Past and Future Test Beams for Experiments at Brookhaven

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BNL

The importance of test beams

MARK II/SLC Note 99

Date: 1 July 1985

TO: MARK II/SLC Collaboration
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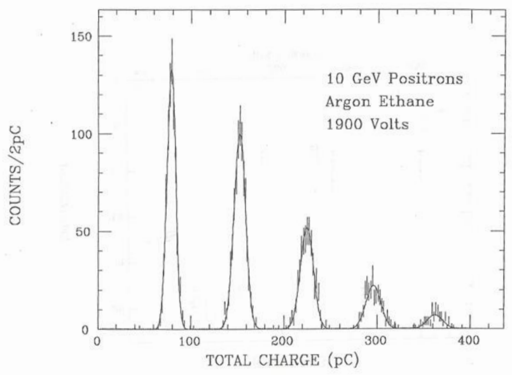
SUBJECT: Results of End Cap Positron Beam Test

This memo describes the results of the beam test of the end cap calorimeter in beam line 19 at SLAC (experiment T-356). We have found the minimum resolution to be about $18\%/\sqrt{E}$. In order to maintain a linear relationship between energy deposited and measured charge, we suggest running the detector with a gain of less than 30 pC/GeV. Several gasses were tested, and each gave about the same results, with linearity and resolution dependent only on gain. The response of the detector was found to be quite uniform over the face of the detector.

- SLAC has a great history in providing test beams

FIGURE 2



AGS test beams before the RHIC era

- BNL test beam facilities contributed extensively to the four original RHIC experiments (PHENIX, STAR, BRAHMS, PHOBOS) but the beamlines were decommissioned at the start of RHIC running in 2000
- When we proposed sPHENIX in 2012, we started a program of test beam experiments at the Fermilab Test Beam Facility (FTBF) which were crucial to the development and approval process

AGS Beams, July 98

Beam	GeV/c	δp/p (% fwhm)	Prod. Angle (deg)	ΔΩ (msr)	Flux / 10^{13} 24 GeV/c protons on target: K^+	K^-	p	$\bar{p}$	π^+	π^-	GeV/c	Purity	Remarks
Separated Charged Particle Beams													
C4	≤ 0.83	4	0	12.0	$4.6x10^6$	$1.5x10^6$	$1.5x10^9$	$1.0x10^6$	$6.0x10^9$	$6.0x10^9$	0.80	$\pi^+/K^+ = 0.4$	L = 18 m – "LESBII" ~ $1x10^6$ stopped $K^+/10^{13}$ protons
C6,C8	≤ 0.75	5	5	10.0	$1.0x10^6$	$3.3x10^5$	$3.3x10^8$	$4.6x10^4$	$2.0x10^9$	$2.0x10^9$	0.70	$\pi^-/K^- = 5$ $\pi^+/K^+ = 1$	L = 15 m – "LESBII"
D6	≤ 1.9	6	5	1.6	$5.5x10^6$	$2.3x10^6$	$3.0x10^8$	$1.1x10^6$	$4.9x10^8$	$4.1x10^8$	1.80	$\pi^-/K^- = 0.8$ $\pi^-/\bar{p}$ = .07	L = 31 m – "2GEV"
Unseparated Charged Particle Beams													
A1*	5–28	3	0	0.2	$1.9x10^6$	$2.9x10^4$	$5.0x10^9$	$2.3x10^3$	$3.0x10^7$	$1.0x10^7$	18		L = 130 m to MPS – "HEUB"
A2	< 6.5	5	3.5	0.75	$5.8x10^7$	$1.9x10^7$	$6.9x10^8$	$6.3x10^6$	$1.3x10^9$	$8.8x10^8$	6		L = 34 m – "6GEV"
A3*	1–28	4	0	0.1			$6.0x10^8$		$1.0x10^8$	$4.0x10^7$	14		Primarily HI "OR" with A1
B1*	5–28	3	0	0.05			$3.0x10^8$		$3.0x10^7$	$2.0x10^7$	14		HI/Test Beam "OR" with B5
B1'	0.5–28	8	3	.001			$3.0x10^4$		$6.0x10^4$	$4.0x10^4$	5		L = 56 m – Test Beam
B2	< 9	5	6	0.5	$3.4x10^5$	$1.2x10^5$	$8.5x10^6$	$9.5x10^4$	$1.2x10^7$	$9.0x10^7$	4		L = 40 m – Test Beam
C1	1–20	5	0	0.8	$3.0x10^7$	$3.5x10^6$	$1.0x10^9$	$0.7x10^6$	$3.5x10^8$	$1.6x10^8$	13		L = 100 m – "OR" with C5
C5*	1–28	2	0	0.15			$1.0x10^8$				13		L = 81 m – "OR" with C1
Neutral Beam													
B5	2–20		1–4.5	0.1	K^0_L flux = $1.3x10^8$ @ 3.75°						2–20	n/ K^0_L = 20	L = 10 m – "OR" with B1
Muon Channel													
D2	0.025–0.15	9 (π) 30 (μ)	135 (π)	24 (π)	μ^+ flux = $2.0x10^6$ Surface μ^+ flux = $2.0x10^6$								L = 12 m Inactive, not yet commissioned
Neutrino Beam													
U					ν flux = 2.0 x $10^{10}/m^2$ (Wide Band) $\bar{\nu}$ flux = 1.4 x $10^{10}/m^2$ (Wide Band)								Not Presently Available FEB Flux avg. over 1.5 m R. <E> = 1.4 GeV/c^2 Wide Band
g–2 π–μ Transfer Line													
V1	< 3.0	0.6	0		π^+ flux = $1.7x10^8$ μ^+ flux = $7x10^5$						3.0		L = 120, for injection to g–2 ring commissioned in 1996

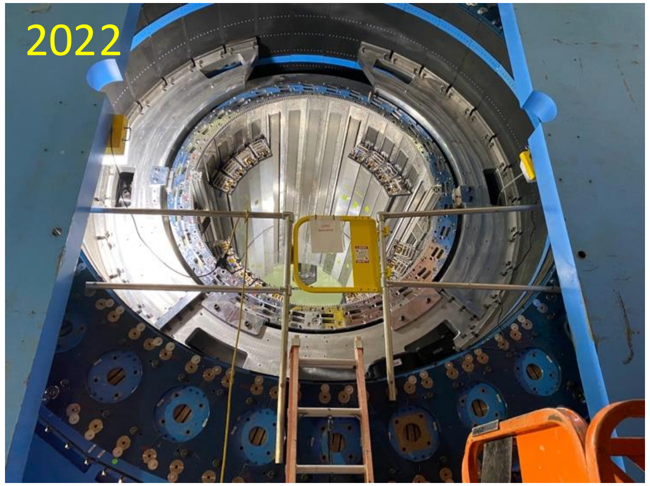
* These 0° beam lines can be used for full energy polarized protons and/or heavy ion beams

A short history of sPHENIX as told by the BaBar solenoid 2013-2024

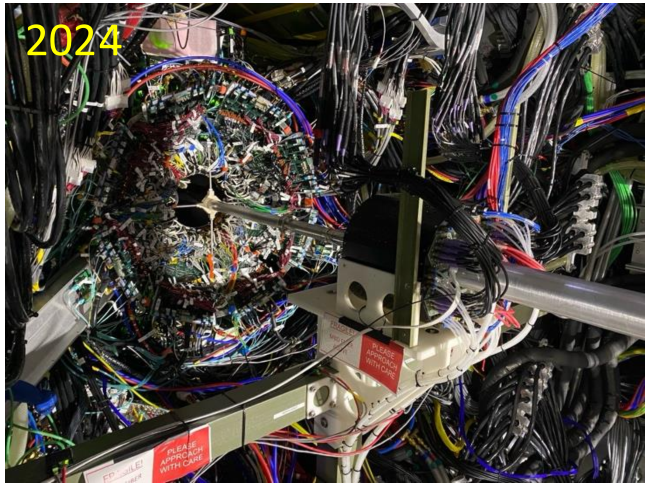
BaBar solenoid at SLAC

BaBar solenoid in I-280

Full field test at BNL



sPHENIX solenoid mapping

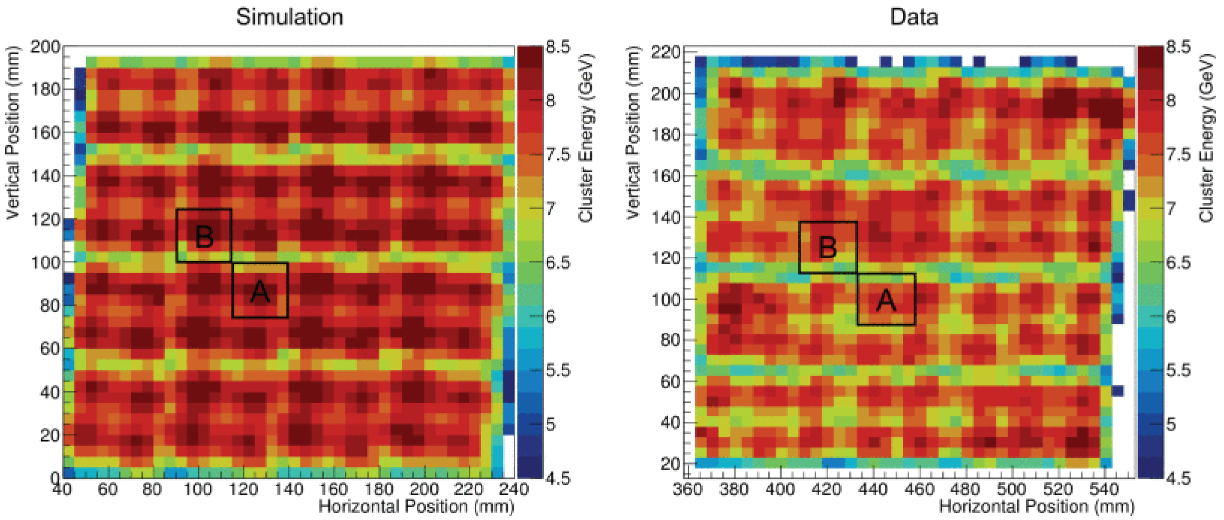


sPHENIX in operation

sPHENIX at the Fermilab Test Beam Facility

Testing calorimeter uniformity at FTBF

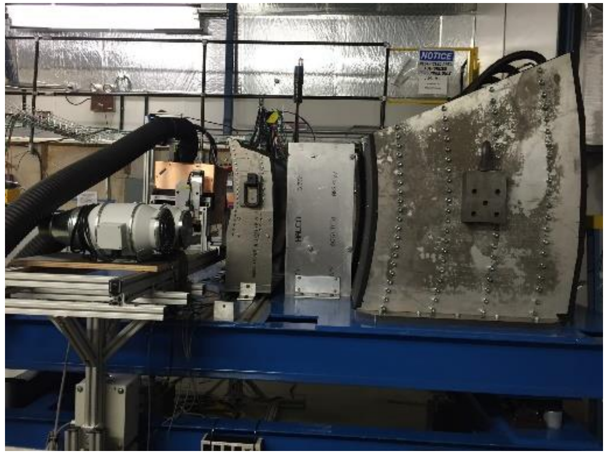
- Testing tungsten powder-scintillating fiber barrel calorimeter readout with SiPM's
- We selected electrons with the FTBF Cerenkov counters to measure the uniformity of response over the face of our calorimeter with a hodoscope to define the location
- Most of our electron physics is in the 1-10 GeV range… we measured the energy resolution mapped the non-uniformity, but a small, clean electron beam would have been great
- What would an ideal test beam for our EMCAL be?
  - "Single" 1-8 GeV e^- or e^+
    - It is difficult to get the constant term without higher energies
  - Spot size ~1 mm
  - >1 kHz
  - Bunch spacing > 100 ns for RHIC, 10 ns for EIC
  - Timing precision not so critical for RHIC, but for the coming streaming readout DAQ architectures the considerations are different



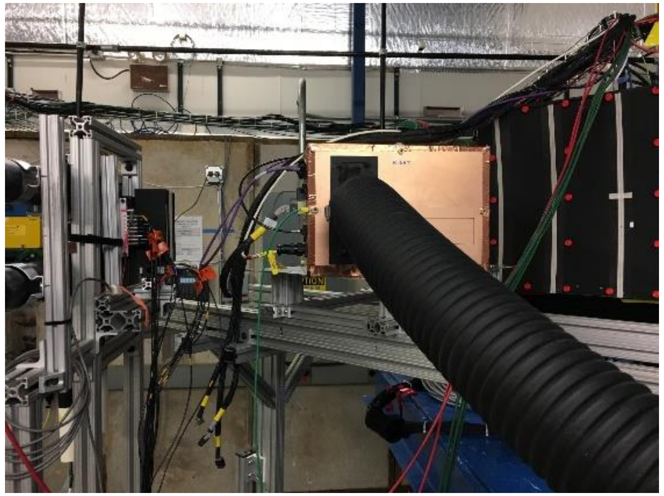
https://ieeexplore.ieee.org/document/9321702

Calorimeter beam tests at CD-2

February 2014
Proof of principle

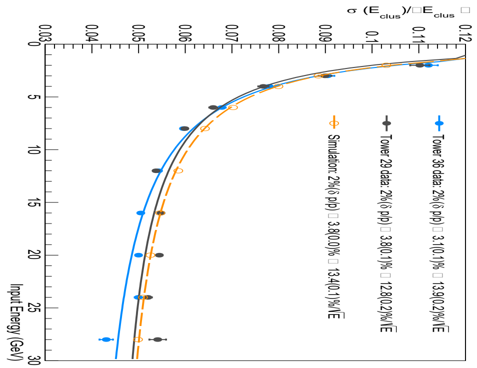


February 2016
η~0
sPHENIX geometry
https://arxiv.org/abs/1704.01461
(published IEEE TNS)



February 2017
η~0.9

February 2018



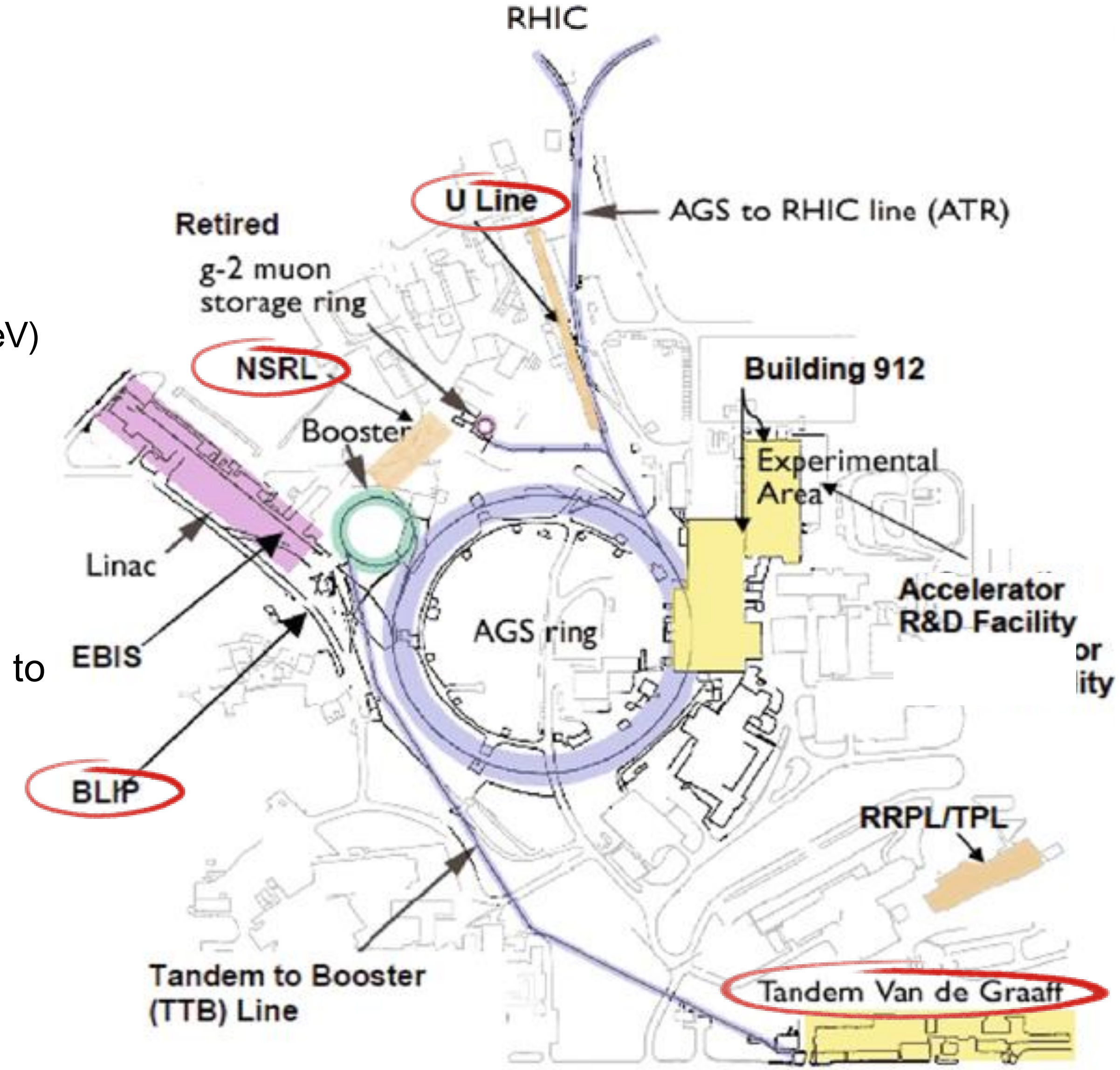
EMCAL meets energy resolution requirement

Hadron Injection Complex

BNL capabilities available to users:

- Tandem van de Graaff (~25 MeV)
- BNL LINAC Isotope Producer (BLIP) (~200 MeV)
- NASA Space Radiation Laboratory (NSRL) (~2.5 GeV)
- Alternating Gradient Synchrotron (AGS) (~25 GeV)
  - U-line Proposal

HEET is a proposal to DoW for slow extracted beams delivered to 912 for electronics testing (https://www.bnl.gov/heet/)

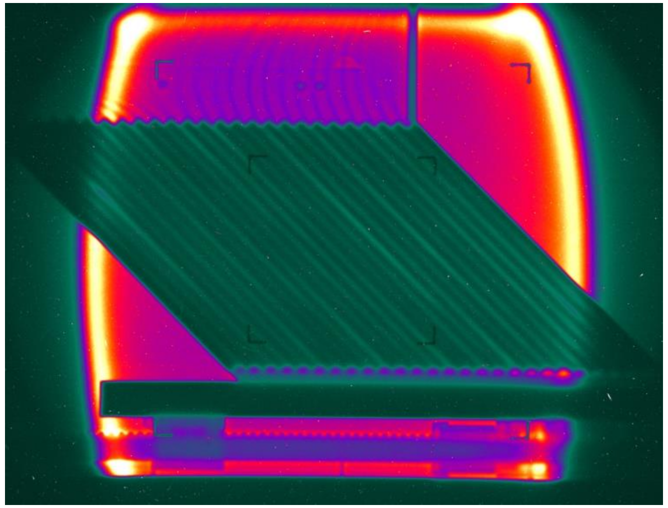


NASA Space Radiation Laboratory (NSRL)

Beams of heavy ions from booster to simulate cosmic rays and assess radiation risks

- Ions and protons up to 2.5 GeV
- Electronics single-event effects (SEE)
    - AMS-2 performed radiation tests of electronics for silicon detector upgrade in FY24 (6 hrs)

We are looking for ways to make beam from the booster available for physics



PHENIX/sPHENIX ZDC in 2014

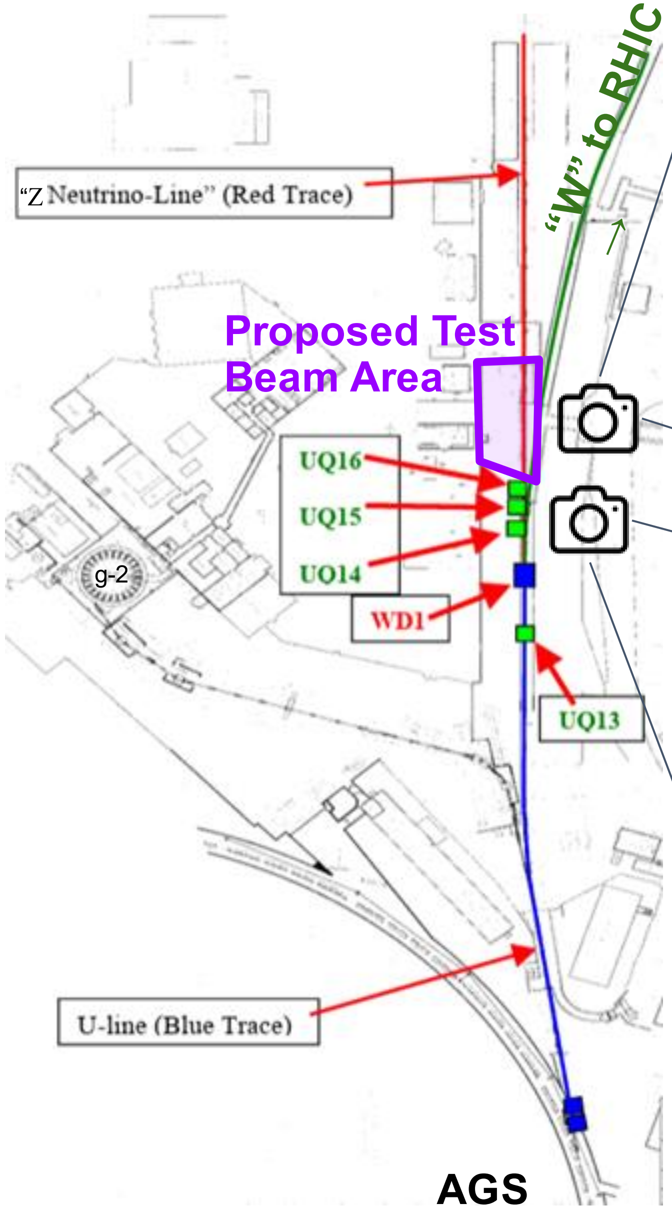
https://www.bnl.gov/nsrl/

Brookhaven National Laboratory

Alternating Gradient Synchrotron (AGS)

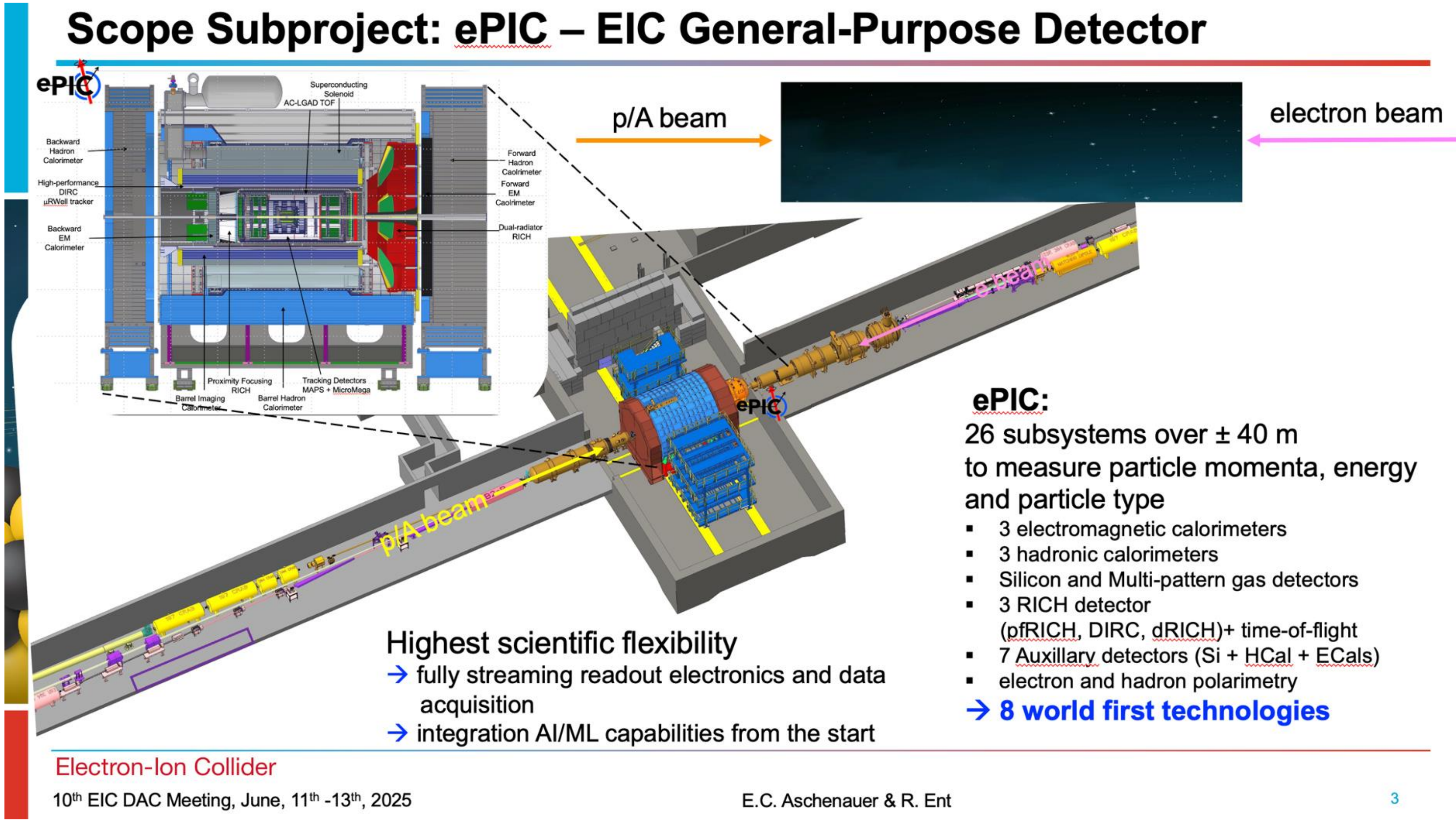
Propose to resurrect and refurbish "U" beamline in AGS-to-RHIC tunnel

- up to 25 GeV fast-extraction beam
    - not in AGS Fixed Target Area
    - different proposal from High Energy Effects Test Facility (HEET)
- upstream U-W splitter actively used for RHIC
- area last hosted experiments in 2009
    - E972/E973 Proton Interrogation Experiment (DTRA)



Next up: ePIC experiment for EIC

- Many new detectors under development and testing



Conclusion

- Test beams are a crucial ingredient to the development of experiments!
- Shutdowns of facilities around the world in the next few years create a challenge to the development of new detectors
- Many varieties of test beams are needed, from pure low intensity single particle beams to characterize detector elements to high intensity beams to study radiation damage and radiation upset effects
- Test beams need infrastructure to be really successful—FTBF was fantastic!
  - People who can translate local customs for users (physicists and technicians)
  - Equipment and hardware available (80/20, NIM bins, computing and networking)
  - Ensure safe operation

Thanks

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