BNB Decay Pipe Inspection Robot

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A Hearty Thank You to All Involved

• The last week we successfully inspected and made B-field measurements in the decay pipe.

• Much work and effort by many
  – AD-Target Systems: Keith Anderson, Mike Andrews, Frankie Kelly, Cervando Castro, Jim Zahurones, Ralph Ford, Mike Steinman, Bob Albrecht, Henry Schram, Bob Zwaska, and others
  – Rad Safety: Joel Fulgham
  – AD-external beams: Tom Kobilarcik, Craig Moore, Rick Ford, Mike Backfish
  – Big thanks to Steve Clayton (LANL P-25) who designed/built the instrumentation package and DAQ/GUI code.
Robot FRED: Finding Radiation Evidence in the Decay pipe

LT-F Surveillance Robot from SuperDroid Robots

- Using the flippers, it can traverse 20” rise/step.
- Will use a bridge/gateway to traverse the 23” collimator region.
- Robot Dimensions: Total height (floor to top of treads or camera housing): ~7 inches, total width: ~18.625 inches, total length: ~27 inches
- Built in video camera and lights. Camera is a high quality 27X zoom, and low light capable
Robot FRED: Instrumentation Package

- Deployable mast for Hall probes 1 & 2
- Hall probe 1
- Forward-looking LIDAR
- Hall probe 2
- Hall probe 3
- Camera & Light & Mic
- PoE / USB power distribution system
- LabJack digitizer
- Flipper arm
- Tether & strain relief
- Rear-looking LIDAR
- Water level
- Gyro
- Accelerometer
Instrument Package (Steve Clayton/vdwater – LANL)

• Hall probes (Ametes DMFS-3 Axis)
  – 0-75 Gauss range – 3% reading accuracy

• Hall probes read out via LabJack ADC
  – 14 channels
  – 16 bit
Instrument Package (Clayton/vdwater – LANL)

• 3 Axis gyro (STIM 210) to determine orientation B-field probes.
  – Integrated accuracy 0.5 degrees/hr. Maximum 400 degree/s.

• Accelerometer (STMicroelectronics LIS344ALH) provides orientation backup to the gyro.

• IR laser LIDAR-Lite in front/back → order cm resolution
  – marginal utility in center long portions of decay pipe
Hinged-Ramp Entry Through Collimator to Decay Pipe
Boldly go where no one has gone...

FRED ready to go into the horn chase

FRED in the collimator

FRED climbing the 25m step

FRED at the 50m absorber, what the heck is that...

Deployment Ladder

5/4/15 FNAL AEM
• Construction diagrams show end cap → no info about composition or thickness.
• Burn marks/cracking of surface coating (galvanized steel?)
• What is in 4” gap between end cap and 50m absorber? (air, soil?)
Initial Results on B-field Measurements

- $+B_x = \text{forward along beam line}$
- $+B_y = \text{Left of beam forward}$
- $+B_z = \text{Up}$

- Within each region, B-field mostly stable/constant
- Gyro/Accelerometer recorded tank centered on desired axis with < 5 degrees

Collimator (Gauss)
$B_x = 0.1, B_y = 0, B_z = 0.1$

25 absorber Chase (Gauss)
$B_x = 0.2, B_y = -0.1, B_z = -0.6$

Collimator to 25 absorber (Gauss)
$B_x = 0.4, B_y = -0.1, B_z = -0.1$

25 to 50 absorber (Gauss)
$B_x = 0.3, B_y = -0.1, B_z = 0$
No change right up against end cap
No change with Berm cooling on/off
Integrating B-field over distance

Gauss-meter

+Bx = forward along beam line, +By = Left of beam forward, +Bz = Up

- Collimator (2m):
  - Bx = 0.2, By = 0, Bz = 0.2 G-m

- Collimator to 25m Absorber(20m):
  - Bx = 8.0, By = -2.0, Bz = -2.0 G-m

- 25m Absorber Chase (5m):
  - Bx = 1.0, By = -0.5, Bz = -3.0 G-m

- 25m to 50m Absorber(20m):
  - Bx = 6.0, By = -2.0, Bz = 0.0 G-m

- Integrating over entire length:
  - Bx = 15.2, By = -4.5, Bz = -5.2 G-m

- Figure of merit: 250 G-m will produce a 1 mRad beam deflection

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Summary

• Inspection and B-field measurements successful!

• Visual inspection found no problems → only surprise is 50m endcap

• No significant magnetic fields → < 0.1 mRadian deflections of off-target proton beam

• Tank resides at Fermilab → future inspection missions?

• Huge thanks to all those involved.