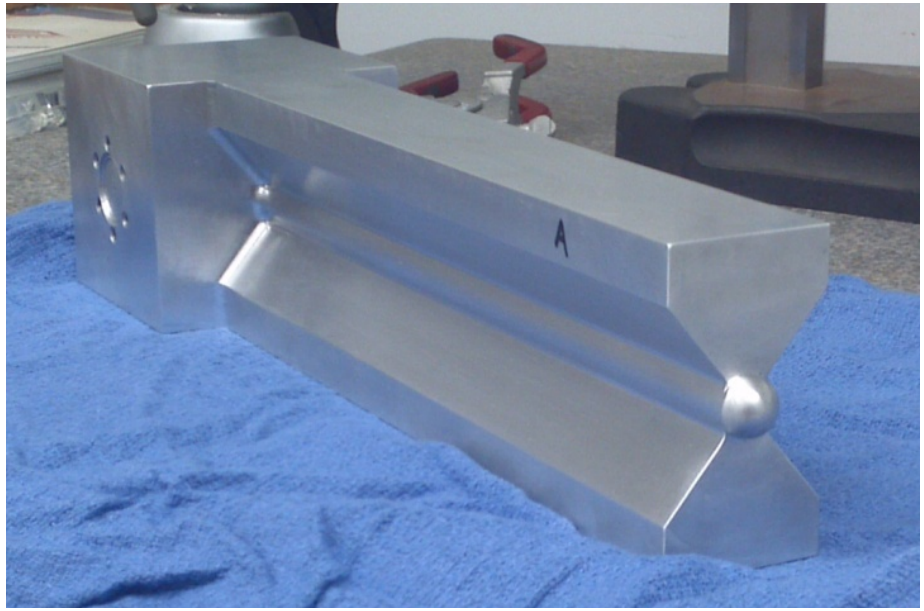
Analysis of BigBite vs. HRS

John Arrington
Argonne National Lab

Rate calculations by Zhihong Ye (ANL)
Backgrounds from D. Gaskell (JLab)



Tritium family readiness review

Newport News, VA

Mar 16, 2016

Office of Nuclear Physics
Exploring Nuclear Matter - Quarks to Stars

U.S. DEPARTMENT OF ENERGY

Updated evaluation of MARATHON runplan

Some aspects of the experiment differ from the original proposal

- Final target design (lower luminosity, thicker windows)
- No collimators to exclude target windows
- SOS Quadrupoles on HRS spectrometers

BigBite+HRS vs 2xHRSs

- Acceptance for HRS is about 5msr, BigBite is ~40msr; Naïve gain is factor 45/10
  - Large momentum bite used to take 2 x_{Bj} points at a time
- BigBite limited to larger scattering angles
  - Total rates and pi/e ratios become too high at small angle
  - Acceptance and resolution decrease at large E'
  - HRS can run at lower angle (lower Q^2 and W^2), significantly increasing cross section
  - HRS better than BB at low-to-moderate x, need to keep Q^2, W^2 large enough at large x
- Large x: HRS momentum bite +/-4.5%; BB is +/-2% (to keep Δx=0.04 bins)

Relatively small difference in Figure of Merit for 2xHRS and BB+HRS

BigBite needs additional time for commissioning, removal

Risk of luminosity limitations from physics/others backgrounds

Work exclusion zone around target makes BigBite work difficult

Updated runtime estimates (Zhihong Ye)

Accounting for all target/detector changes from original proposal

Comparison of HRS and BigBite runplan options

F2ALLM97 cross section, estimated 20% Rad. Corr. , W^2>3 GeV^2 cut

Key assumptions:

- Modified target design (20% reduction in average luminosity)
- Cut on central 15cm of target (40% loss) to endcap contribution [vs. collimators]
  - 10% loss of HRS acceptance for use of SOS Quad
- Assumed 20% (30%) deadtime/inefficiency for HRS (BigBite)
- 40 msr solid angle (-10%) for BigBite
  - –Proposal assumed 45msr (accounting for reduction due to detector repositioning)
  - –Nominal: ~75msr at small E', reduced factor of 2-3 at large E'
  - –Updated runplan has all high-x data at larger E' values

- *"Final" runplans: BB checkout/optics and 'new' HRS optics: ~1 week (3 PAC days)*
- *No time for BigBite removal*

Other issues

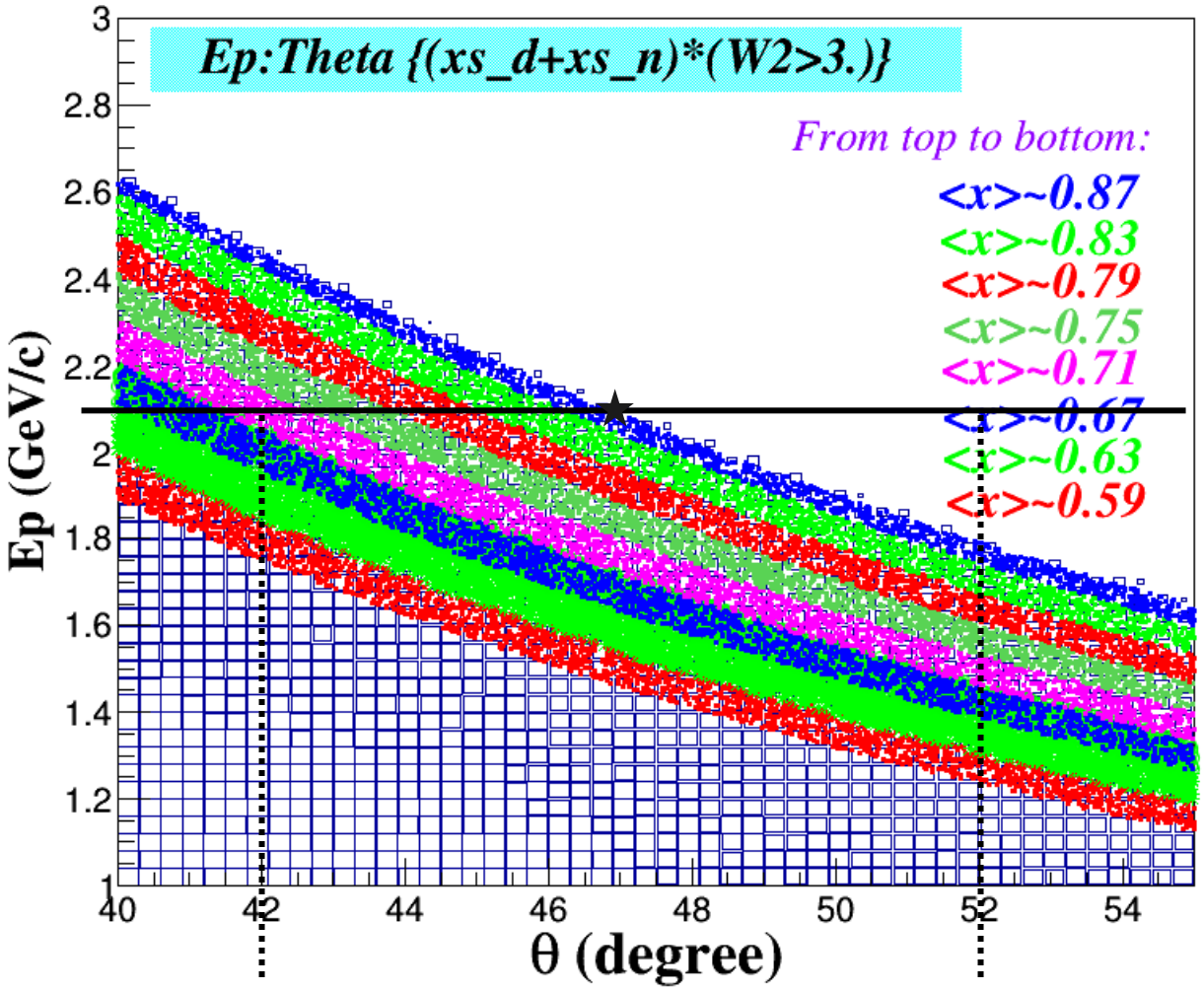
BB estimates based on small momentum bite (+/-4.5%), large solid angle

Effect largest at high x

At fixed x, worse at low W^2

Colored bands: fixed x bins

At 47 degrees central angle, BigBite covers 42-52 degrees



Other issues

BB estimates based on small momentum bite (+/-4.5%), large solid angle

- Fixed E' bins correspond to lower average x_{bj} due to rapidly falling cross section

x_{Bj}	$\langle x_{Bj} \rangle$	W^2	E'	θ	from proposal
0.87	0.80	3.10	2.07	47.10	
0.83	0.80	3.87	1.48	57.10	
0.79	0.78	4.71	1.41	57.10	
0.75	0.75	5.25	1.58	51.90	

- Initial estimates: Yields lower <x> values for the points

- Final estimates: binned data in x_{Bj}
  - Reduces average cross section at large x
  - Significant effect for small W^2 values

Runtime summary: minimal adjustments

Experimental Settings	Total Time [Days] ($\langle x \rangle_{max}$)	Excluding x = 0.87
1. HRS+BB as proposed	29 (0.87)	23 (0.83)
2. HRS+BB updated	116 (0.80)	96 (0.80)
3. HRS+BB updated (lower W^2)	96 (0.80)	**77 (0.80)**
4. 2xHRS, same settings	381 (0.83)	276 (0.82)
5. 2xHRS, W^2 minimized	116 (0.83)	**11 (0.78)**
5b. HRS with intermediate W^2 (estimate)		**20 (0.80-0.81)**

Tweaked kinematics: reduced to **77 days, x_{max}=0.8** [8 x_{Bj} points, 4 BigBite angles]

- Modest W^2 reduction at most x values
- Could save time by reducing ^{2}H statistics (limit ratios to deuterium to lower x)

HRS only: **20 days, x_{max}=0.8**

- 20 days is a slight underestimate - used 4 GeV for both spectrometers
- Larger W^2 reduction for high-x values

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3c. HRS+BB at highest x	**38 (0.80) [31 (0.84) with x-binning]**	
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BigBite parked at one angle: 39 days, x_{max}=0.8

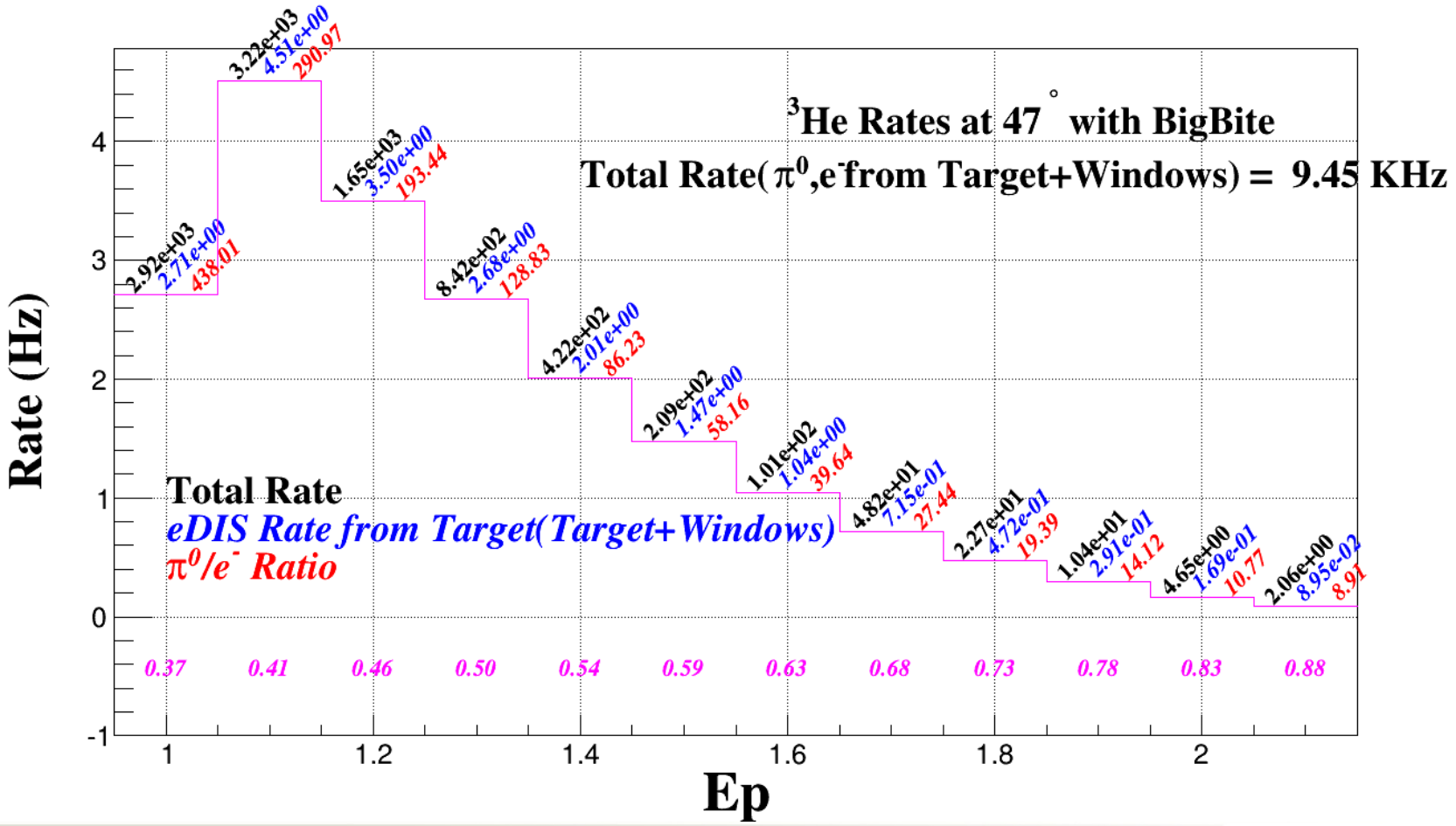
Final evaluation, looking at data in x bins gives 31 days, x_{max}=0.84

Refined runplans:

- ~20 PAC production data taking to allow time for checkout, calibration, optics, target luminosity scans, positron/pion/dummy target runs, etc…
- No time assumed for BigBite removal (done between run periods)
- BigBite has to run at fixed angle to make up for lost FOM → new constraints
  - Angle must give acceptable rates at high x
  - Must give acceptable backgrounds at low x
  - Low-x acceptance limited by angle and momentum acceptance (E’ > 1 GeV)

Initial background/ trigger rate estimates (Z.Ye and D.Gaskell)

- 47 degrees: 10 kHz (probably higher) total event rate, pion dominated
- Low E' (x<0.6) → pi/e ratios of 100-500, low-x limited by offline PID



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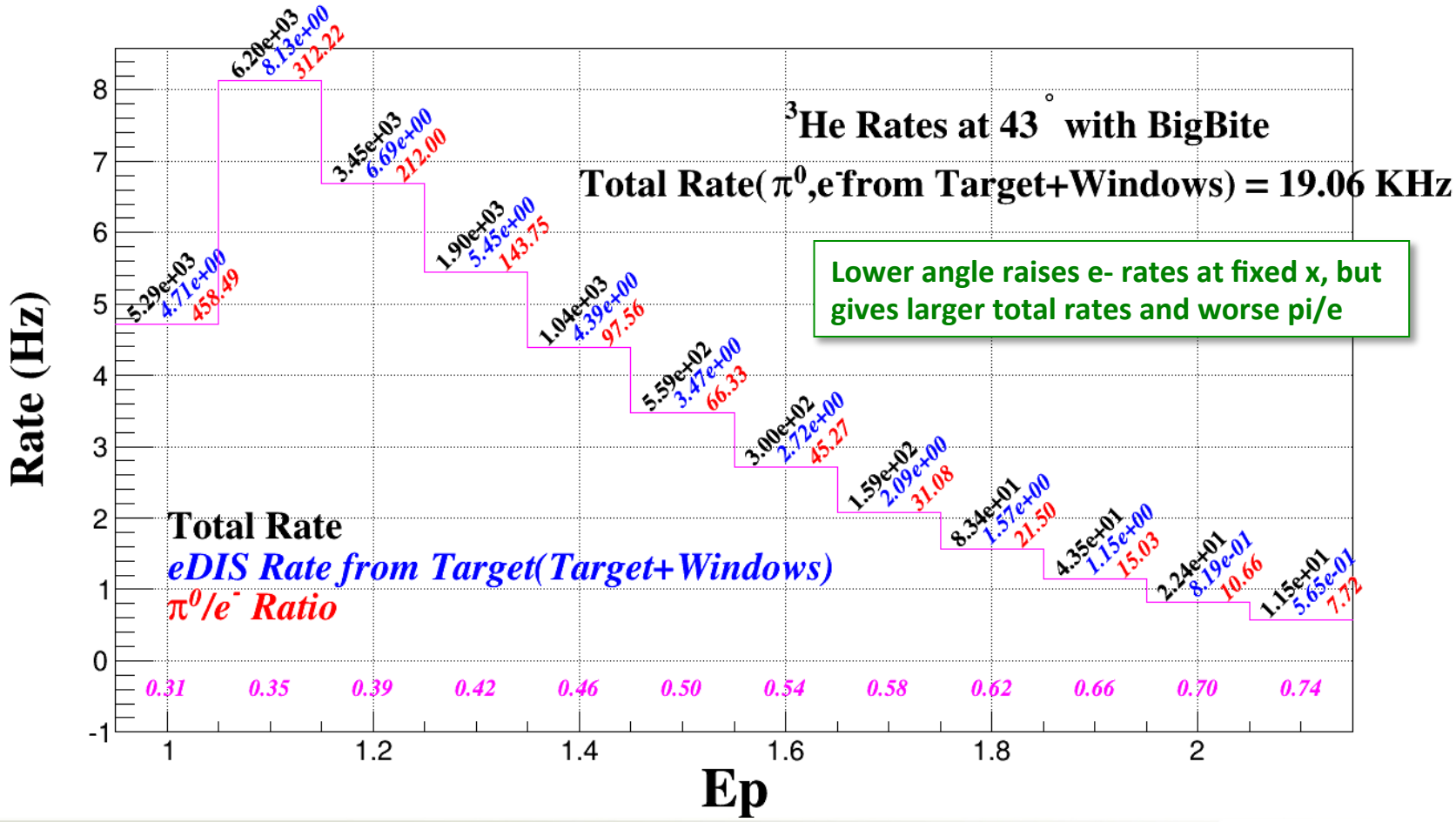

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- HRS only:
  - x=0.79 with W^2>4 and full statistics
  - x=0.82 with W^2>3.5, 50% statistics
  - [HRS at maximum momentum for nearly all settings]

- BB version:
  - x=0.81 with W^2>4 and full statistics
  - x=0.84 with W^2>3.5, 50% statistics
  - HRS does x<0.5, and some 0.5 < x < 0.75 overlap points

Summary

- HRS-only (Left+Right)
  - Cover $0.20<x<0.80$ at $W^2>4$, $x=0.83$ at lower W^2, reduced statistics
  - Somewhat lower W^2 values compared to BigBite option

- Bigbite+HRS runplan (BB fixed at $\theta \approx 47$ degrees)
  - $0.45 < x < 0.83$, larger x with reduced statistics (better W^2)
  - HRS covers low x region

BigBite option gives slightly greater x coverage, but brings significant risk

- May need to use beam time for BigBite removal (not accounted for)
- Offline pion rejection may limit low-x coverage in BB
- Online pion rejection could limit beam current (or yield greater sensitivity position-dependent or time-dependent efficiencies)
- Luminosity could be limited by background rates in unshielded detectors
- Potential issues working on BigBite due to 'work exclusion zone'

Considered too great of a risk for at best a small increase in x (W^2)