Spin Asymmetries of the Nucleon Experiment

BETA Analysis Update

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Outline

SANE

- $4.7GeV$ and $5.9GeV$ beam energies
- Polarized Ammonia Target
- Big Electron Telescope Array

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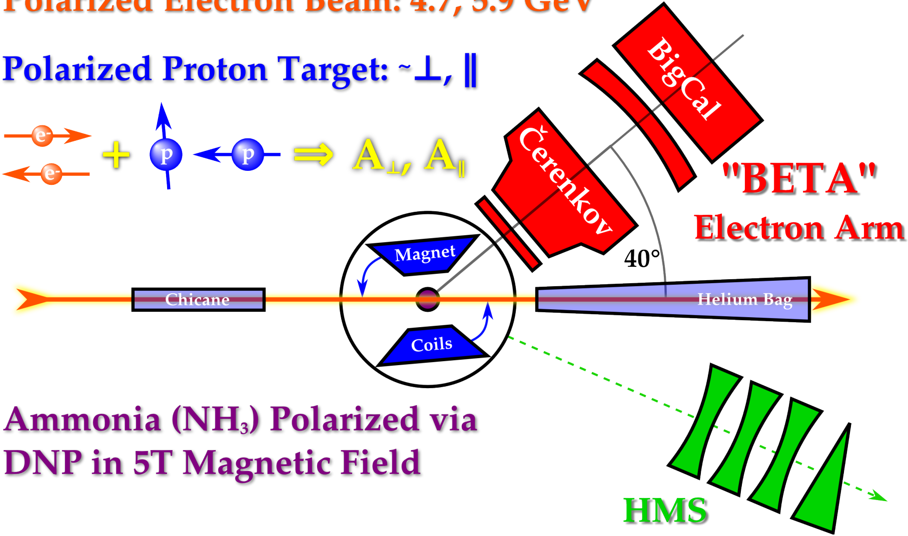
BETA is a unique detector

- Large solid angle 200mSr
- Open configuration
- No momentum selecting magnet

Polarized Electron Beam: 4.7, 5.9 GeV

Polarized Proton Target: ~⊥, ∥



Ammonia (NH_3) Polarized via DNP in 5T Magnetic Field

Physics

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3. Evaluate g_1 and g_2 as functions of a scaling variable.
4. Calculate Moments $\rightarrow d_2^p$

... the whole point of the operator product expansion is to separate the parts of Feynman diagrams where every line carries a large momentum, which in asymptotically free theories can be calculated using perturbation theory, from the contribution of the parts of Feynman diagrams through which small momenta flow, which cannot be calculated perturbatively [1]

[1] S. Weinberg, The Quantum Theory of Fields, Vol 2, p 288

A twist-3 sum rule

Using the Operator Product Expansion for the non-local operators showing up in the S matrix, one can arrive a the infinite set of sum rules below. For $n \geq 3$ and n odd, we have

$$\int_0^1 dx x^{n-1}\{g_1 + \frac{n}{n-1}g_2\} = \frac{1}{2}\sum_i \delta_i d^i_{n-1} E^n_{2,i}(Q^2, g) \quad (1)$$

For $n = 3$

$$\int_0^1 x^2\{g_1 + \frac{3}{2}g_2\}dx = \frac{1}{2}d_2 \quad (2)$$

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Interpretations of d_2

- Color Polarizabilities (X.Ji)
- Average Color Lorentz force (M.Burkardt)

Quark-gluon Correlations

M. Burkardt

$d_2 = 3 \int x^2 \bar{g}_2(x) dx = \frac{1}{2MP^{+2} S^x} \langle P, S \mid \bar{q}(0) g G^{+y}(0) \gamma^+ q(0) \mid P, S \rangle$

but with $\vec{v} = -c\hat{z}$

$\sqrt{2} G^{+y} = -E^y + B^x = -(\vec{E} + \vec{v} \times \vec{B})^y$

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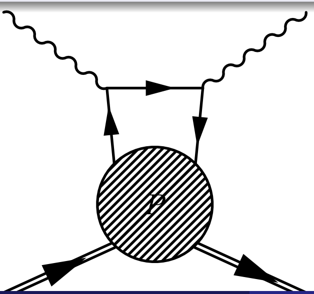
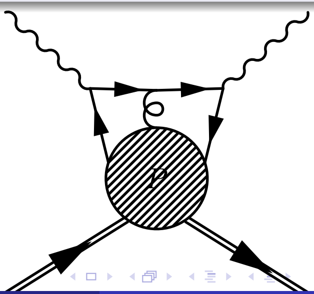
$d_2 \Rightarrow$ average color Lorentz force acting on quark moving backwards (since we are in inf. mom. frame) the instant after being struck by the virtual photon. $\langle F^y\rangle = -2M^2 d_2$





g_1^p Data

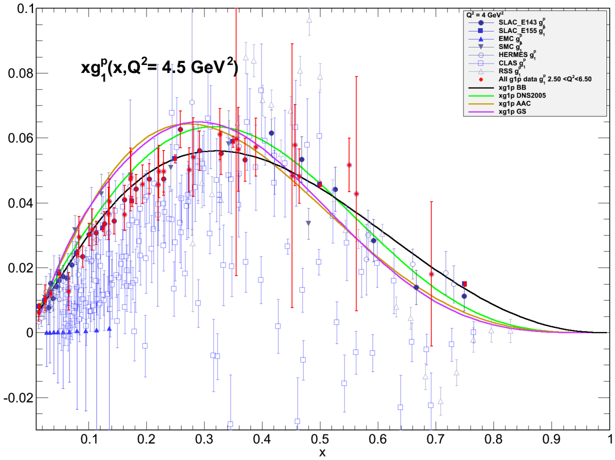


Figure: World data on $g_1^p(x)$. The red data points fall within the SANE Q^2 range.

g_2^p Data

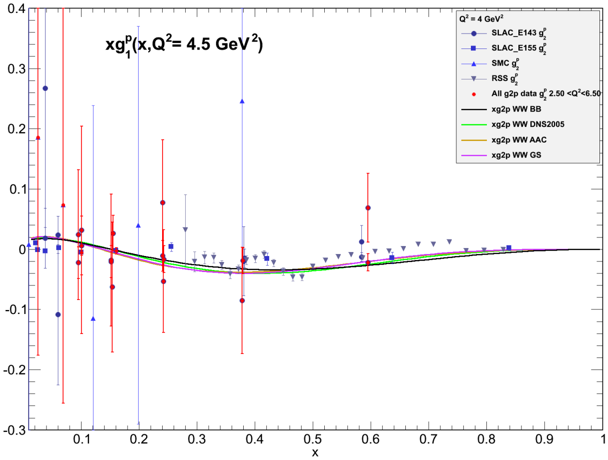


Figure: World data on $g_2^p(x)$. The red data points fall within the SANE Q^2 range.

$d_2 = \int_0^1 x^2\{2g_1 + 3g_2\}dx$

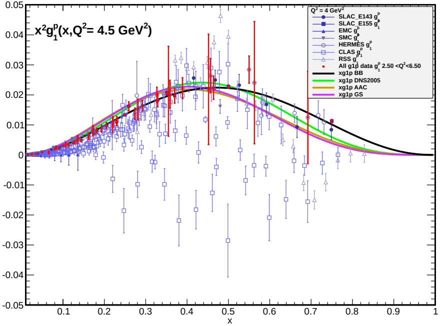
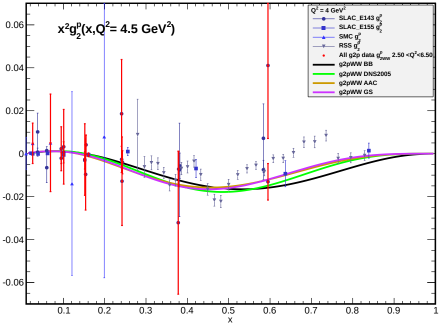


Figure: The $g_1^p(x)$ contribution to the d_2^p integrand.



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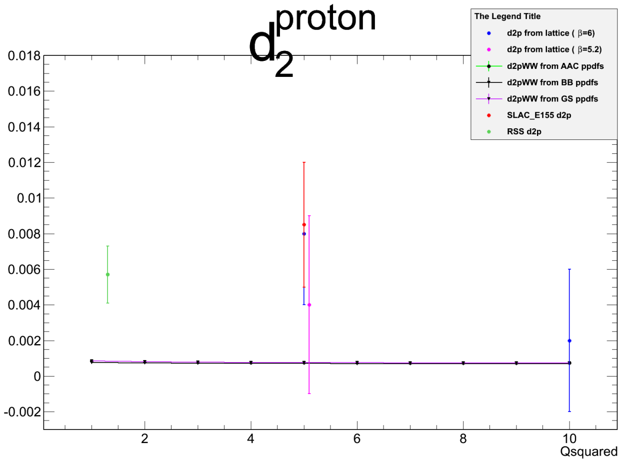
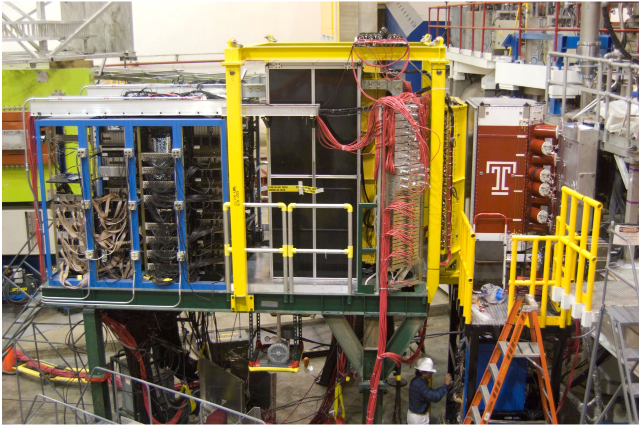


Figure: $d_2^p(Q^2)$

Outline

Big Electron Telescope Array



SANE used BETA to detect inclusive electrons with a large acceptance at angles around 40°for energies above about 1 GeV.

Bigcal

Two Sections

The upper section from Yerevan Physics Institute used during RCS experiment.

- It consists of $4x4x40cm^3$ lead-glass blocks
- They are arranged in a 30x24 array

Lower section from IHEP in Protvino, Russia.

- It consists of $3.8x3.8x45cm^3$ lead-glass blocks
- They are arranged in 32x32 array

1,744 lead glass blocks total.

Figure: Bigcal lead-glass blocks

Bigcal was previously used in the GEp series of experiments

SANE Gas Čerenkov

Gas Čerenkov is from Temple University.

Design

- Filled with nitrogen gas at atmosphere.
- Uses 4 spherical and 4 toroidal mirrors to focus light to photomultiplier tubes.
- Used 3 inch quartz window Photonis PMTs for UV transparency
- Mirror blanks were sent to CERN for special coating for high reflectivity far into the UV.

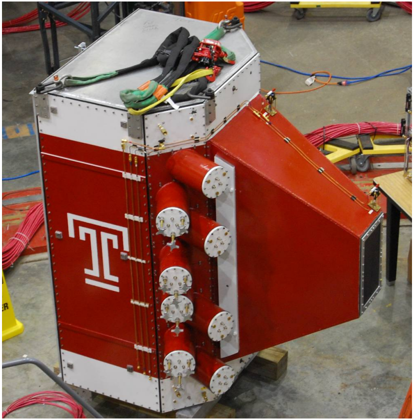


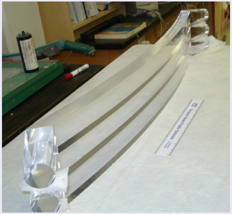
Figure: Gas Čerenkov on Hall C floor

Lucite Hodoscope

Lucite Hodoscope is from North Carolina A&T State University.

Design

- 28 curved Lucite bars with light guides mounted to edges cut at 45°
- PMT with light guide mounted at both ends of each bar.



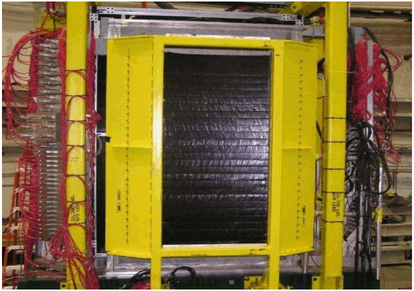


Figure: Lucite Hodoscope in Hall C

Forward Tracker

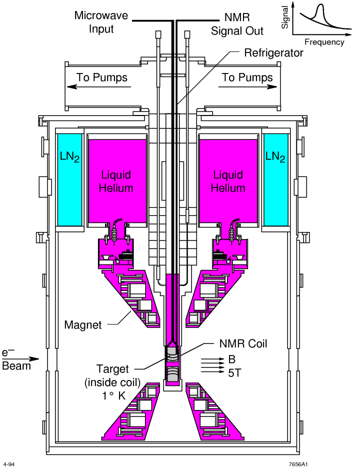
Forward tracker is from Norfolk State University and University of Regina

Design

- 3 layers of $3mmx3mm$ scintillators.
- 1 horizontally segmented layer closest to the target consisting of 72 segments
- 2 vertically segmented layers consisting of 128 segments each
- WLS fibers glued to each bar with fibers connected to Hamamatsu 64-Channel PMTs

Figure: Forward tracker in position between Čerenkov snout and target OVC

Polarized Target



Polarized Target

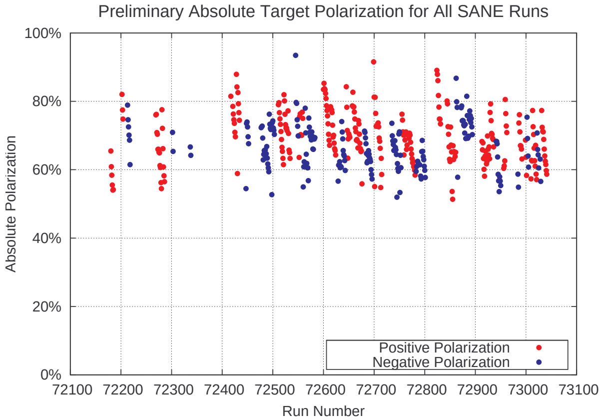


Figure: Target polarization during the experiment by James Maxwell

Average polarization was about 70%

Pair Symmetric Background

Sources

- $\pi^0 \rightarrow \gamma\gamma^* \rightarrow \gamma e^+ e^-$ (primary source)
- $\gamma \rightarrow e^+ e^-$

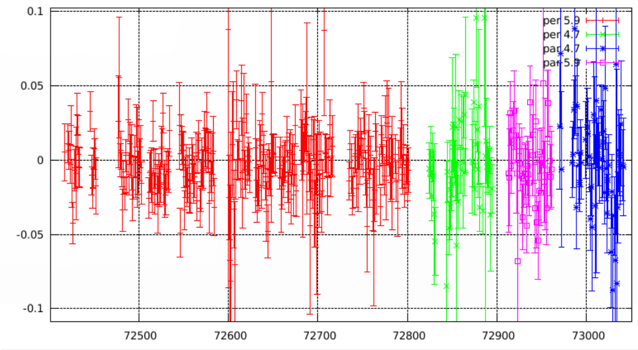


Figure: π^0 asymmetry vs run number courtesy of Luwani Ndukum

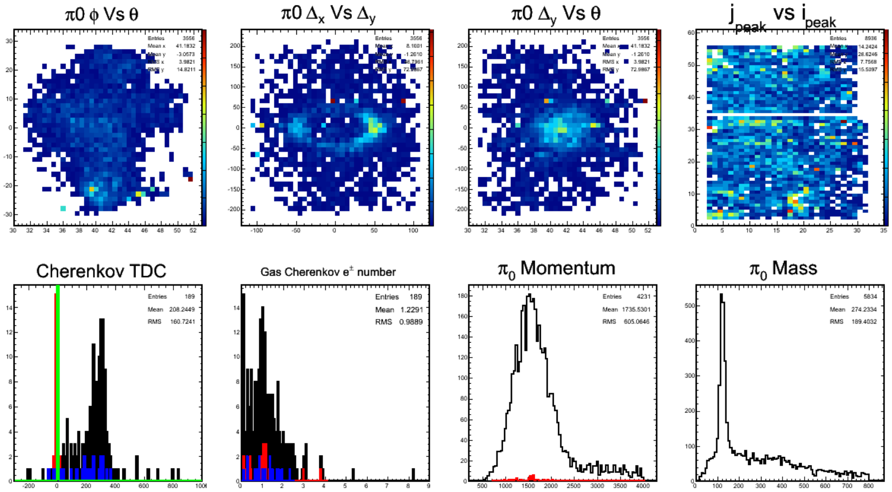


Figure: Starting at the top left plot: $\phi_{\pi 0}$ vs $\theta_{\pi 0}$, $\Delta y_{cluster}$ vs $\Delta x_{cluster}$, $\Delta y_{cluster}$ vs $\theta_{\pi 0}$, $j_{peak} vs i_{peak}$, Cherenkov TDC (red showing tdc cut), Number of Electrons Detected (red = TDC cut, blue = Events with 3 clusters), $E_{\pi 0}$, $M_{\pi 0}$

Outline

Direct access to the polarized structure functions can be obtained utilizing the following

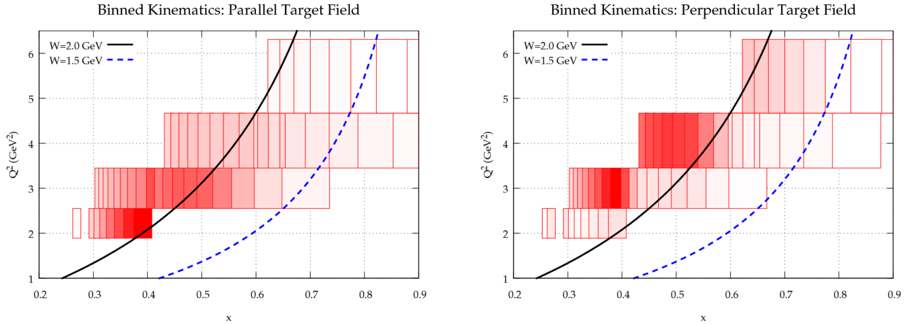
$$A_{\parallel} = D(A_1 - \xi A_2) \tag{3}$$

$$A_{\perp} = d(A_2 - \xi A_1) \tag{4}$$

$$A_1 = \frac{g_1 - (4M^2x^2/Q^2)g_2)}{F_1} \tag{5}$$

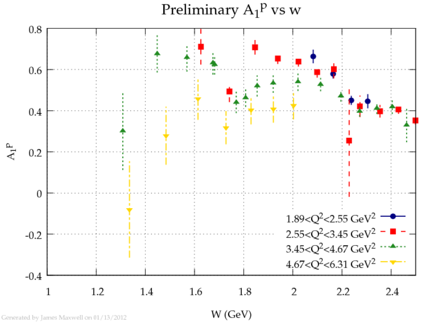
$$A_2 = \frac{2Mx}{\sqrt{Q^2}}\frac{g_1 + g_2}{F_1} \tag{6}$$

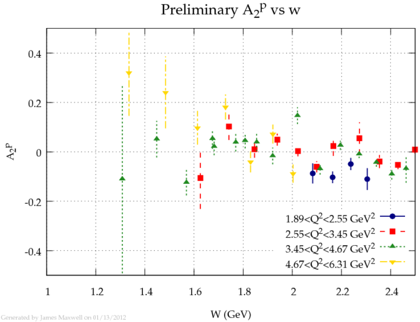
Kinematic Coverage



Plot by James Maxwell

Preliminary Results





Preliminary results for A_1^p and A_2^p courtesy of James Maxwell

Outline

Conclusion and Future Work

Analysis in progress

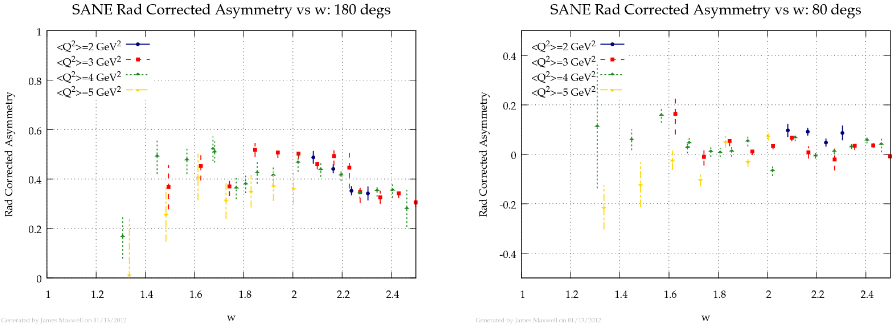
- Dilution factors for BETA from MC.
- Optimize pair symmetric background cuts
- Understand kinematic cuts
- Radiative Corrections
- Determining the systematic errors

More results soon to come...

Thank You!

Backup Slides

Radiative Corrections



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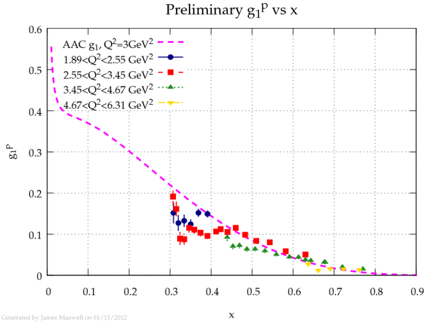

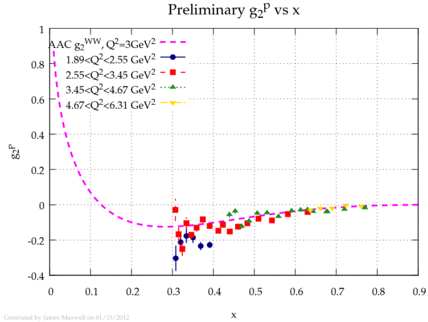

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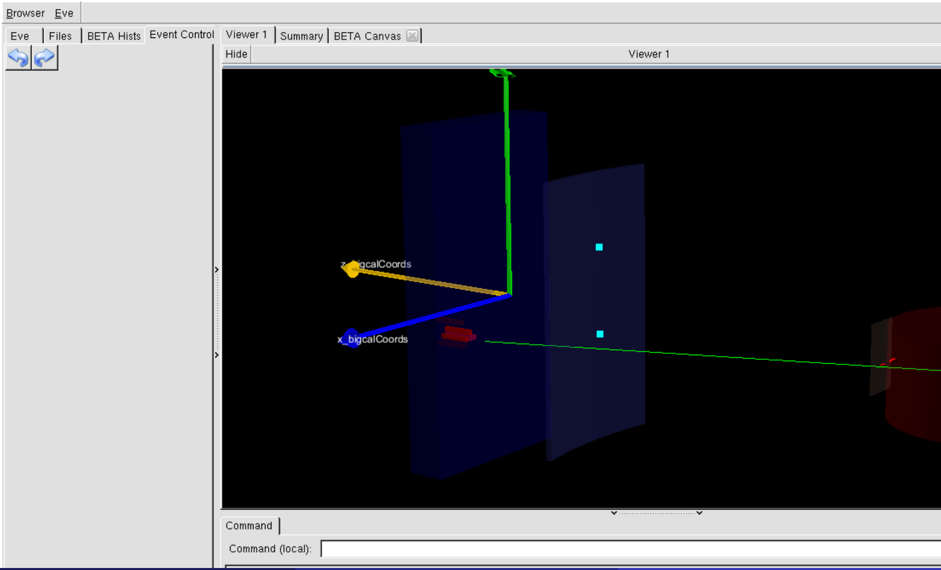
InSANE Event Display



InSANE

- Focus on physics analysis
- Not a CODA decoder
- Multiple analysis passes
- Make full use of ROOT I/O
- Easier transition MC → DATA

Experimental Run

- Oct. 28, 2008 - First beam. Commissioning and calibrations.
- Nov. 3, 2008 - Series of target quenches. Magnet broken.
- Dec. 18, 2008 - Magnet Quenches. Refrigerator went bad and magnet is really broken.
- Jan. 24, 2009 - Magnet is fixed. *Many thanks to Bill Vulcan, Jlab staff, and UVa target group!*
- Jan. 30, 2009 - Start perpendicular 4.7 GeV production.
- Feb. 9, 2009 - Start perpendicular 5.9 GeV production
- Feb. 27, 2009 - Resume perpendicular 4.7 GeV production
- March 6, 2009 - Start parallel 5.9 GeV production
- March 12, 2009 - Start parallel 5.9 GeV production
- March 16, 2009 - Experiment finished