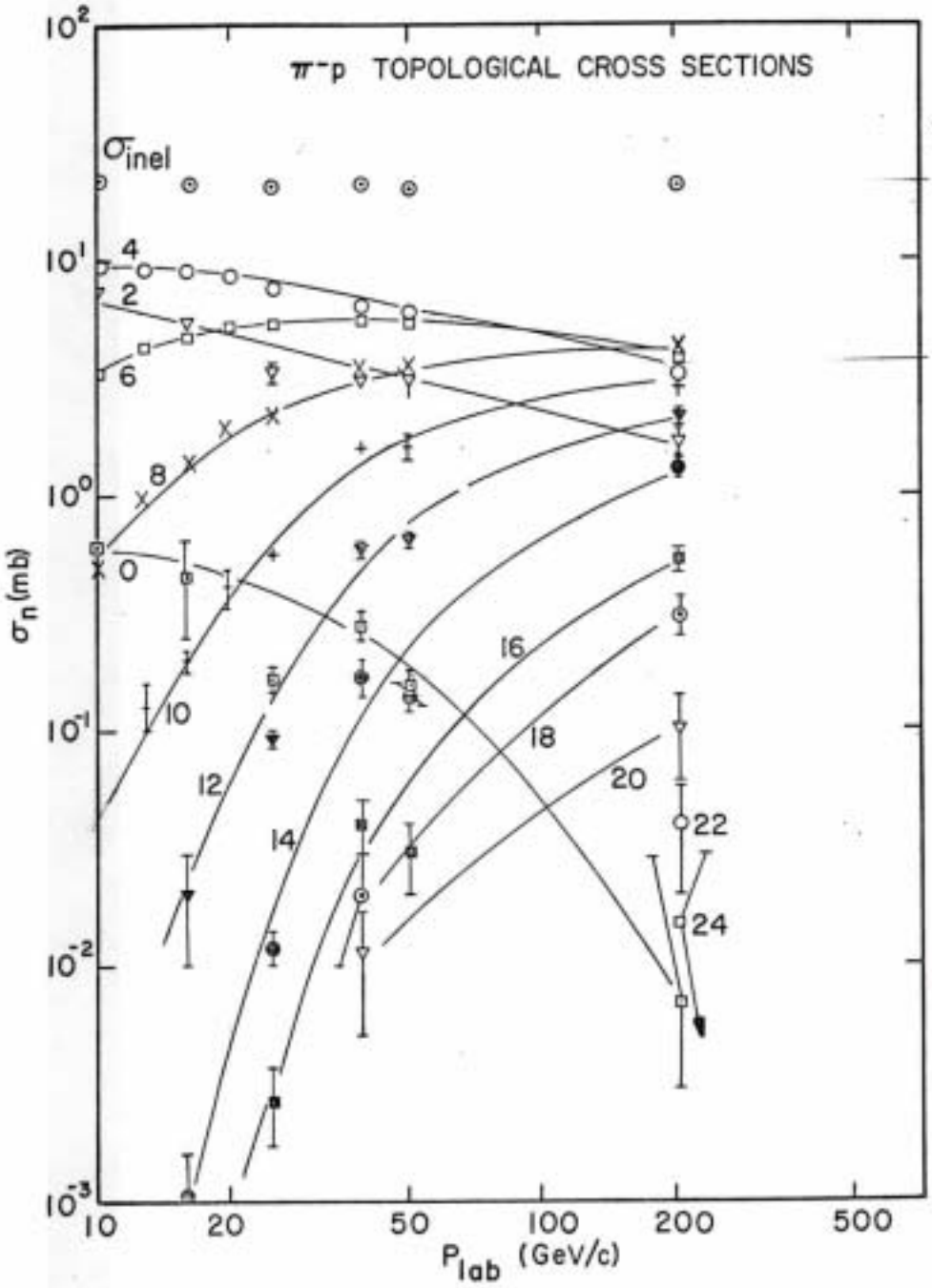

π⁻p TOPOLOGICAL CROSS SECTIONS
σinel
σn (mb)
Plab (GeV/c)
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10
20
50
100
200
500
0
2
4
6
8
10
12
14
16
18
20
22
24

Fig. 9(a)

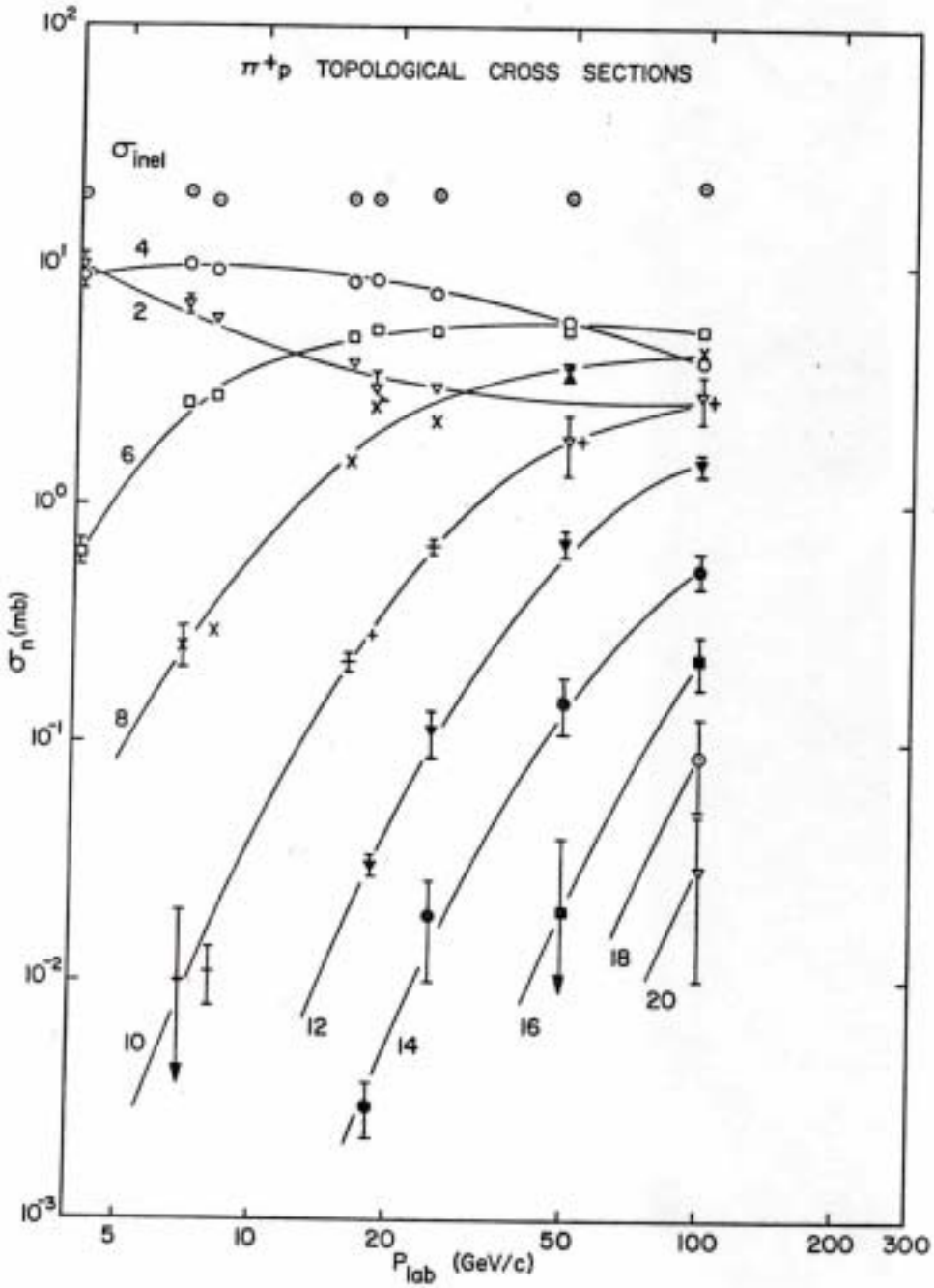

π^+p TOPOLOGICAL CROSS SECTIONS
σ_{inel}
σ_n (mb)
P_{lab} (GeV/c)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
5
10
20
50
100
200
300
2
4
6
8
10
12
14
16
18
20

Fig. 9(b)

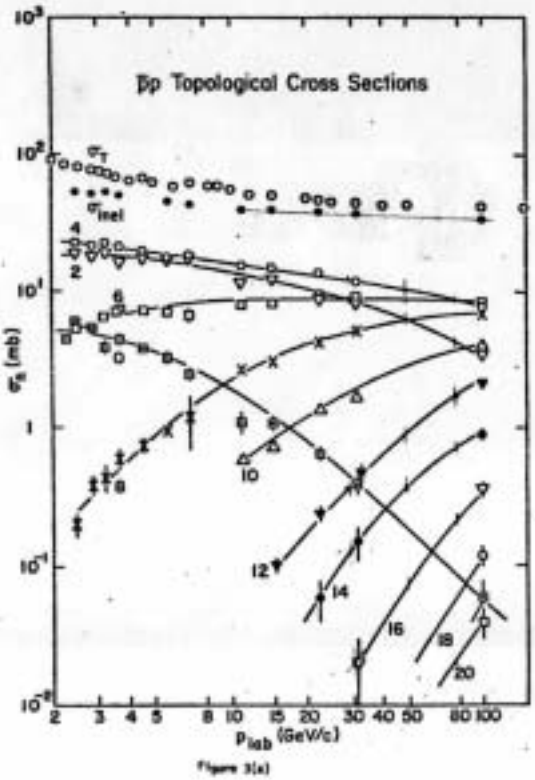


Figure 3(a)

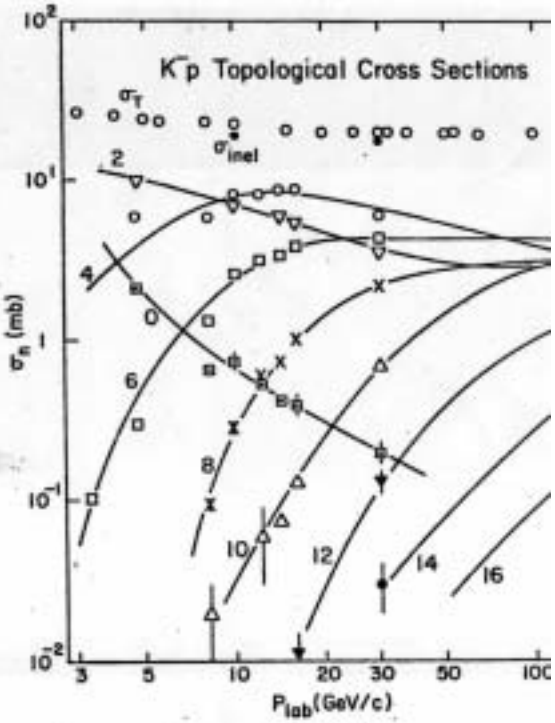


Figure 3(b)

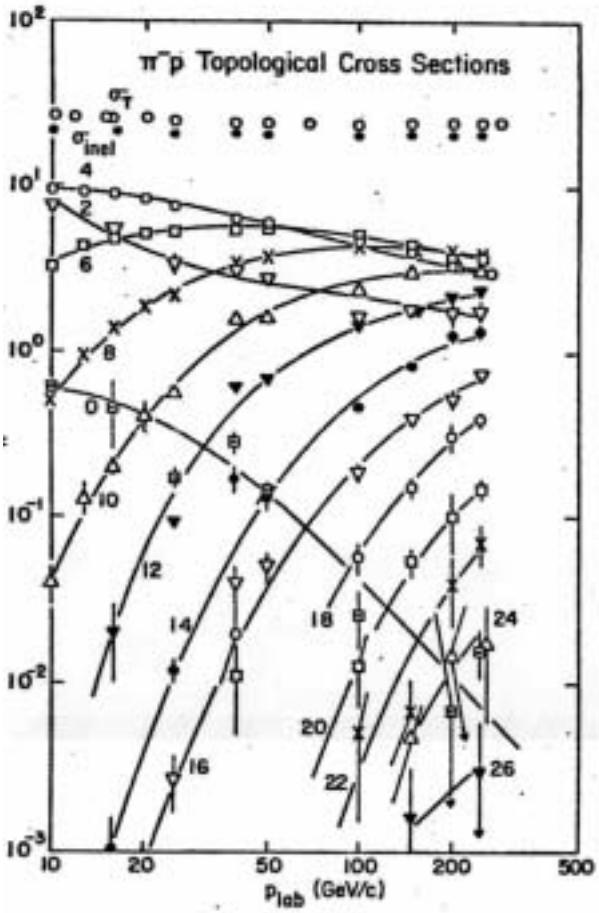


Figure 3(c)

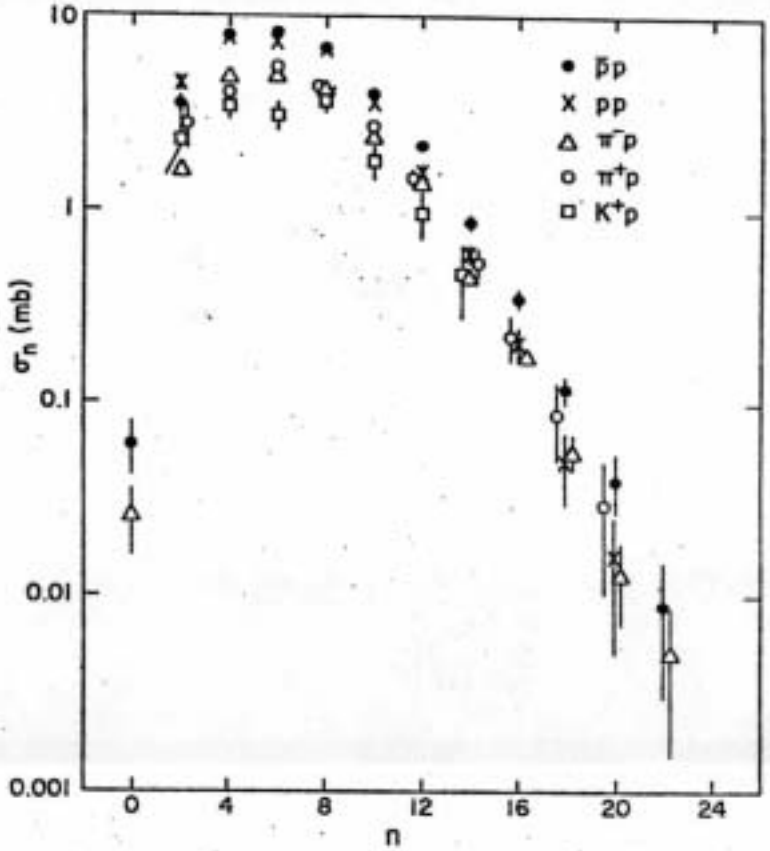


Figure 4

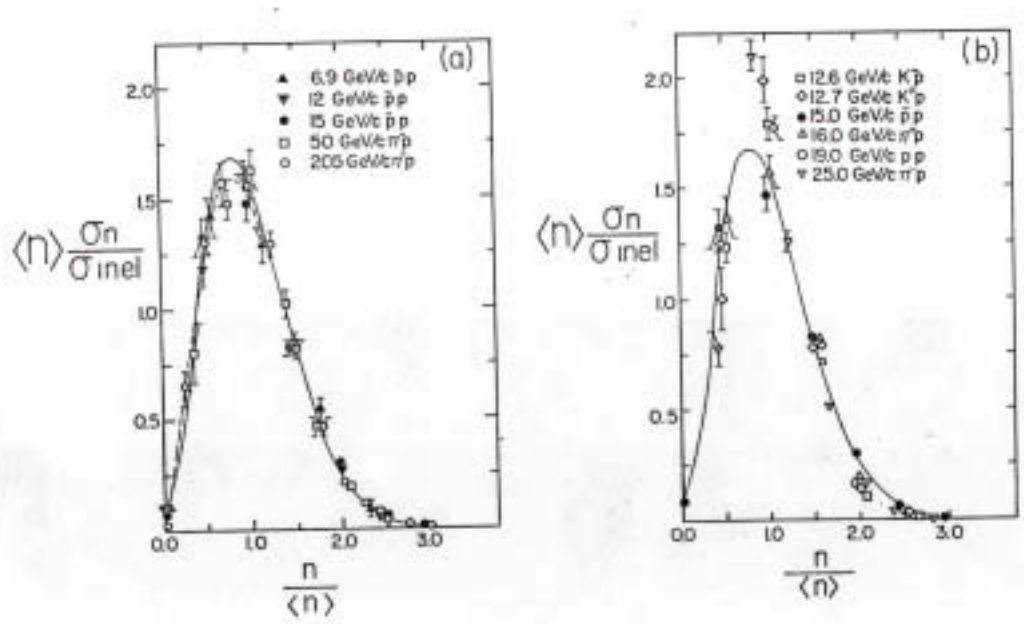

(a)
6.9 GeV/c p̄p
12 GeV/c p̄p
15 GeV/c p̄p
50 GeV/c π⁻p
205 GeV/c π⁻p
⟨n⟩ σn / σ inel
n / ⟨n⟩
(b)
12.6 GeV/c K⁻p
12.7 GeV/c K⁺p
15.0 GeV/c p̄p
16.0 GeV/c π⁺p
19.0 GeV/c pp
25.0 GeV/c π⁻p
⟨n⟩ σn / σ inel
n / ⟨n⟩

Fig. 20

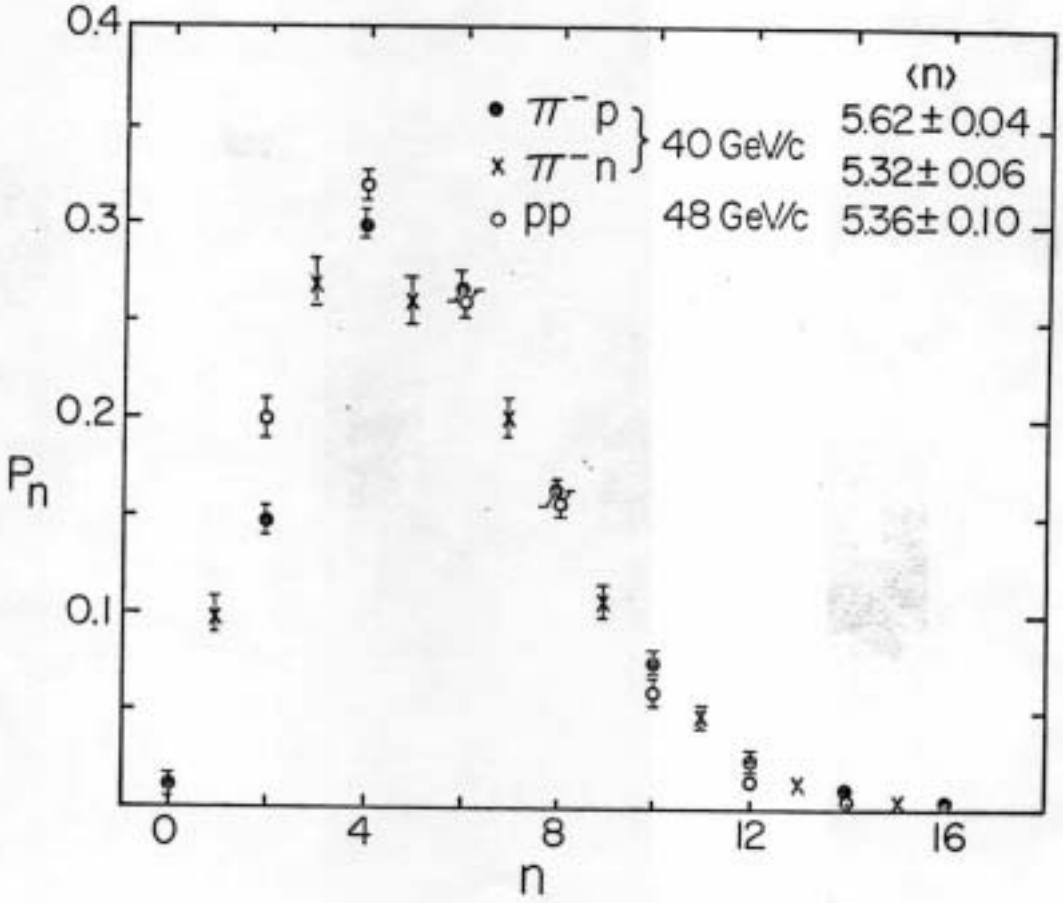

0.4
0.3
0.2
0.1
P_n
0
4
8
12
16
n
$\pi^- p$
$\pi^- n$
pp
40 GeV/c
48 GeV/c
⟨n⟩
5.62 ± 0.04
5.32 ± 0.06
5.36 ± 0.10

Fig. 25

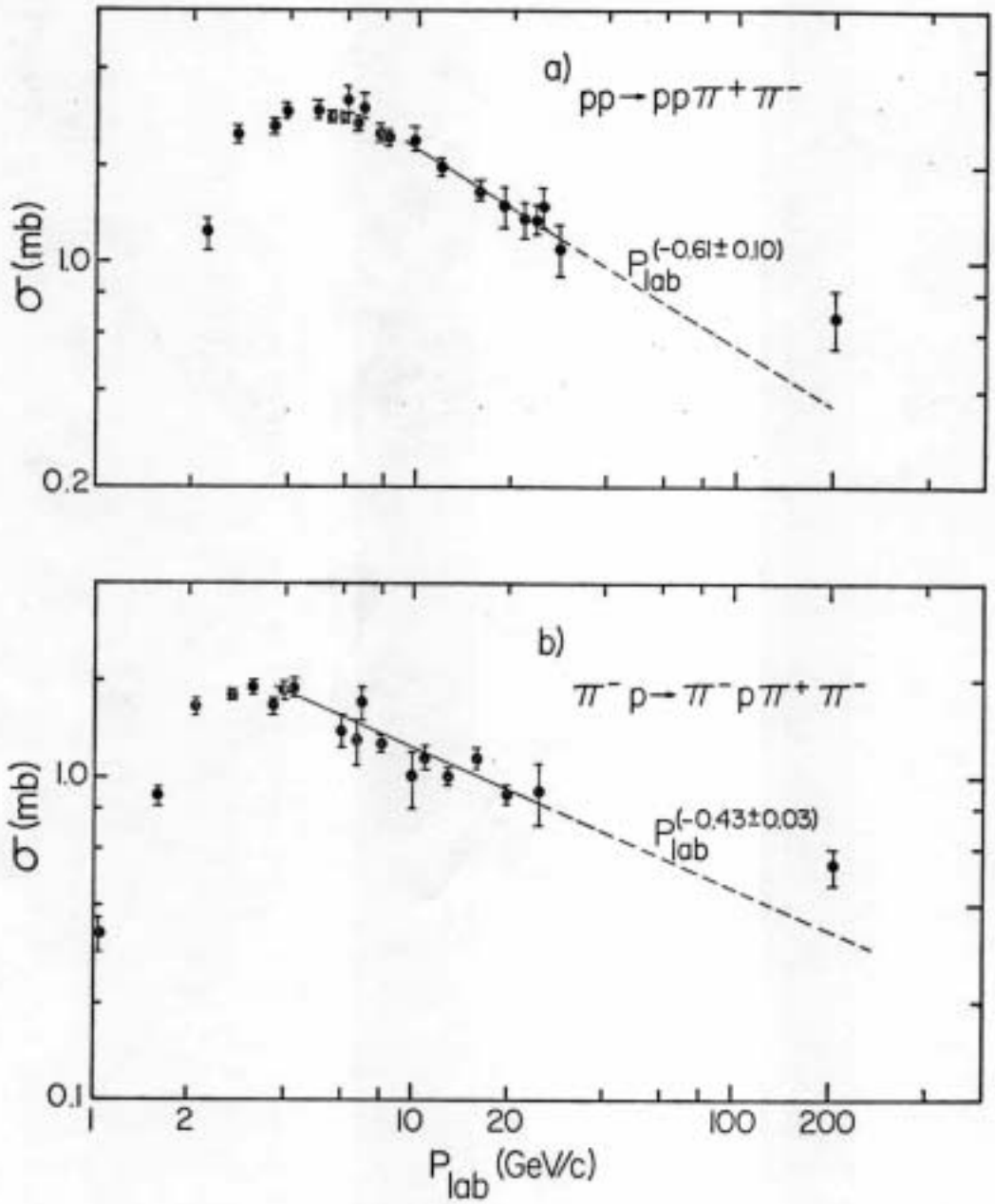

a)
pp → ppπ⁺π⁻
σ (mb)
1.0
0.2
P_lab^(-0.61±0.10)
b)
π⁻p → π⁻pπ⁺π⁻
σ (mb)
1.0
0.1
P_lab^(-0.43±0.03)
1
2
10
20
100
200
P_lab (GeV/c)

Fig. 38

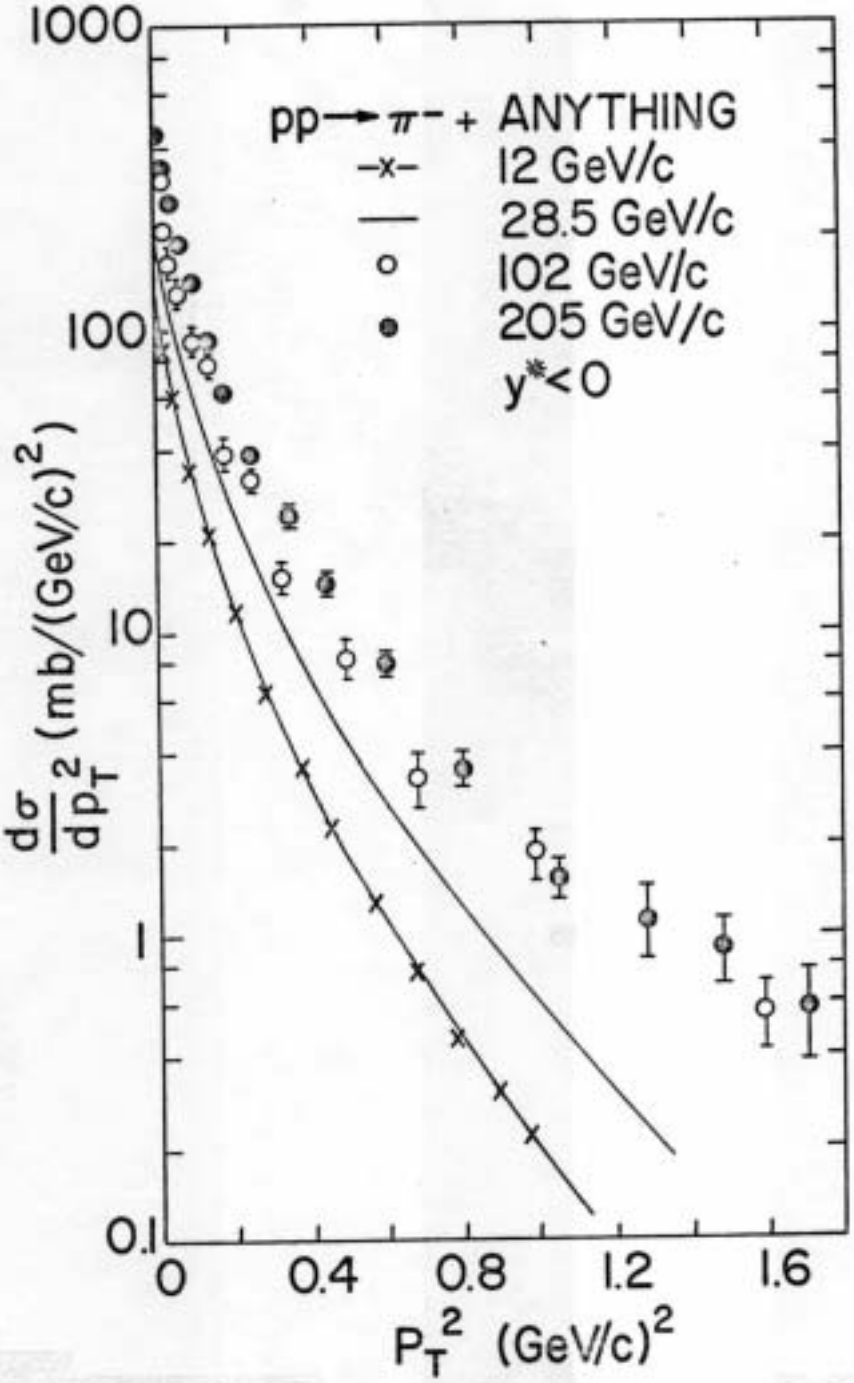

pp→π⁻ + ANYTHING
12 GeV/c
28.5 GeV/c
102 GeV/c
205 GeV/c
y*<0
1000
100
10
1
0.1
0
0.4
0.8
1.2
1.6
dσ/dp_T² (mb/(GeV/c)²)
P_T² (GeV/c)²

Fig. 60

- Why we cannot use CH2-C for getting H2 data for what we need.

- CH2 target 1%
- C=1% H2=0.16%

- Delta H/H = 6x1.414x delta CH2/CH2

- Systematic errors due to dynamics

- Diffractive region messed up by C fragmentation

- Loss of symmetry forward vs backward hemisphere in pp.

Plan of action

Fermilab fronts us $15K + techs till January till NSF grant fate becomes known. 2 cryocoolers refurbished.

If NSF grant comes thru, use it to payback Fermilab.

If no NSF, we have $30K from Livermore. We need another $20K to complete target and controlls.

Can also entertain the possibility of getting HARP target.

HARP cryogenic targets

Harp Cryogenic targets:

Hydrogen, Deuterium, Nitrogen, Oxygen

Liquefaction temperatures:

H_2	20.4 °K	H_2 / D_2 target
D_2	23.6 °K	
N_2	77.4 °K	N_2 / O_2 target
O_2	90.2 °K	

Dimensions:
6 cm long, 2 cm diameter
Actual target volume ~0.075 liters
Mylar targets inserted in a target arm (vacuum)

physical properties

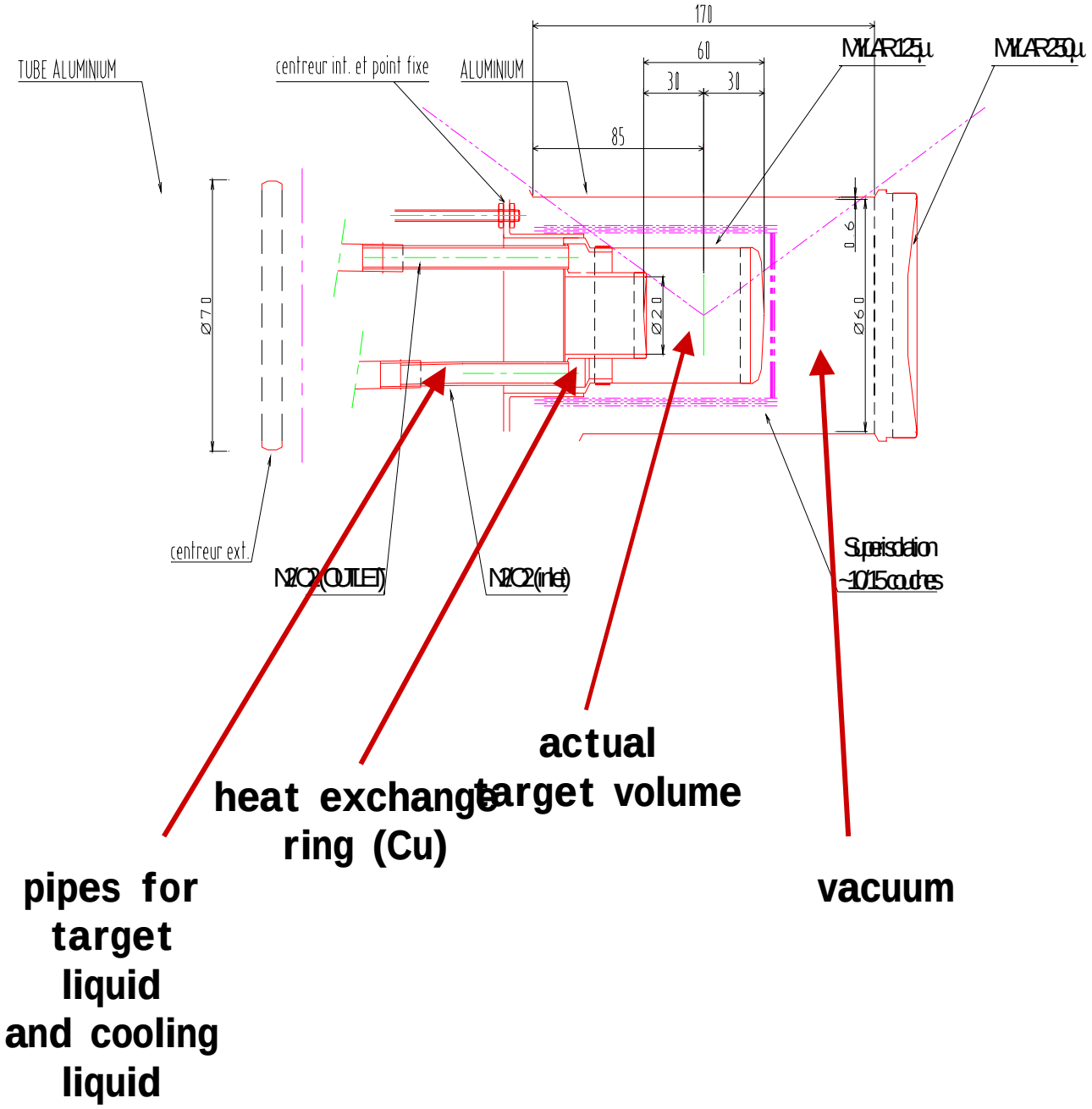
Physical properties of gases used for the HARP cryogenic targets

		H_2	D_2	N_2	O_2
Boiling point	[ºC]	-252.87	-249.6	-195.8	-182.96
Boilting point	[ºK]	20.28	23.6	77.35	90.19
Melting point	[ºC]	-259.14	-254.6	-209.86	-218.4
Melting point	[ºK]	14.01	18.6	63.29	54.8
Liquid density at the boiling point	[kg/l]	0.071	0.162	0.808	1.140*
Gas density at the boiling point	[kg/m^3]	1.329		4.613	4.474
Ratio of densities liquid/gas at boiling point		~53		~175	~255
Gas density at 0ºC	[kg/m^3]	0.0899	0.177	1.251	1.428
Gas density at 20ºC	[kg/m^3]	0.0838			1.330
# interaction length, for 6 cm long target	[%]	0.84	2.13	5.52	7.52
# radiation length, for 6 cm long target	[%]	0.70	0.79	12.76	19.98

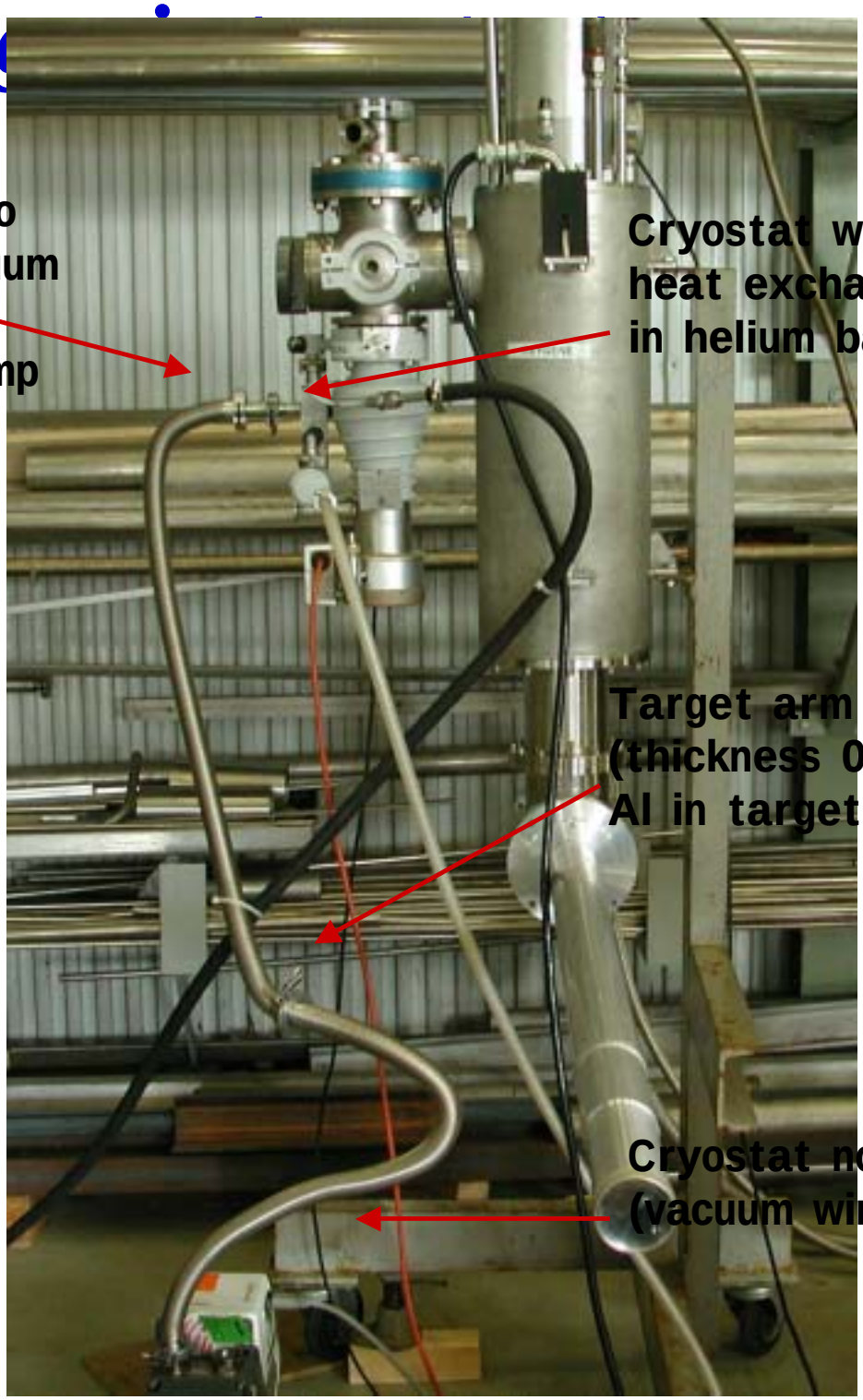
Notes:
Boiling and melting point are given for normal atmospheric pressure.
The targets are normally operated at an overpressure of ~100 mbar.

*: Liquid density increases with 0.5% for each degree of temperature reduction

geometry of the targets



cryog


Connection to primary vacuum pump and diffusion pump
Cryostat with heat exchange in helium bath
Target arm (thickness 0.6 m
Al in target reg
Cryostat nose (vacuum window