Tagging ^{3}He (≡h) breakup

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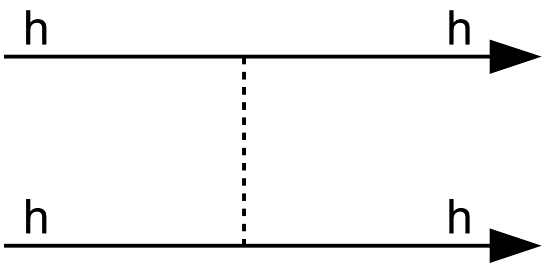
for brevity here
helion ^{3}He≡h

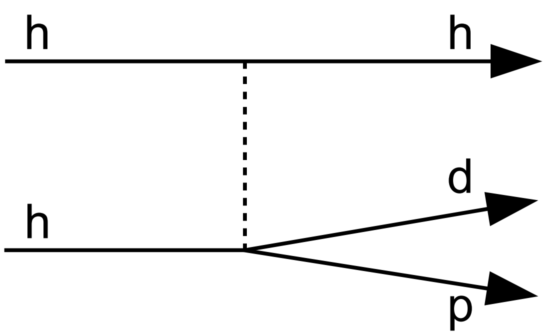
- h breakup processes
- Beamline downstream of target:
  breakup tagging; kinematic range
- Strategy:
  combined tagging, recoil missing mass
- Requirements on EIC ring
- Tests @ RHIC
- Homework
- Extra: tagging d breakup

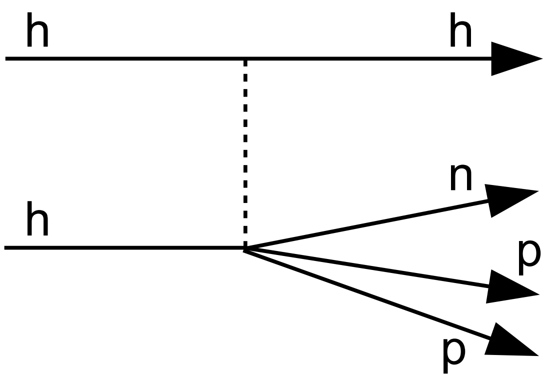
Processes

- Absolute h polarimeter needs
  elastic scattering process:



- Lowest lying h breakup state is h→dp, $m_d+m_p-m_h$ = 5.5 MeV
- Next is h→npp, $m_n+2m_p-m_h$ = 7.7 MeV

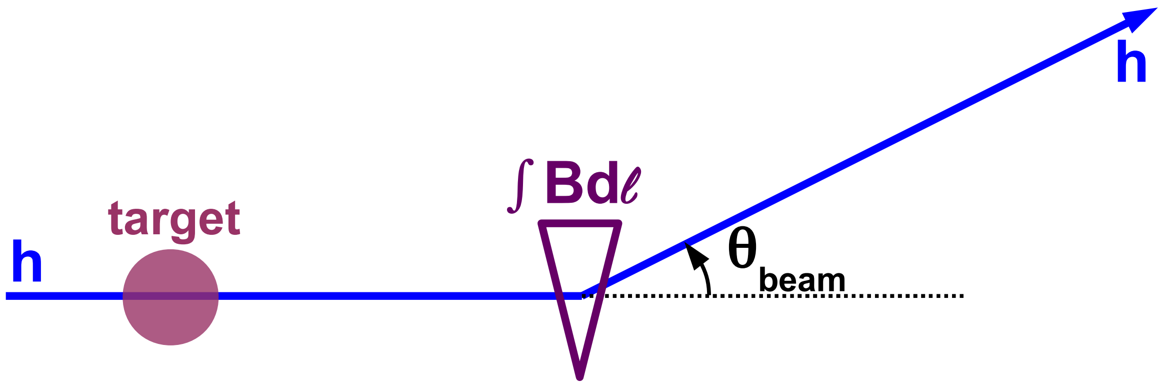




- If breakup vertex is target recoil: d,p,n may hit polarim. detectors
  - rejected by energy-TOF PID h selection
- If breakup vertex is beam recoil: target h may hit polarim. detectors
  - recoil target h missing mass measurement needs ~MeV resolution to distinguish from elastic, very challenging
- Can we tag beam breakup downstream from target?

Downstream beamline

- Somewhere downstream of absolute polarimeter target, beam bent by dipole:
(In RHIC this is DX dipole splitting beams ~12 m from IP)

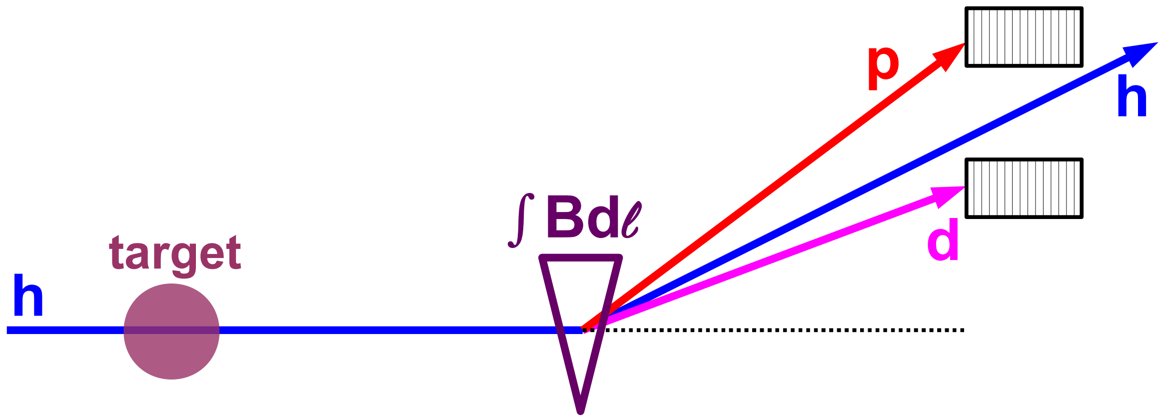


- Beam energy E_{beam}
- h has Z=2; dipole imparts transverse momentum $2 \cdot \int B d\ell$
- Small angle $\theta_{beam} \sim 2 \cdot \int B d\ell / E_{beam}$
- In RHIC DX θ_{beam} ~ 30* mrad

*discrepancy 15/30 mrad, see drawings sl. 24,25

Tagging h→dp breakup

- Consider d,p with p_T~0 w.r.t. beam
  i.e. target recoil p_T~0, threshold $m_{dp} = m_d+m_p$
- d has energy 2/3 E_{beam}; Z=1, dipole kick $\int Bd\ell$
  $\theta_d = (\int Bd\ell)/(2/3\ E_{beam}) = ¾\ \theta_{beam}$
- p has energy 1/3 E_{beam}; Z=1, dipole kick $\int Bd\ell$
  $\theta_p = (\int Bd\ell)/(1/3\ E_{beam}) = 3/2\ \theta_{beam}$



- d,p bent out of beam
- Can tag with e.g. calorimeters

Tagging h→npp breakup

- Consider n,p with $p_T \sim 0$ w.r.t. beam

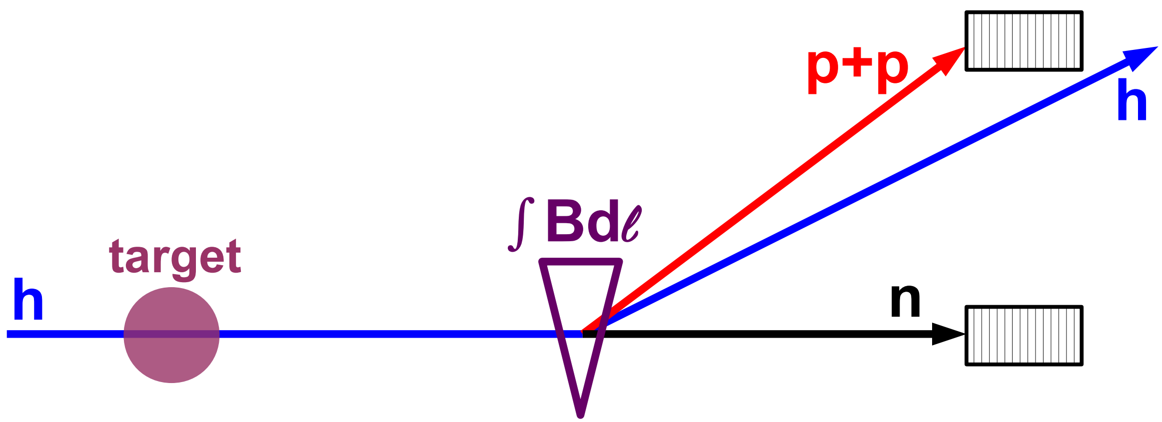
  i.e. target recoil $p_T \sim 0$, threshold $m_{npp} = m_n + 2m_p$

- n has energy 1/3 E_{beam}; Z=0, dipole kick 0

  $\theta_n = 0$

- p have energy 1/3 E_{beam}; Z=1, dipole kick $\int B d\ell$

  $\theta_p = (\int B d\ell)/(1/3\ E_{beam}) = 3/2\ \theta_{beam}$



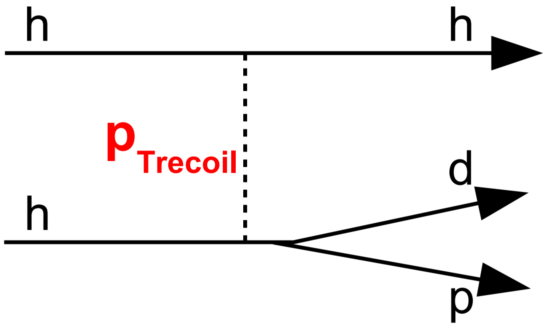
- p's bent out of beam, n not bent
- Can tag with e.g. calorimeters

Fragment p_T: recoil $|t| \sim p_{Trecoil}^2$

- So far considered fragments with $p_T \sim 0$ w.r.t. beam
  - defines 0° point in taggers for each fragment
- Fragments will have some p_T and spread around 0° point, from:
  - beam-target recoil p_T
  - fragmentation system c.m.s. p_T

<u>Recoil p_T:</u>

- Entire fragmentation system (dp, npp) gets $p_{Trecoil} \sim \sqrt{|t|}$ from target recoil:

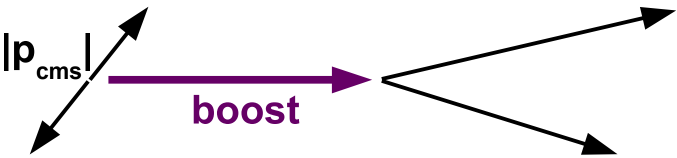


- Some rough numbers: h similar E_{kin} range in Hjet detectors (details extra slide)   helion E_{beam} = 100 GeV/nucleon
  taggers 10-20 m from target

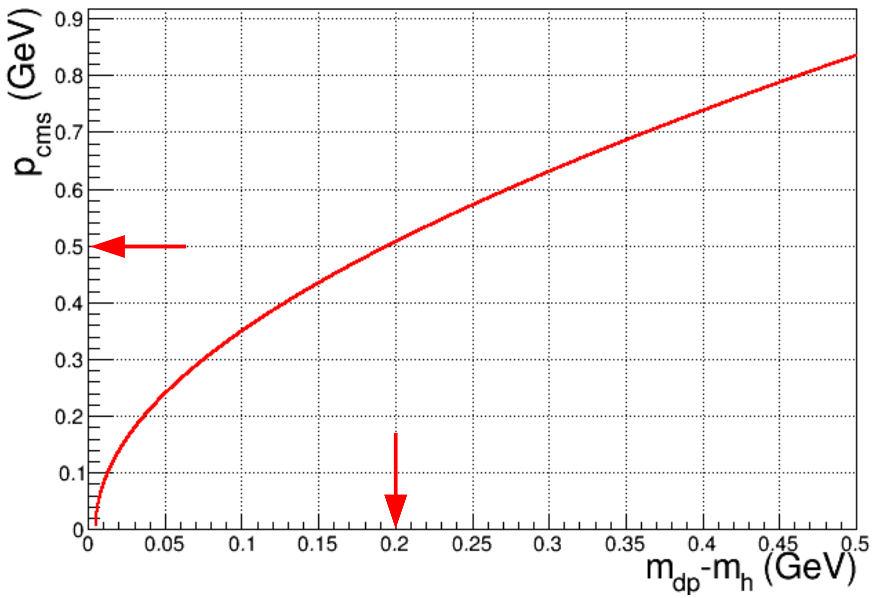
⇒ 0° spot spread 0.6-1.2 cm
recoil spread easily contained in a reasonable tagger

Fragment p_T: c.m.s. $|p|$

- For $m_{fragments} > m_{threshold}$: p_T in fragment c.m.s.
  e.g. for $m_{dp} > m_d + m_p$:



- p_{cms} vs. m_{dp}-m_h :
  (inelastic-elastic mass difference)
- Fragments get up to $p_T = p_{cms}$
  higher m_{dp}-m_h → higher p_T



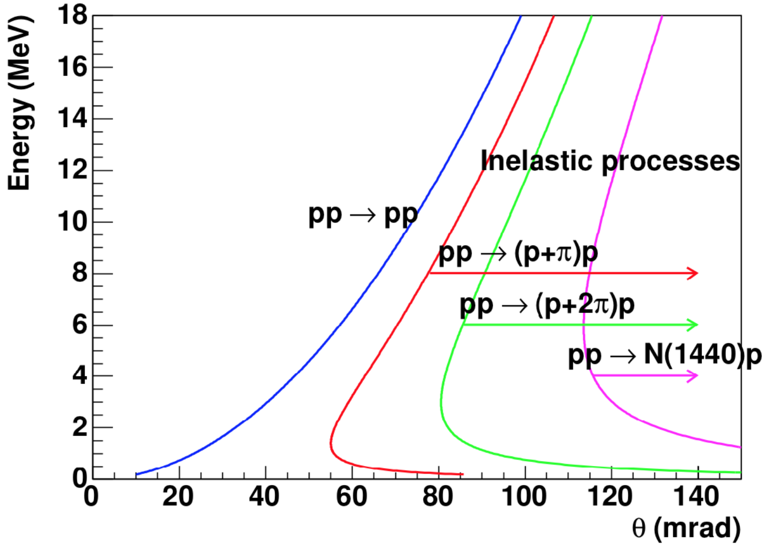
- Some rough numbers: helion E_{beam} = 100 GeV/nucleon
  (details extra slide) taggers 10-20 m from target
  20-40 cm wide (can fit among beam elements)
  ⇒ tag up to m_{dp}-m_h = 200 MeV

<u>Main point:</u> finite tagger size limits $m_{fragments} < m_{tag}^{max}$

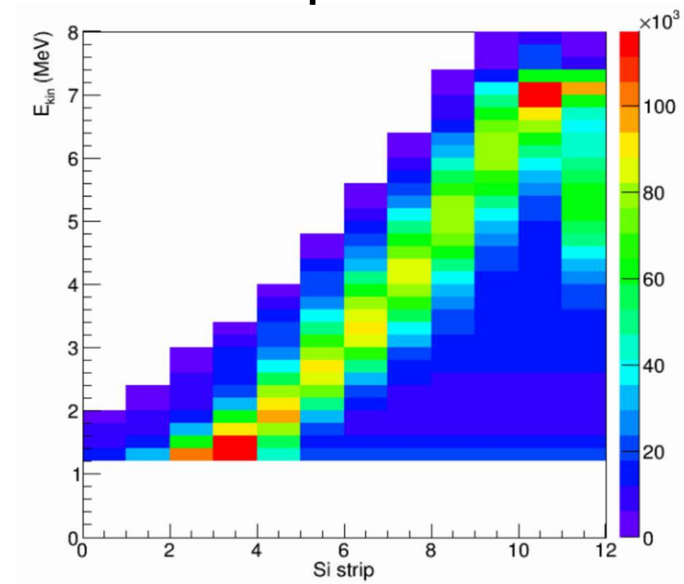
Recoil mass

Hjet target recoil proton

- kinematics: E vs θ



- data: E vs strip # ∝ scattering angle



- Elastic pp→pp / inelastic pp→ppX separated mass gap ≥ m_π ~140 MeV
- Inelastic lower E cut out: min. E each strip

- Similar for h beams, but:
  - mass gap h ↔ dp, npp only few MeV, close to elastic curve
  - elastic/inelastic separation limited by recoil resolution
    energy resolution, target & detector size → angular resolution
    backgrounds

Main point: recoil resolution limits $m_{fragments} > m_{recoil}^{min}$

Strategy

- Direct fragmentation tagging:

  - tag low $m_{fragments} < m_{tag}^{max}$

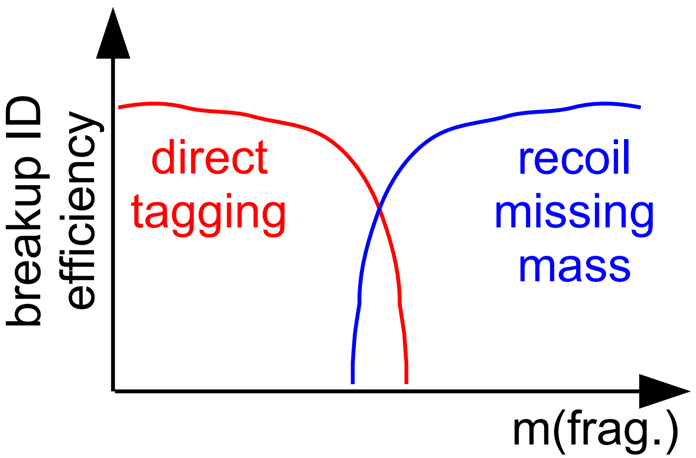
- Recoil missing mass resolution:

  - identify high $m_{fragments} > m_{recoil}^{min}$

  separate elastic/inelastic

- Try to get overlap $m_{tag}^{max} > m_{recoil}^{min}$,

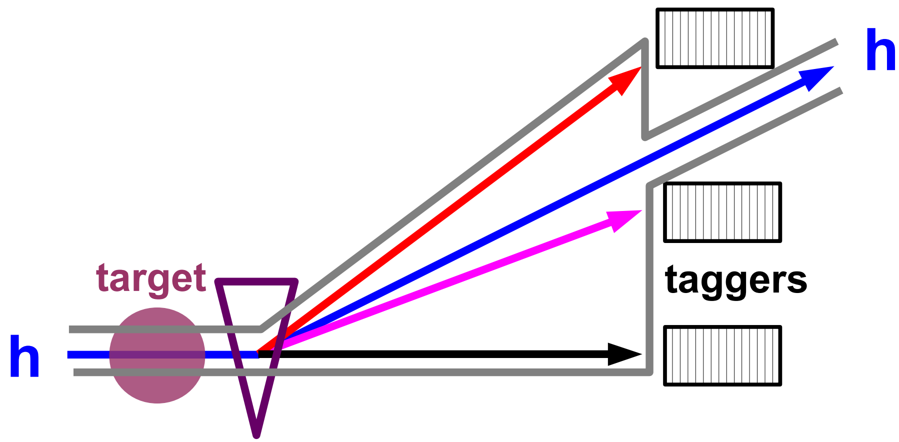
  or m_{tag}^{max} as high as possible



- Inevitably some gaps:
  use measured kinematic distributions,
  estimate loss in gaps

- If breakup is only few % as expected,
  small uncertainty on correction

Requirements EIC ring



<u>Need strong dipole in ring with:</u>

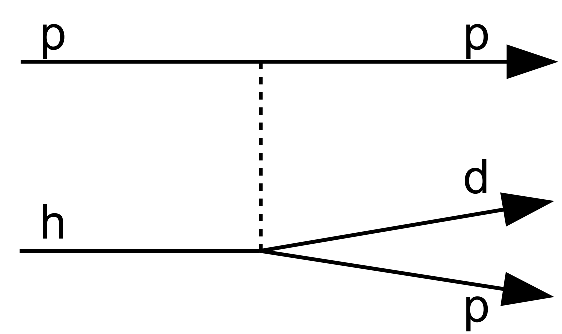
- Space for target upstream
- Drift space downstream, fragments separate from beam
- Space for taggers
- Vacuum chamber w/ exit windows for fragments

Tests @ RHIC next years

<u>Can test h breakup with:</u>

existing Hjet p target →

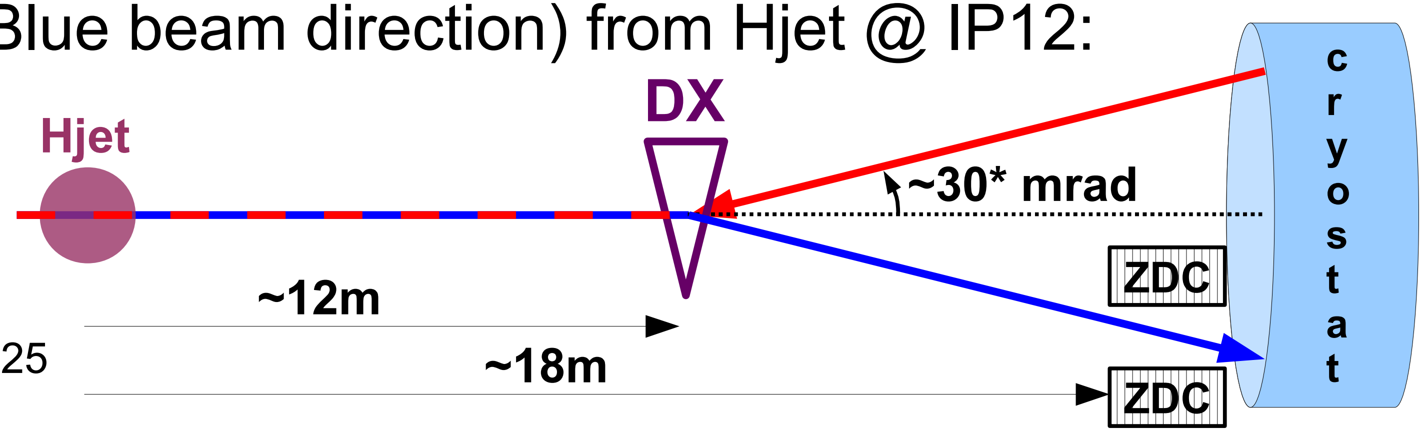
h beam (APEX session) →



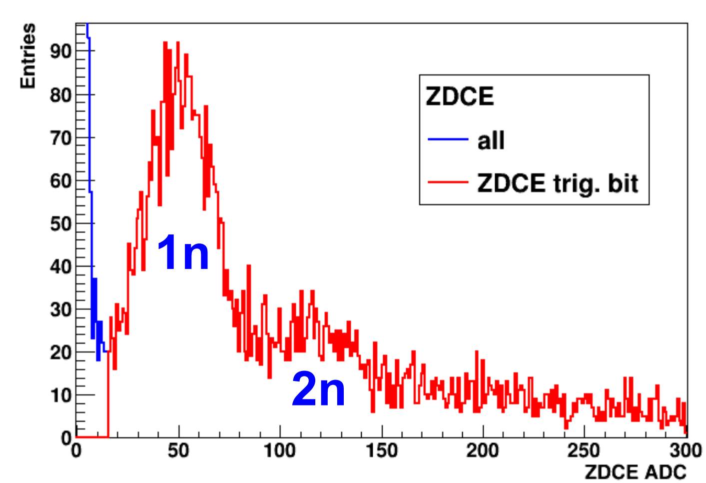
- Downstream (Blue beam direction) from Hjet @ IP12:

• not to scale

* discrepancy 15/30 mrad
drawings extra slides 24,25



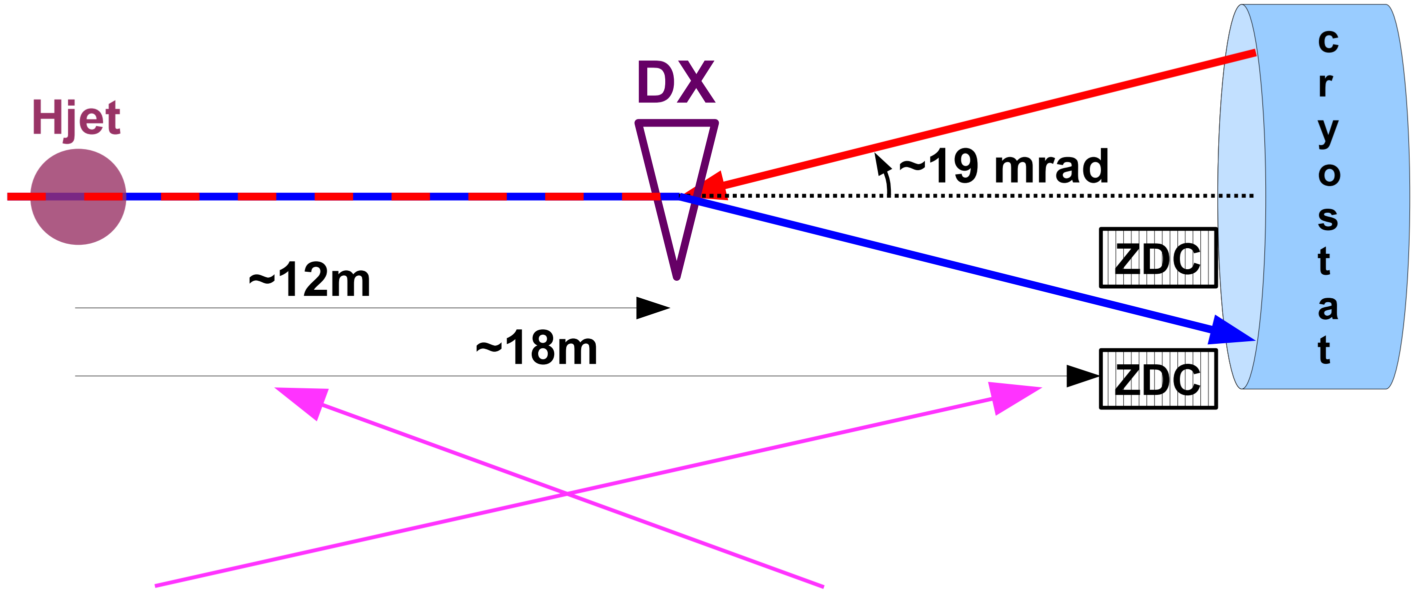
- Blue beam bent horizontally ~30* mrad by DX dipole, center @ ~12 m
- Space for taggers up to ~18 m,
  blocked beyond by cryostat
- 2 Zero Degree Calorimeters (ZDCs)
  from Brahms/Phobos available
  - mediocre hadronic calorimeter
  - adequate for tagging



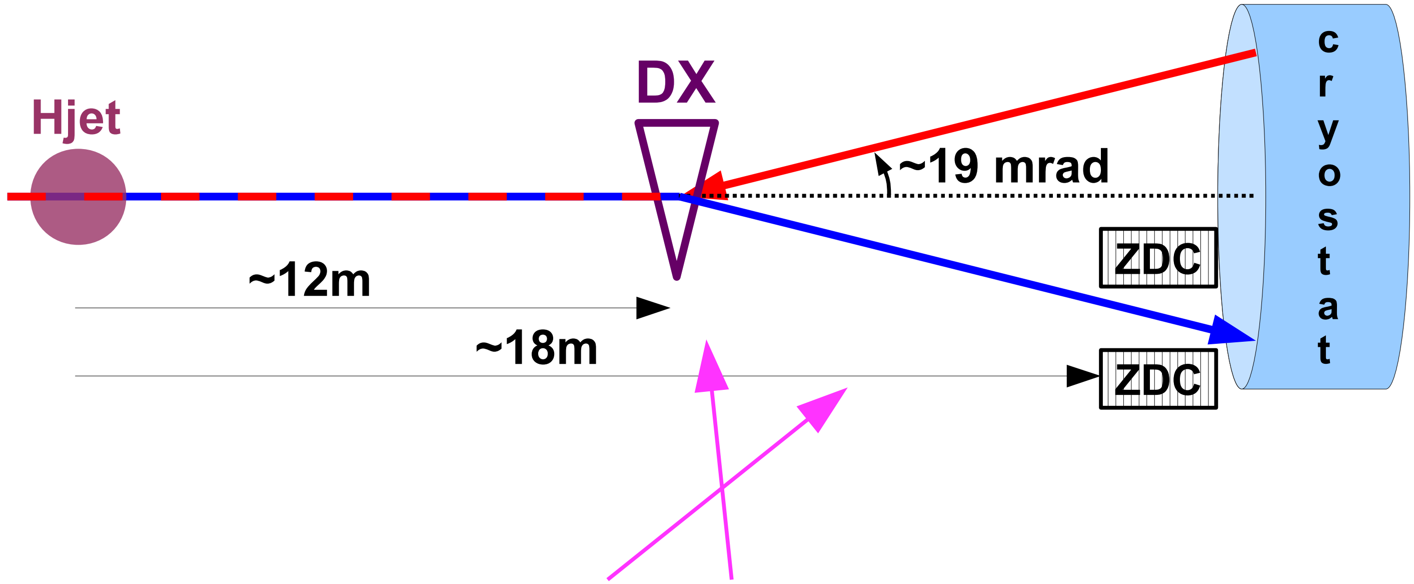
100 GeV neutrons

*discrepancy 15/30 mrad, see drawings sl. 24,25

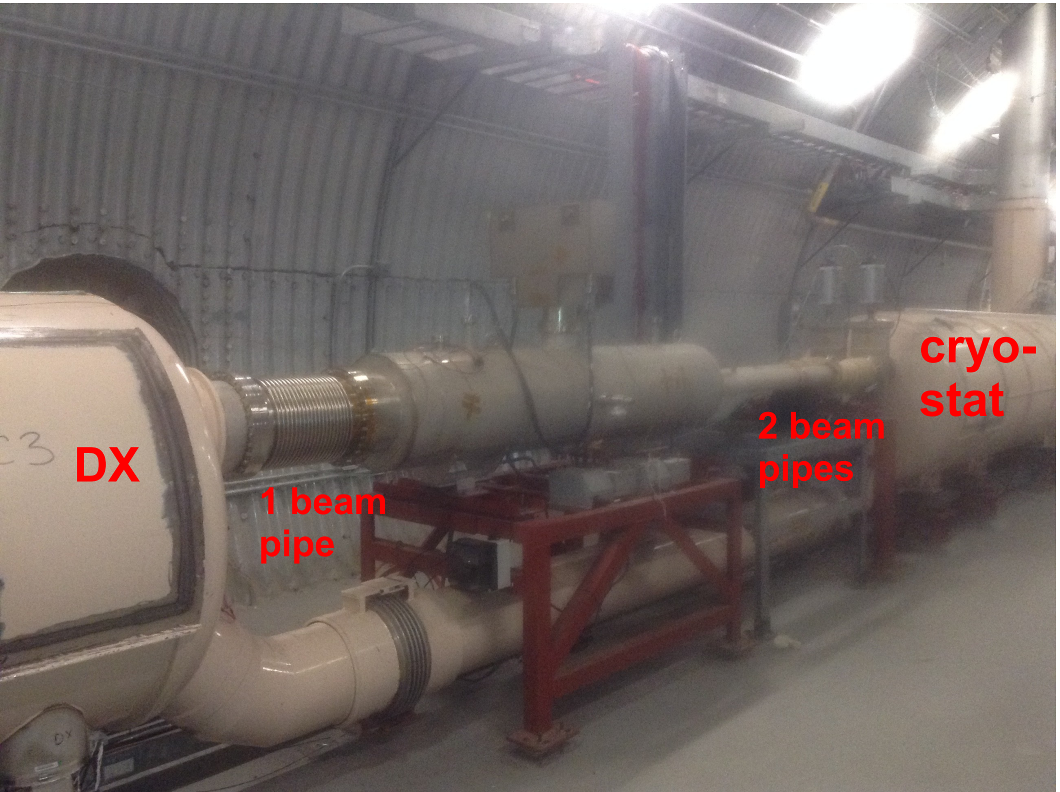
Tests @ RHIC



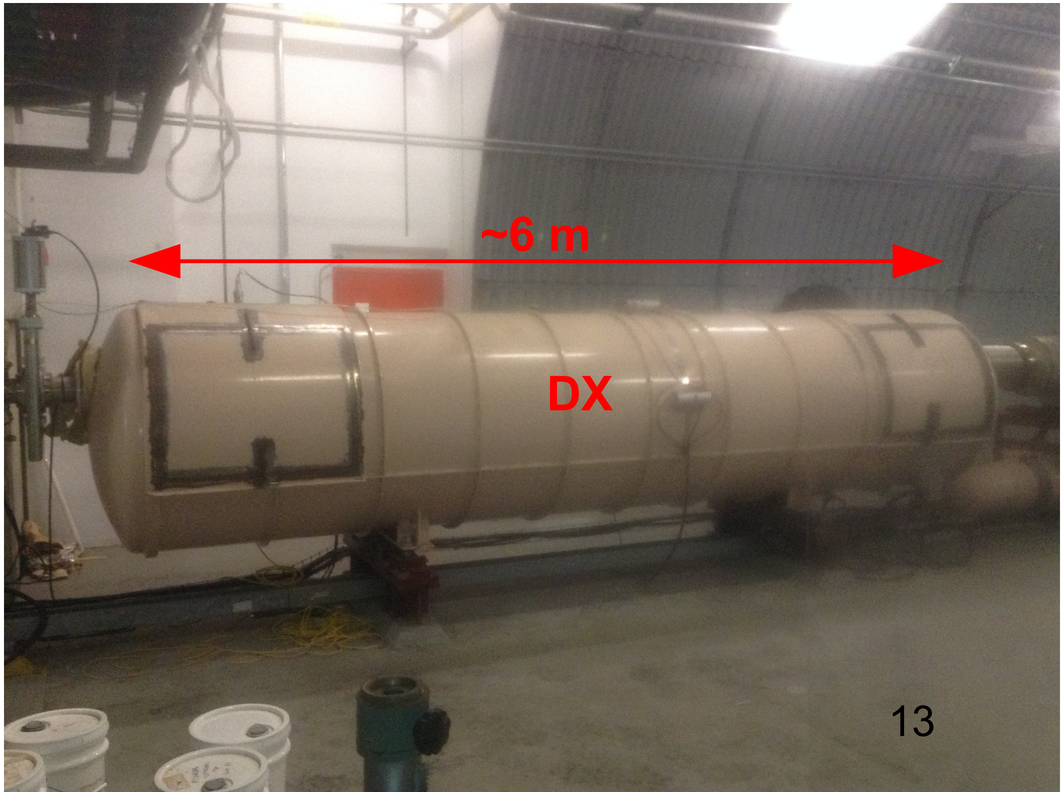
Tests @ RHIC



Hjet
DX
~19 mrad
cryostat
ZDC
ZDC
~12m
~18m

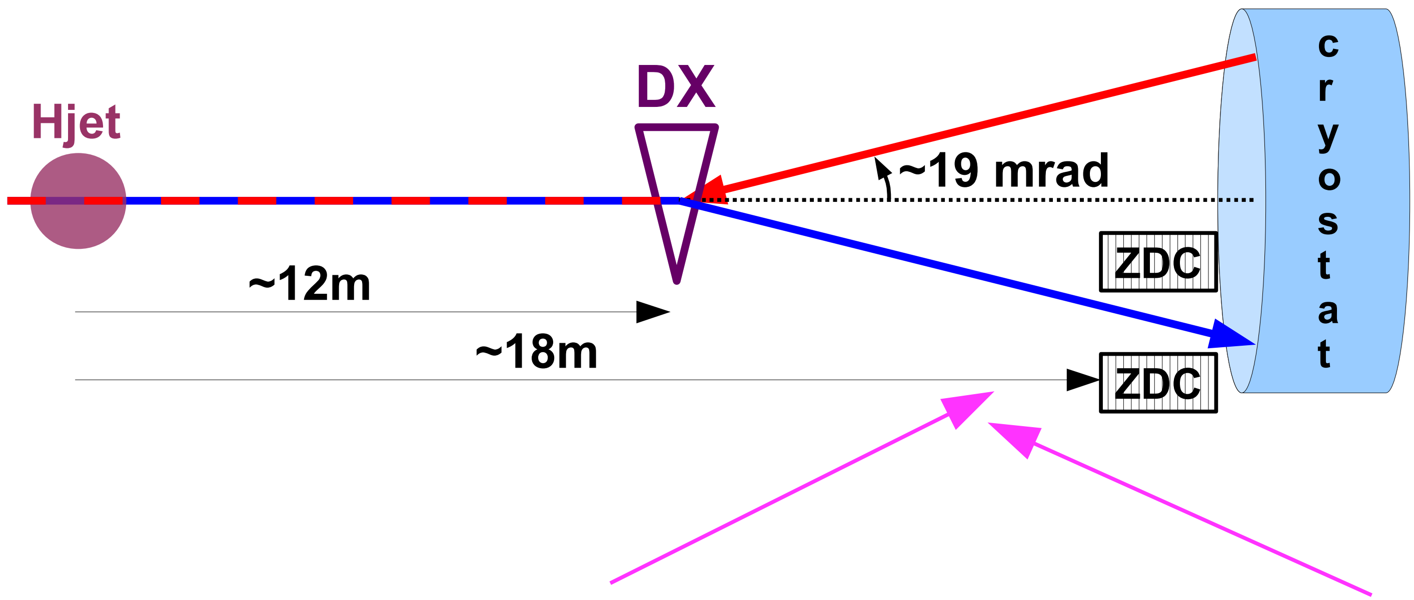


DX
1 beam pipe
2 beam pipes
cryo-stat

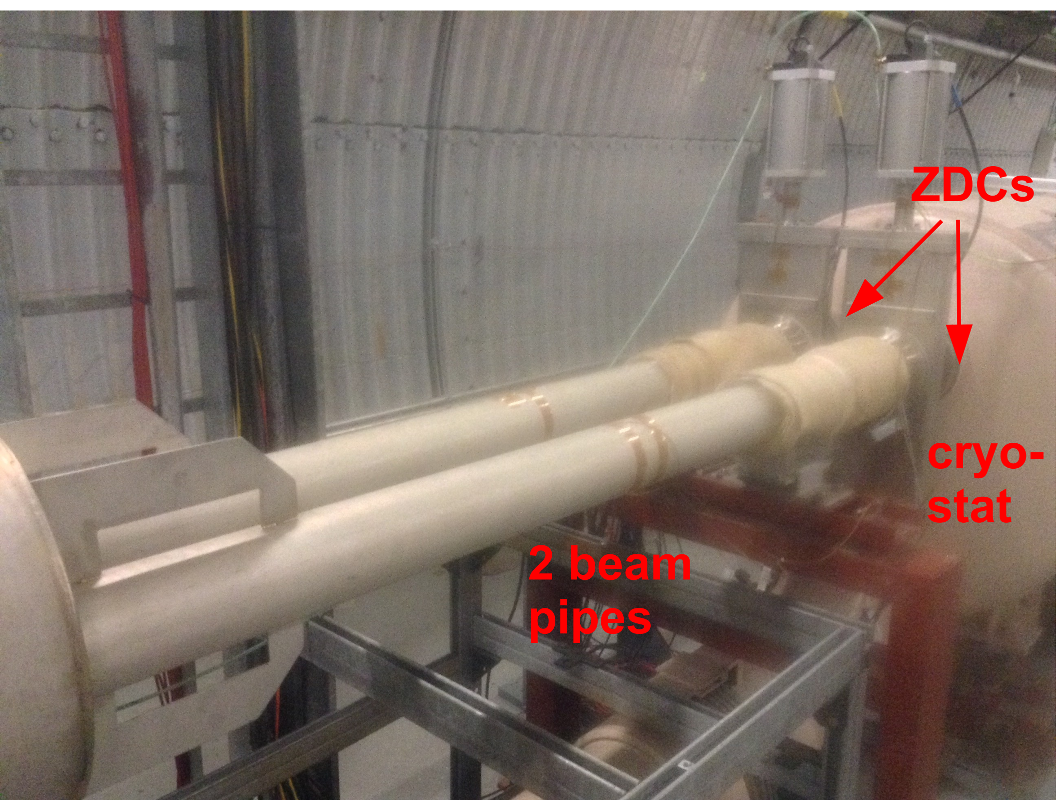


~6 m
DX

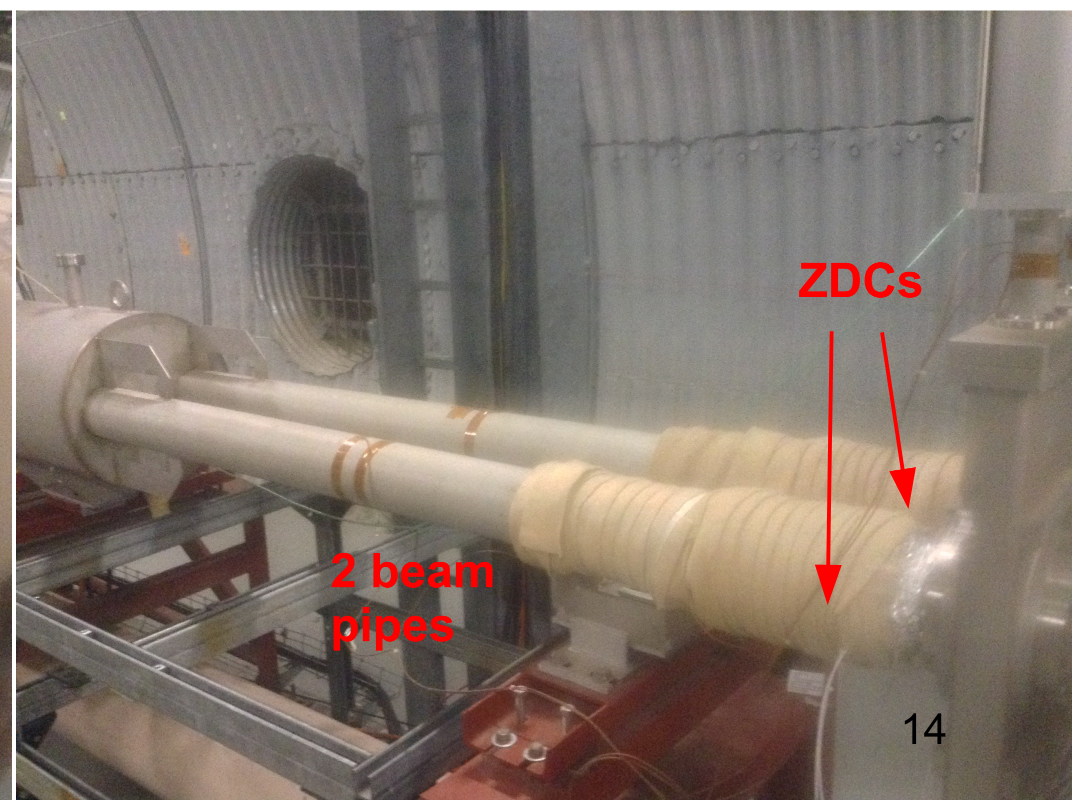
Tests @ RHIC



DX
Hjet
~19 mrad
cryostat
ZDC
ZDC
~12m
~18m

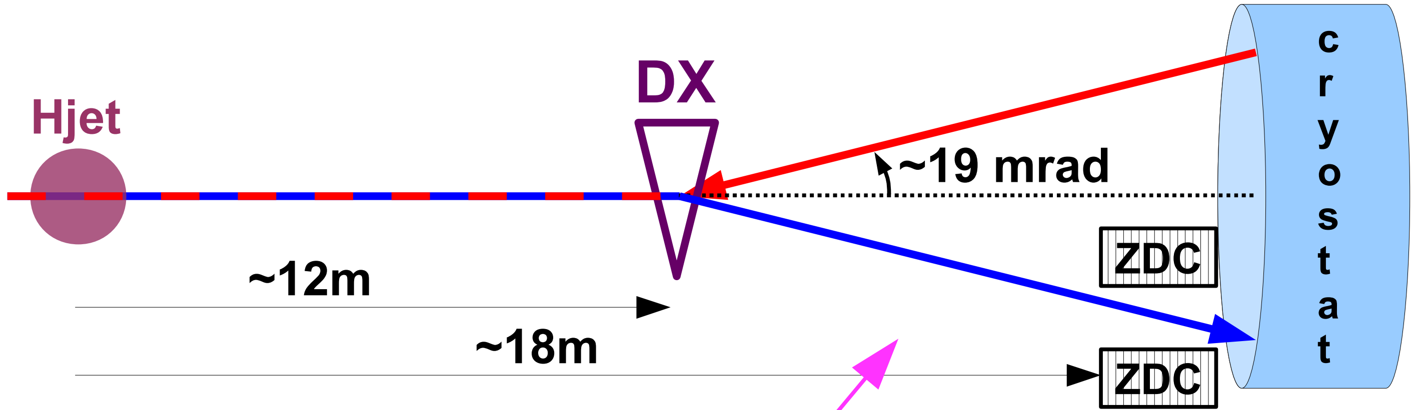


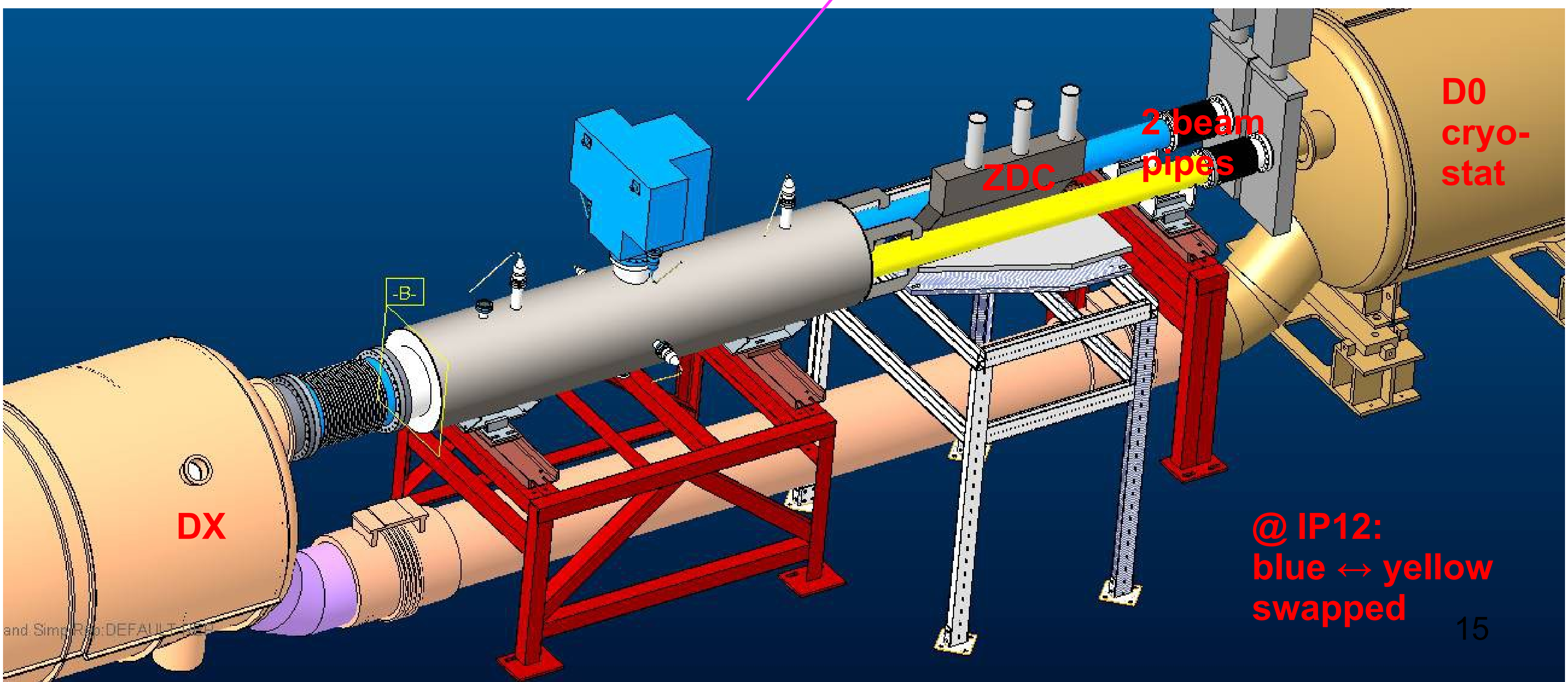
ZDCs
cryo-
stat
2 beam
pipes



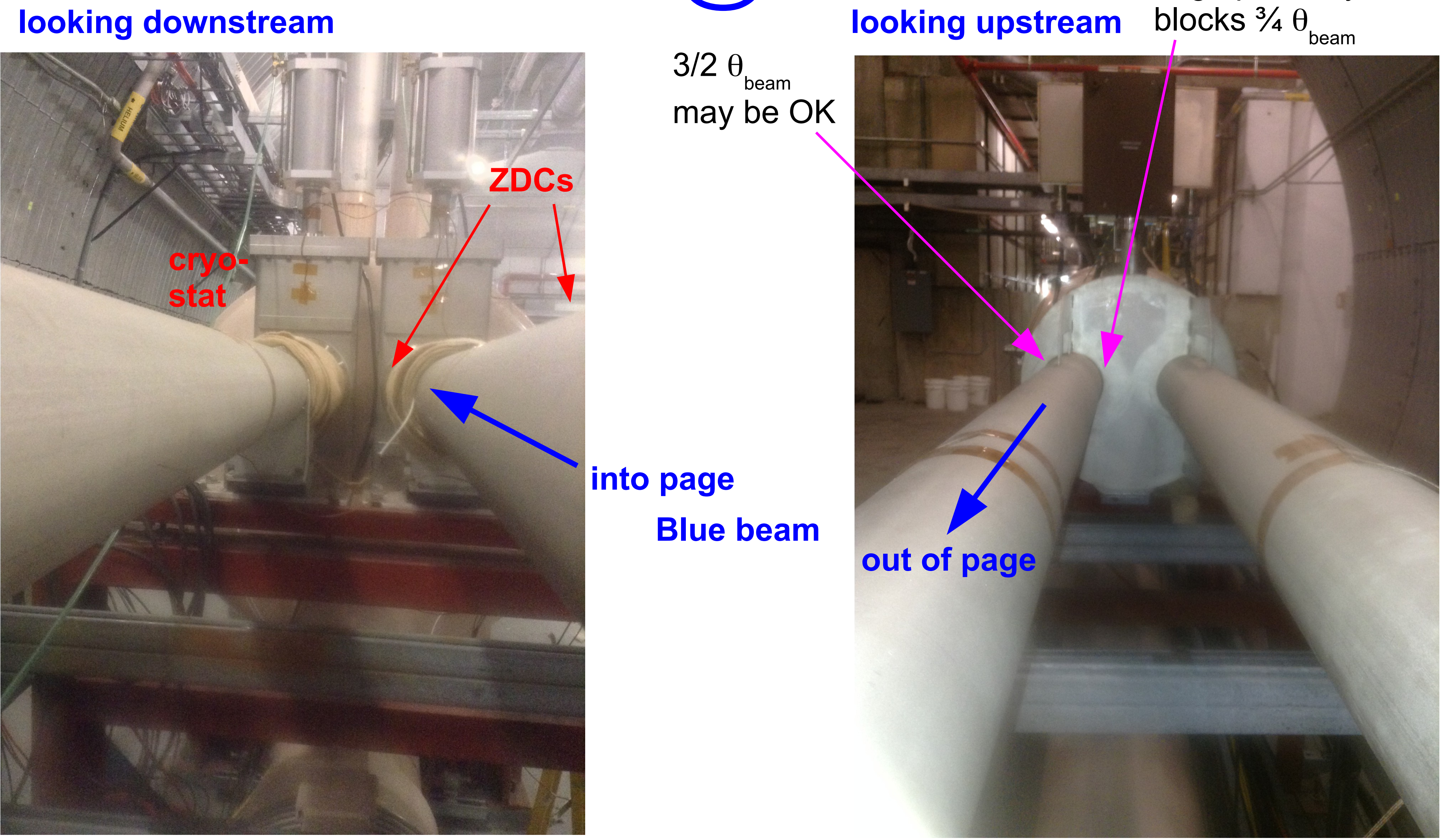
ZDCs
2 beam
pipes

Tests @ RHIC


Hjet
DX
~19 mrad
cryostat
ZDC
~12m
~18m
ZDC


-B-
ZDC
2 beam pipes
D0 cryo-stat
DX
@ IP12:
blue ↔ yellow swapped

Tests @ RHIC



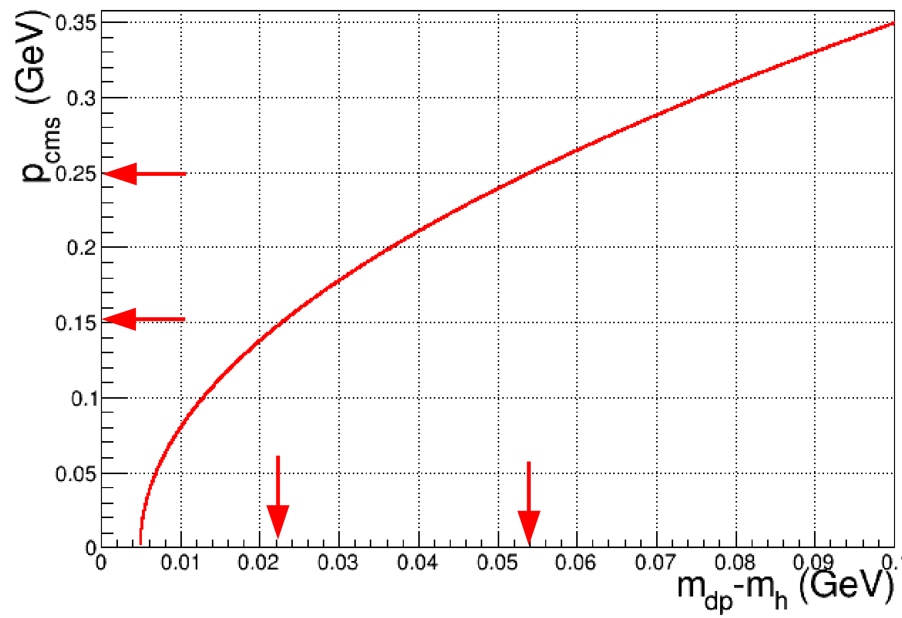
- Detailed measurements, component drawings: where can put ZDCs, angular range covered

Tests @ RHIC

- ZDCs: ~18 m from target, 10×10 cm wide
  $\Rightarrow$ tag fragments up to $\theta_{n,p,d}$ ~ 2.5 mrad

- helion polarized E_{beam} = 60 GeV/nucleon → fragment p_T < 0.25 GeV
  unpolarized E_{beam} = 100 GeV/nucleon → fragment p_T < 0.15 GeV

- Tag m_{dp}-m_h up to
  20 MeV / 55 MeV



- Correlate fragment tags ↔ protons in Hjet recoil detectors
- Does Hjet have resolution to see:
  <u>elastic/inelastic mass gap ~ 20-50 MeV?</u>

Homework

Fragment tagging

- Get accurate layout @ RHIC:
  - possible ZDC positions, $m_{fragments}$ coverage
- Simulation for EIC w/ realistic dipole bend
  - tagging efficiency vs $m_{fragments}$ for tagger parameters:
    dipole |B|, tagger sizes, position

Target recoil missing mass (Hjet experts)

- Strategy for hh, hp: E_{kin} range
- Simulation (toy MC or sophisticated):
  - Missing mass resolution,
    how low m_{recoil}^{min} distinguish elastic?

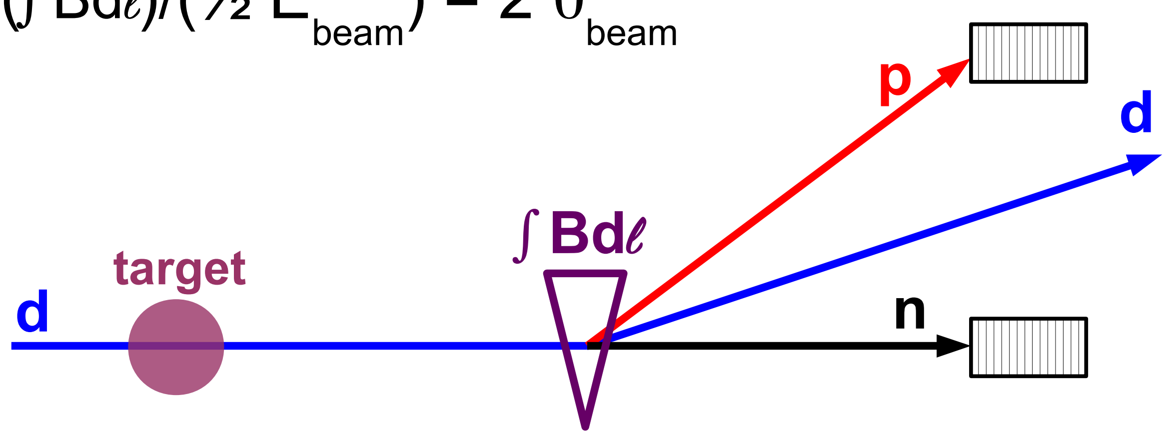
EIC ring

- Find / develop appropriate dipole & neighborhood

Extras

Tagging d→np breakup

- Consider n,p with $p_T \sim 0$ w.r.t. beam
  i.e. target recoil $p_T \sim 0$, threshold $m_{np} = m_n + m_p$
- d has energy E_{beam}; dipole kick $\int B d\ell$
  $\theta_{beam} = \int B d\ell / E_{beam}$
- n has energy ½ E_{beam} ; Z=0, dipole kick 0
  $\theta_n = 0$
- p has energy ½ E_{beam} ; Z=1, dipole kick $\int B d\ell$, same as d
  $\theta_p = (\int B d\ell)/(½\, E_{beam}) = 2\, \theta_{beam}$

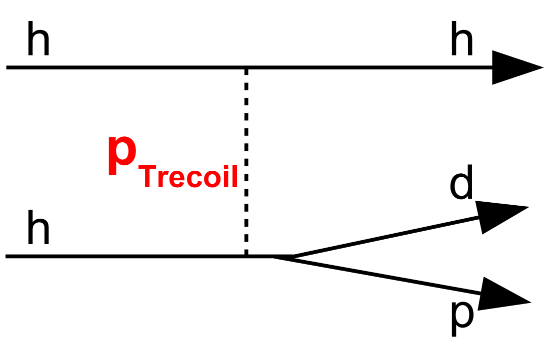


- p bent out of beam, n not bent; can tag with e.g. calorimeters

Fragment p_T: recoil $|t| \sim p_{Trecoil}^2$

- So far considered fragments with $p_T \sim 0$ w.r.t. beam
  - defines 0° point in taggers each fragment
- Fragments will have some p_T and spread around 0° point, from:
  - beam-target recoil p_T
  - fragmentation system c.m.s. p_T

<u>Recoil p_T:</u>

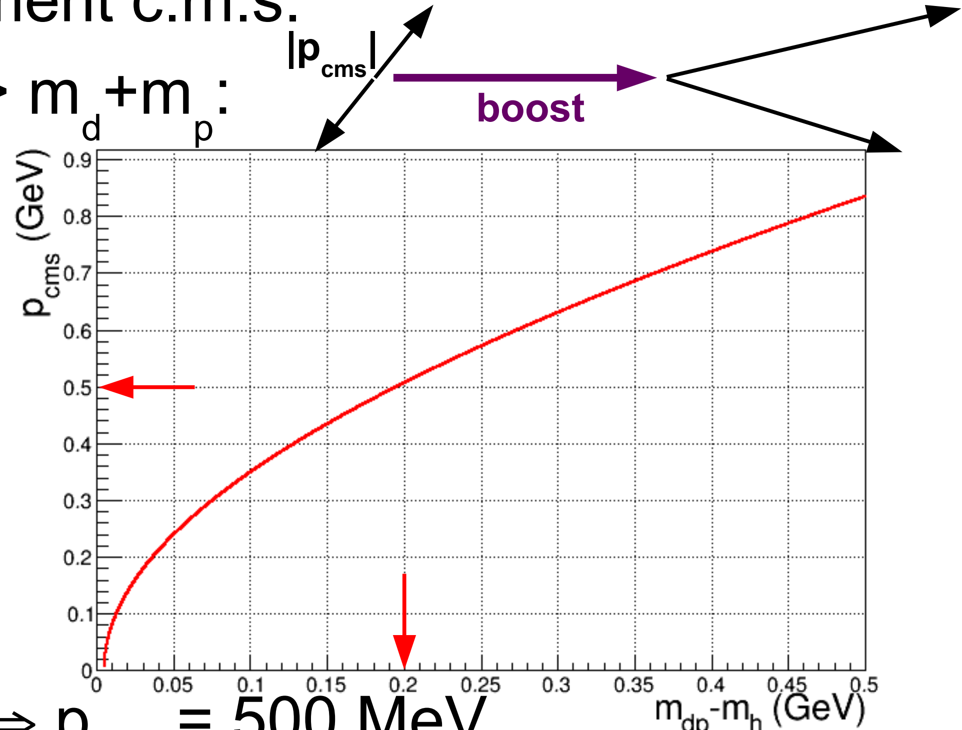


- Entire fragmentation system (dp, npp) gets $p_{Trecoil} \sim \sqrt{|t|}$ from target recoil:
- For |t| range present Hjet: $50 < p_{Trecoil} < 100$ MeV
  For h same E_{kin}, need higher |t|: $90 < p_{Trecoil} < 180$ MeV
- Whole fragmentation system angle $\theta_{recoil} \sim p_{Trecoil}/E_{beam}$
- For total E_{beam} = 300 GeV: max. $\theta_{recoil} \sim 0.6$ mrad
- For taggers 10-20 m from target, 0° spot spread 0.6-1.2 cm

$\Rightarrow$ recoil spread easily contained in a reasonable tagger

Fragment p_T: c.m.s. |p|

- For $m_{fragments} > m_{threshold}$, some p_T in fragment c.m.s.
  e.g. for $m_{dp} > m_d + m_p$:

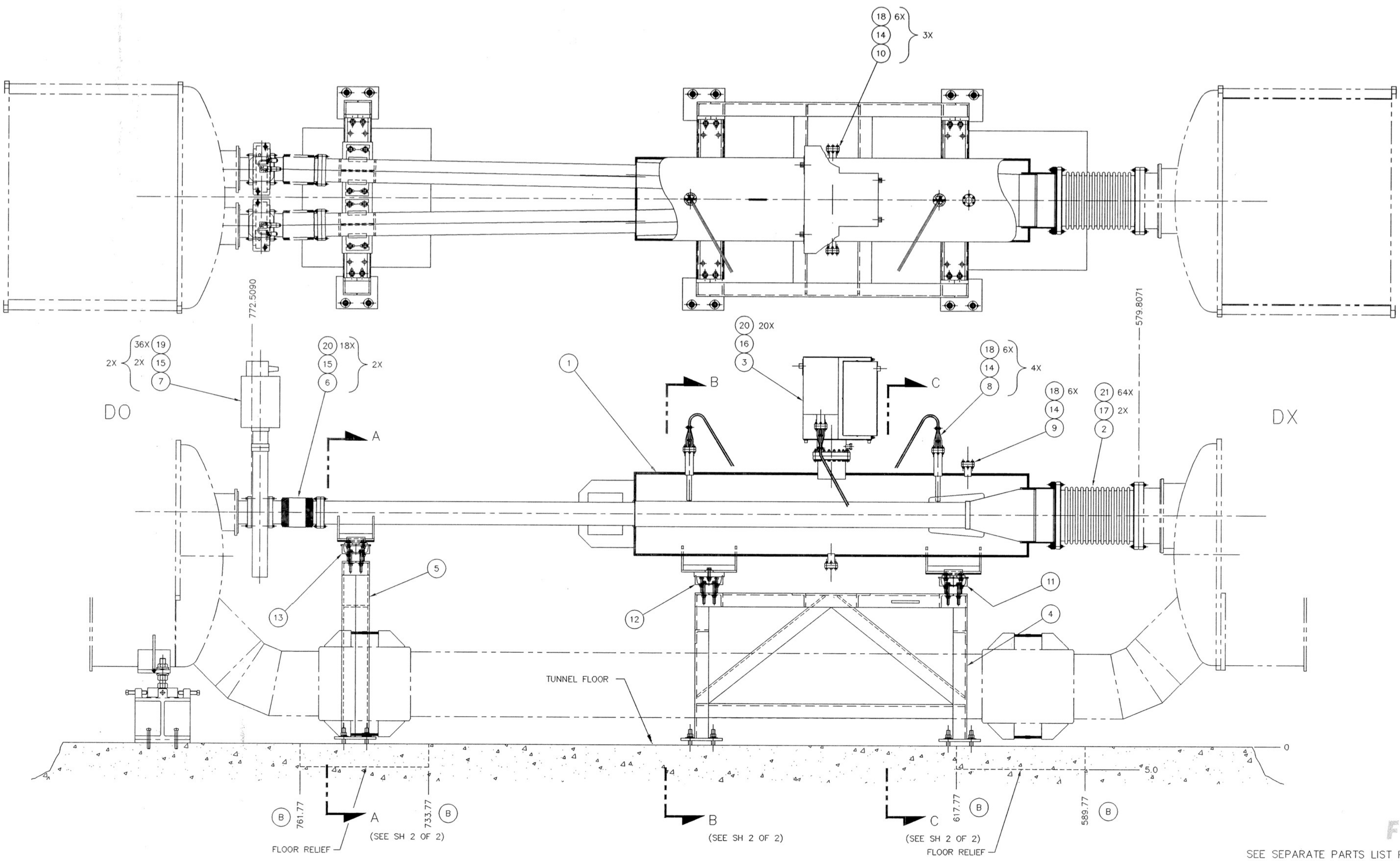


- p_{cms} vs. m_{dp}-m_h :
  (inelastic-elastic mass difference)
- If c.m.s. decay ⊥ beam direction,
  fragments get up to $p_T = p_{cms}$
- Slower proton kicked widest angle
  $\theta_p = p_{cms}/E_p \quad \theta_d = p_{cms}/E_d$
- E.g. tag up to e.g. m_{dp}-m_h = 200 MeV ⇒ p_{cms} = 500 MeV
- E_{beam} = 300 GeV, E_p ~ 100 GeV: θ_p ~ 5 mrad
- For taggers 10-20 m from target, 0° spot spread 5-10 cm
  ⇒ need taggers 20-40 cm wide to tag up to m_{dp}-m_h = 200 MeV

- For c.m.s. decay || beam direction, fragments faster/slower than nominal, bent less/more in dipole. Need simple simulation, estimate effect
- 3-body break up, mean p_{cms} smaller, small angles, easier to tag

NOTES:
1. AFTER CHAMBER HAS BEEN BOLTED INTO POSITION, WELD AS SHOWN ON SH 2 OF 2 TO ESTABLISH AN ANCHOR POINT.

REVISIONS							
REV	ZONE	ECN NO.	DESCRIPTION	BY	DATE	CKR	APP
A			INITIAL RELEASE	PAH	4/3/98	SN	DH
B	A-3,6-7	CR346	AS PER ECN	SN	[illegible]		



42035021-01 AS SHOWN
42035021-02

FINAL

SEE SEPARATE PARTS LIST PL42035021-01&-02

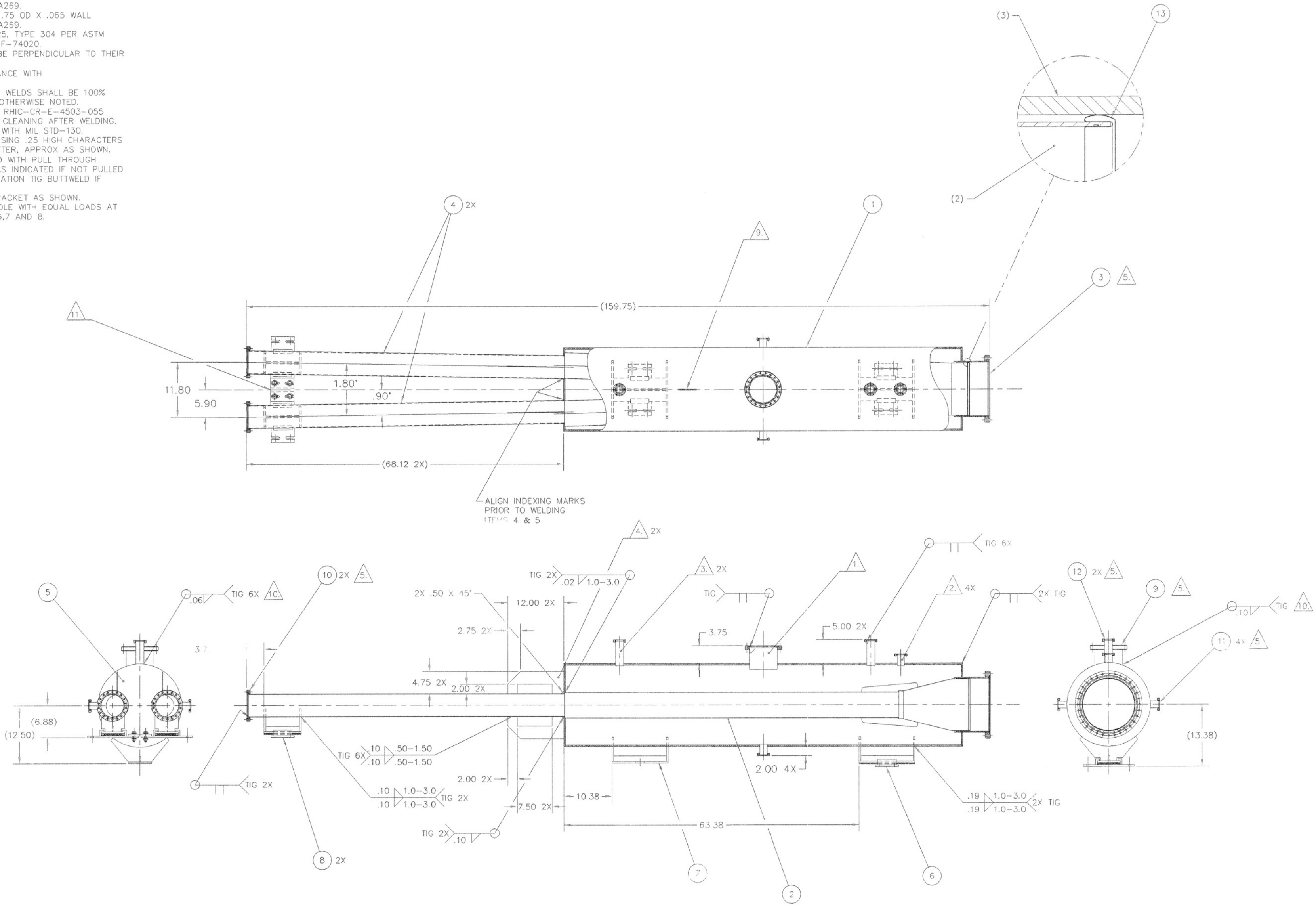
OUTSTANDING ECN NUMBERS	INTERPRET IN GENERAL ACCORDANCE WITH ASME Y14.24M-1989	RHIC		BROOKHAVEN NATIONAL LABORATORY ASSOCIATED UNIVERSITIES, INC. UPTON, N.Y. 11973
	UNLESS OTHERWISE SPECIFIED	DRAWN BY	P.A.HEILIG 12/02/97	TITLE: INSTALLATION, MANIFOLD, DX-DO WARM BORE CHAMBER (TADR)
	DIMENSIONS ARE IN INCHES DECIMAL TOLERANCES .X ± .06 .XX ± .02 .XXX ± .005 ANGULAR TOLERANCE ± 1°	DESIGN APPROVAL	D. Weiss 4/1/98	
		CHECKED BY	S. Norton 4/1/98	
		ENGINEER APPROVAL	D. Weiss 4/1/98	
		SUPERVISOR APPROVAL	D. Hseuh 4/1/98	SIZE E — DRAWING NUMBER: 42035021 — REV. B
	NA FINISH — BREAK SHARP EDGES MAX. .03 MIN. .01	Q.A. APPROVAL	T.R. Muller 4/2/98	
		SAFETY ENGINEERING	R. Alforque 4/2/98	Q.A. CATEGORY: A-3 — SCALE: 1/8 — WEIGHT: NA — SHEET 1 OF 2

DWG NO 42035021 SHT 1 OF 2 REV B

REVISIONS							
REV	ZONE	ECN NO.	DESCRIPTION	BY	DATE	CKR	APP
A			INITIAL RELEASE	PAH	11/14/97		

NOTES:

1. MATERIAL: TUBE, SST 6.00 OD X .120 WALL TYPE 304L PER ASTM A269.
2. MATERIAL: TUBE, SST 1.50 OD X .065 WALL TYPE 304L PER ASTM A269.
3. MATERIAL: TUBE, SST 1.75 OD X .065 WALL TYPE 304L PER ASTM A269.
4. MATERIAL: SST SHT .125, TYPE 304 PER ASTM A240. BNL STOCK NO. F-74020.
5. ALL FLANGES ARE TO BE PERPENDICULAR TO THEIR AXIS WITHIN .015".
6. FABRICATE IN ACCORDANCE WITH RHIC-CR-E-4503-055.
7. ALL EXTERNAL VACUUM WELDS SHALL BE 100% PENETRATION, UNLESS OTHERWISE NOTED.
8. CLEAN ALL PARTS PER RHIC-CR-E-4503-055 PRIOR TO WELDING. NO CLEANING AFTER WELDING.
9. MARK IN ACCORDANCE WITH MIL STD-130. VIBRO ETCH MANUAL, USING .25 HIGH CHARACTERS PART NO. AND REV LETTER, APPROX AS SHOWN.
10. PORTS MAY BE FORMED WITH PULL THROUGH METHOD. FILLET WELD AS INDICATED IF NOT PULLED THROUGH. FULL PENETRATION TIG BUTTWELD IF PULLED THROUGH.
11. INSTALL TEMPORARY BRACKET AS SHOWN. ONCE ASSEMBLED, HANDLE WITH EQUAL LOADS AT ALL SUPPORTS, ITEMS 6,7 AND 8.



FINAL

SEE SEPARATE PARTS LIST PL42035022

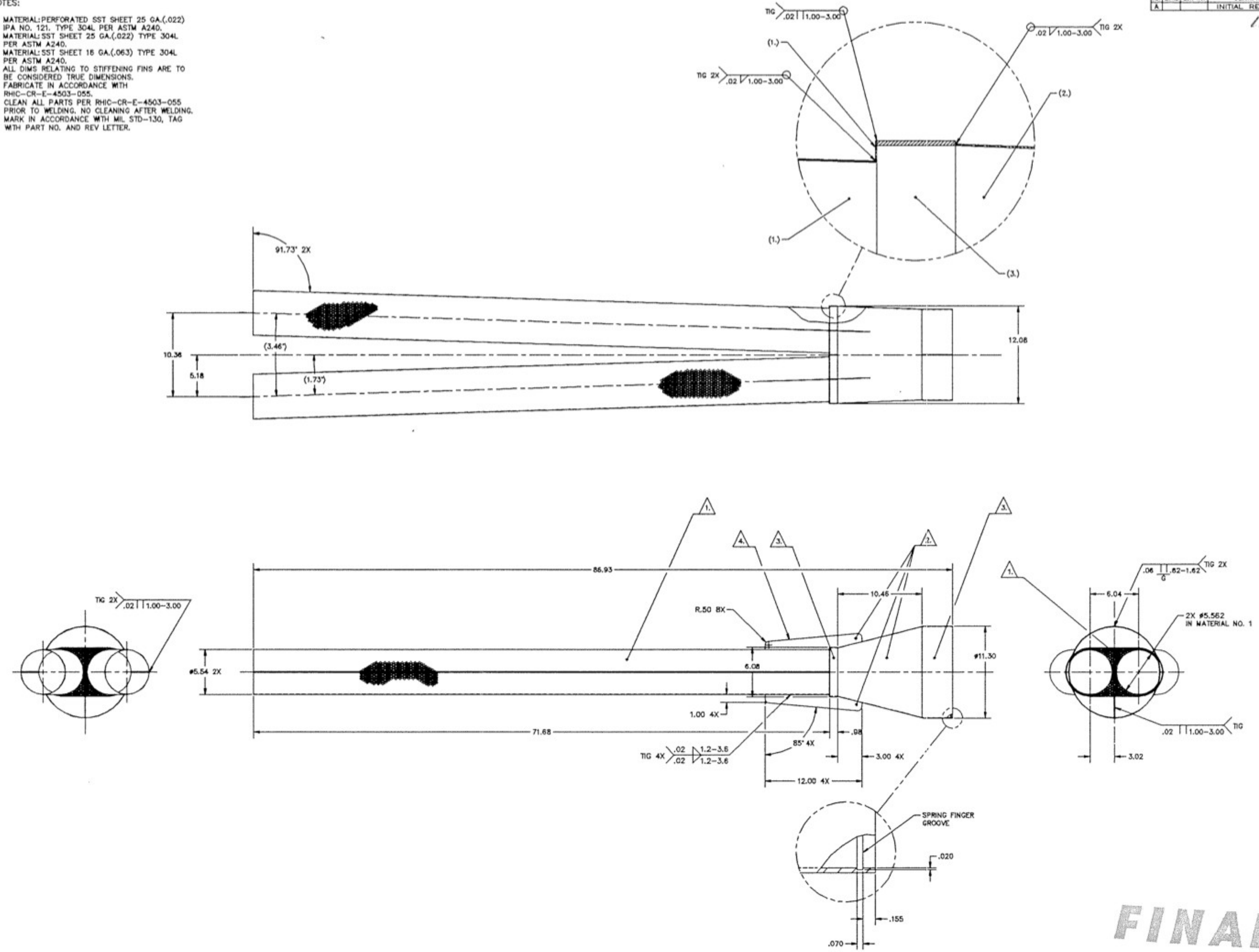
OUTSTANDING ECN NUMBERS	INTERPRET IN GENERAL ACCORDANCE WITH ASME Y14.24M-1989	RHIC	BROOKHAVEN NATIONAL LABORATORY ASSOCIATED UNIVERSITIES, INC. UPTON, N.Y. 11973
	UNLESS OTHERWISE SPECIFIED	DRAWN BY P.A.HEILIG 10/21/97	TITLE: ASSEMBLY, MANIFOLD, DX-DO WARM BORE CHAMBER
	DIMENSIONS ARE IN INCHES DECIMAL TOLERANCES .X ± .06 .XX ± .02 .XXX ± .005 ANGULAR TOLERANCE ± 1°	DESIGN APPROVAL / CHECKED BY / ENGINEER APPROVAL / SUPERVISOR APPROVAL / Q.A. APPROVAL / SAFETY ENGINEERING	SIZE E DRAWING NUMBER: 42035022 REV. A
	NA FINISH / BREAK SHARP EDGES MAX .03 MIN. .01		Q.A. CATEGORY: A-3 SCALE: 1/8 WEIGHT: NA SHEET 1 OF 1

DWG NO 42035022

REV	ZONE	ECN NO.	DESCRIPTION	BY	DATE	CKR	APP
A			INITIAL RELEASE	PAH	11/14/97		

NOTES:

1. MATERIAL: PERFORATED SST SHEET 25 GA.(.022) IPA NO. 121. TYPE 304L PER ASTM A240.
2. MATERIAL: SST SHEET 25 GA.(.022) TYPE 304L PER ASTM A240.
3. MATERIAL: SST SHEET 16 GA.(.063) TYPE 304L PER ASTM A240.
4. ALL DIMS RELATING TO STIFFENING FINS ARE TO BE CONSIDERED TRUE DIMENSIONS.
5. FABRICATE IN ACCORDANCE WITH RHIC-CR-E-4503-055.
6. CLEAN ALL PARTS PER RHIC-CR-E-4503-055 PRIOR TO WELDING. NO CLEANING AFTER WELDING.
7. MARK IN ACCORDANCE WITH MIL STD-130, TAG WITH PART NO. AND REV LETTER.



FINAL

BROOKHAVEN NATIONAL LABORATORY
UPTON, N.Y. 11973

RHIC

P.A.HEILIG

TITLE: RF SHIELD, DX-DO, WARM BORE CHAMBER

SIZE E — DRAWING NUMBER 42035034 — REV A

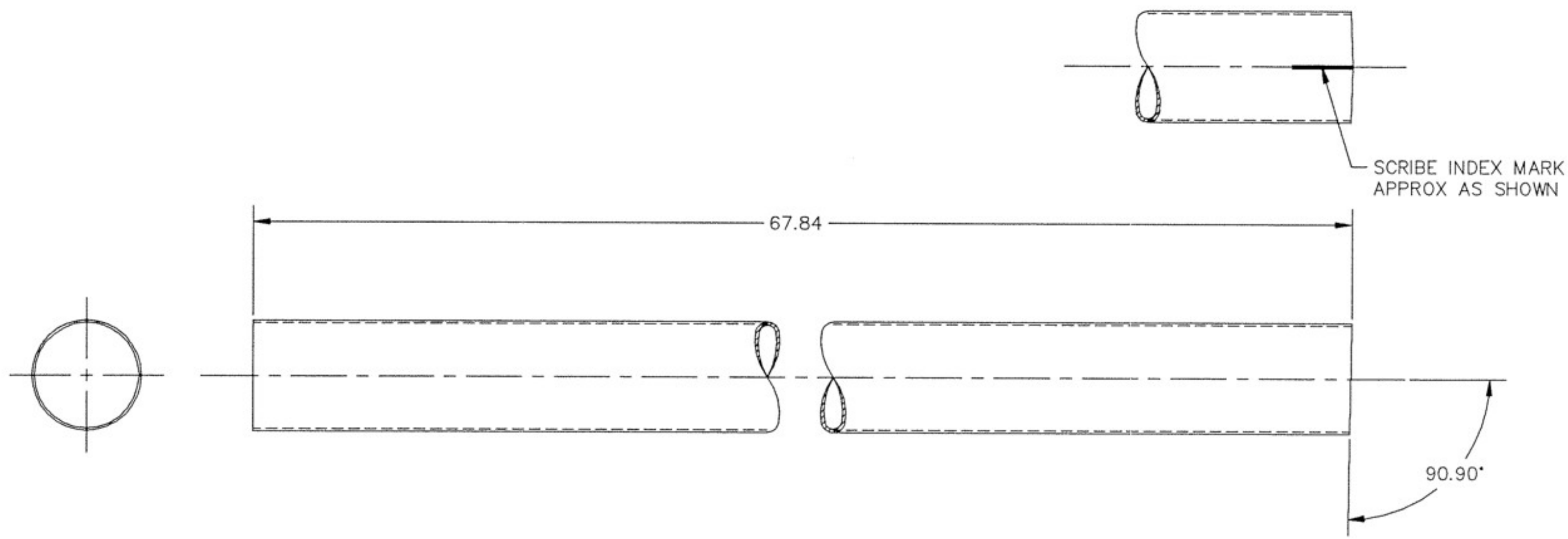
A-3 — SCALE 1/4 — WEIGHT NA — SHEET 1 OF 1

125/ FINISH — .03 — .01

REVISIONS							
REV	ZONE	ECN NO.	DESCRIPTION	BY	DATE	CKR	APP
A			INITIAL RELEASE	PAH	11/14/97		

NOTES:

1. MATERIAL: TUBING, SST TYPE 304L PER ASTM A249. 5.00 O.D. X .109 WALL.
2. BUILD PER RHIC-CR-E-4303-0086.
3. IDENTIFICATION OF THE SUGGESTED SOURCE(S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILTY AS A SOURCE OF SUPPLY FOR THE ITEM(S).
4. MARK IN ACCORDANCE WITH MIL STD-130, TAG WITH PART NO. AND REV LETTER.



FINAL

SOURCE CONTROL DRAWING

APPROVED SOURCES OF SUPPLY		
PART NO.	VENDOR / ADDRESS	ITEM IDENTIFICATION
42035025	TUBESALES PROSPECT PLAINS RD CRANBURY, N.J. 08512	19200-42035025

OUTSTANDING ECN NUMBERS	INTERPRET IN GENERAL ACCORDANCE WITH ASME Y14.24M-1989	RHIC
	UNLESS OTHERWISE SPECIFIED	DRAWN BY: P.A.HEILIG 10/22/97
	DIMENSIONS ARE IN INCHES DECIMAL TOLERANCES .X ± .05 .XX ± .02 .XXX ± .005 ANGULAR TOLERANCE ± 1°	DESIGN APPROVAL / CHECKED BY / ENGINEER APPROVAL / SUPERVISOR APPROVAL
	125 FINISH / BREAK SHARP EDGES MAX. .03 MIN. .01	Q.A. APPROVAL / SAFETY ENGINEERING

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UPTON, N.Y. 11973

TITLE: TUBE, MANIFOLD, DX-D0 WARM BORE CHAMBER

SIZE	DRAWING NUMBER:	REV.
C	42035025	A
Q.A. CATEGORY: A-3	SCALE: 1/4	WEIGHT: NA
SHEET 1 OF 1		

DWG NO 42035025 SHT 1 OF 1 REV A