Polarized Proton Elastic Scattering at very low -t region in RHIC

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Outline

- Theoretical background on proton elastic scattering process, and previously obtained experimental results
- Aspects for the proton polarimetry in high energy spin physics (RHIC Spin)
- Experimental techniques (setup, complex)
  - pC CNI measurements at RHIC, AGS
  - pp CNI measurements with H Jet target
- Recent results from Run-2004
- Issues and technical difficulties
Introduction for polarized proton elastic scattering
Polarized Proton-proton elastic scattering

- Measurement of helicity amplitudes at high energy
  → dynamical mechanism in asymptotic region
- 5 independent amplitudes $\phi_i$ (6th exists for non-identical particles scattering)

Non-flip: $\phi_1(s,t) = \langle ++ | M | ++ \rangle$

**double spin flip:** $\phi_2(s,t) = \langle ++ | M | -- \rangle$

Non-flip: $\phi_3(s,t) = \langle + - | M | + - \rangle$

**double spin flip:** $\phi_4(s,t) = \langle + - | M | - + \rangle$

**single spin flip:** $\phi_5(s,t) = \langle ++ | M | + - \rangle$

The region at RHIC
$|t| << m << \sqrt{s}$

Total cross-section (optical theorem)
$$\sigma_{\text{tot}} = \frac{4\pi}{s} \text{Im} \left[ \phi_1(s,t) + \phi_3(s,t) \right] \bigg|_{t=0}$$

differential cross-section
$$\frac{d\sigma}{dt} = \frac{2\pi}{s^2} \{ |\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + |\phi_4|^2 + 4|\phi_5|^2 \}$$

In case of, $p + \text{Spin0}$
Only “Non-flip” or “Single-flip” exist
Spin dependent asymmetries

- Use initial state polarization of beams
- 7 spin independent asymmetries ($A_N', A_{LS}'$ degenerate for identical particles)

\[ A_N = \frac{d\sigma}{dt} = \frac{4\pi}{s^2} \text{Im}\{\phi^*_3 (\phi_1 + \phi_2 + \phi_3 - \phi_4)\} \]

\[ A_{NN} = \frac{d\sigma}{dt} = \frac{4\pi}{s^2} \{2|\phi_3|^2 + \text{Re}(\phi_1^* \phi_2 - \phi_3^* \phi_4)\}, \]

\[ A_{SS} = \frac{d\sigma}{dt} = \frac{4\pi}{s^2} \text{Re}\{\phi_1 \phi_2^* + \phi_3 \phi_4^*\}, \]

\[ A_{SL} = \frac{d\sigma}{dt} = \frac{4\pi}{s^2} \text{Re}\{\phi_3^* (\phi_1 + \phi_2 - \phi_3 + \phi_4)\}, \]

\[ A_{LL} = \frac{d\sigma}{dt} = \frac{2\pi}{s^2} \{ |\phi_1|^2 + |\phi_2|^2 - |\phi_3|^2 - |\phi_4|^2\}. \]

- Needs substantial measurements far from Experimental situation
- Only $A_N$ (analyzing power) extensively measured

Conventional shorthand

\[ \phi_+ = \frac{1}{2}(\phi_1 + \phi_3), \quad \phi_- = \frac{1}{2}(\phi_1 - \phi_3), \]

Cross section diffs. (Longitudinal/Transverse)

\[ \frac{\text{Im} \phi_- (s,0)}{\text{Im} \phi_+ (s,0)} = \frac{1}{2} \frac{\Delta \sigma_L(s)}{\sigma_{\text{tot}}(s)}, \quad \Delta \sigma_L = \sigma_{\uparrow\downarrow} - \sigma_{\downarrow\uparrow}, \]

\[ \frac{\text{Im} \phi_2 (s,0)}{\text{Im} \phi_+ (s,0)} = - \frac{\Delta \sigma_T(s)}{\sigma_{\text{tot}}(s)}, \quad \Delta \sigma_T = \sigma_{\uparrow\uparrow} - \sigma_{\downarrow\downarrow}. \]
Interference of Hadronic/Electromagnetic Interference

around $t \sim -10^{-3} \, (GeV/c)^2$

$A_{\text{hadronic}} \approx A_{\text{Coulomb}}$

$\rightarrow$ Interference

$\text{CNI} = \text{Coulomb} - \text{Nuclear Interference}$

$$\phi_i \rightarrow \phi_i^{\text{had}} + \phi_i^{\text{em}} \exp(i\delta)$$

Single photon exchange is approximated

$$\phi_1^{\text{em}} = \phi_3^{\text{em}} = \frac{\alpha s}{t} F_1^2$$

$$\phi_2^{\text{em}} = -\phi_4^{\text{em}} = \frac{\alpha s \kappa^2}{4m^2} F_2^2$$

$$\phi_5^{\text{em}} = -\frac{\alpha s \kappa}{2m \sqrt{-t}} F_1 F_2$$

QED exact calculation available

$F_1, F_2$ : proton em form factors

$\kappa$: anomalous magnetic moment

Hadronic amplitude

$$\phi_j = \phi_j^R + \phi_j^{As}$$

$$\phi_j^R / \phi_j^{As} \rightarrow 1 / \sqrt{s} \, (s \rightarrow \infty)$$

simple Pomeron pole + something (one model)

$$\text{Im} \, \phi_j^{As}(s) = a_p s + a_F s \ln^2 s$$

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Spin flip amplitude \((r_5)\) and \(A_N(t)_{pp}\)

Asymptotic behavior of non-dominant amplitudes

\[
\begin{align*}
  r_2 &= R_2 + iI_2 = \frac{\phi_2}{2 \text{Im} \phi_+} \\
  r_- &= R_- + iI_- = \frac{\phi_-}{\text{Im} \phi_+} \\
  r_4 &= R_4 + iI_4 = -\frac{m^2 \phi_4}{t \text{Im} \phi_+} \\
  r_5 &= R_5 + iI_5 = \frac{m \phi_5}{\sqrt{-t} \text{Im} \phi_+}
\end{align*}
\]

\[A_N = \frac{\text{Im}\{(2 \phi_+ + 2e^{i\delta} \phi_{\text{em}}^+ + \phi_2) * (\phi_5 + e^{i\delta} \phi_{\text{em}}^5)\}}{|\phi_+ + e^{i\delta} \phi_{\text{em}}^+|^2 + |\phi_-|^2 + (1/2)|\phi_2|^2 + 2|\phi_5 + e^{i\delta} \phi_{\text{em}}|^2|}
\]

\[
\frac{m A_N}{\sqrt{-t} \sigma_{tot}^2} \frac{d\sigma}{dt} e^{-Bt} = \left[\kappa (1 - \delta \rho + \text{Im} r_2 - \delta \text{Re} r_2)\right] \frac{t_c}{t} - 2(1 + \text{Im} r_2) \text{Re} r_5 + 2(\rho + \text{Re} r_2) \text{Im} r_5
\]

\[
\frac{16\pi d\sigma}{\sigma_{tot}^2 \frac{dt}{dt}} e^{-Bt} = \left(\frac{t_c}{t}\right)^2 - 2(\rho + \delta) \frac{t_c}{t} + (1 + \rho^2)(1 + \beta^2)
\]

\[E704 \ p_L = 200\text{GeV} \quad r_5 = 0
\]

\[\delta, \rho \text{ known, } \beta = 0, \ r_i \text{ set to 0 (except } r_5)\]

\(t_c = -8 \pi \alpha / \sigma_{tot}\)

\(r_5\) is the one parameter left, \(A_N\) is function of \(t\)
Extension to $p+C$ elastic scattering

- similar form as $pp$
- substantially modified by nuclear effects
- $A_N(t)$ sensitive to $r_5$

\[
\frac{16\pi}{\sigma_{tot}^C} \frac{d\sigma_{pC}}{dt} A_N^{pC}(t) = \frac{\sqrt{-t}}{m_N} F_C^h(t) \left\{ F_C^{em}(t) \frac{t_c}{t} [\kappa(1 - \delta_{pC}\rho_{pC})] - 2(\text{Im} \ r_5^{pC} - \delta_{pC}\text{Re} \ r_5^{pC}) - 2F_A^h(t)(\text{Re} \ r_5^{pC} - \rho_{pC}\text{Im} \ r_5^{pC}) \right\}
\]

\[
\frac{16\pi}{\sigma_{tot}^C} \frac{d\sigma_{pC}}{dt} = \left( \frac{t_c}{t} \right)^2 [F_C^{em}(t)]^2 - 2(\rho_{pC} + \delta_{pC})(\frac{t_c}{t}) F_C^h(t) F_C^{em}(t) + (1 + \rho_{pC}^2 - \frac{t}{m_p^2} |r_5^{pC}|^2) [F_C^h(t)]^2
\]

$F_C^{em}, F_C^h$ Form factors (Electromagnetic, Hadronic)
express pC process with $r_5$

\[
r_5^{pC}(t) = \frac{1 - i\rho_{pC}(t)}{1 - i\rho_{pN}} r_5
\]

From the fit to $A_N(t)$, determination of $r_5$ and comparison with $pp$ scattering is possible.
Proton Polarimeter
Important Device for the RHIC Spin Physics
RHIC Spin Project
proton spin crisis

\[ \frac{1}{2} = (1/2) \Delta \Sigma + \Delta g + L_Q + L_G \]

\( \Delta \Sigma \): quark spin \( \sim \) 0.2-0.3 (EMC, SMC)

\( \Delta g \): gluon spin \( \Delta g/g = -0.2\pm0.3 \) (SMC)

\( L_Q, L_G \) : orbital angular momentum \( \sim ? \)

- \( \Delta g(x) \) measurement
  - Contribution of gluon polarization to the proton spin
  - The direct probe for gluon originated process using \( \sqrt{s} = 200\text{GeV}, 500\text{GeV} \) polarized proton collisions
- Decomposition of flavor dependent contribution
- Measure Transversity
Polarimeter : Impact on the RHIC Spin project

RHIC-Spin is the first Polarized-Proton collider (E_B = 100-250GeV)

Single Spin

\[
\begin{align*}
N_{\uparrow} & \quad \text{Versus} \quad N_{\downarrow} \\
\end{align*}
\]

Physics Asymmetry

\[
A_L = \frac{1}{P_B} \left( \frac{N_{\uparrow} - N_{\downarrow}}{N_{\uparrow} + N_{\downarrow}} \right) = \varepsilon_L
\]

Double Spin

\[
\begin{align*}
N_{\uparrow\uparrow} & \quad \text{Versus} \quad N_{\uparrow\downarrow} \\
N_{\downarrow\uparrow} & \quad \text{Versus} \quad N_{\downarrow\downarrow} \\
\end{align*}
\]

Same for other Spin configurations (AN, AT, TT, etc)

- To obtain the physics quantity, the raw asymmetry (=ε) needs to be normalized by beam polarization
- Scaling correction, but generally P_B changes time to time
- Reliable and quick proton polarimeter is essential for diagnosing, monitoring the beam polarization, requires \( \frac{dP}{P} < 5\% \)
**E950 measurement at AGS**

- AN measurement for elastic $p+C$ scattering
- 21.7 GeV/c polarized proton beam, calibrated with separate polarimeter (E925) using extracted AGS beam
- Large contribution (~15%) from hadronic spin-flip amplitude

**Constraint**

- Close to the RHIC injection energy (24GeV/c), but one step smaller than the last strong intrinsic resonance
- ~30% measurement error is tied to the ambiguity of beam polarization (E925)

$\Re r_5^{pc} \propto F_s^{had} / \Im F_0^{had}$

$\Re r_5 = 0.088 \pm 0.058$

$\Im r_5 = -0.161 \pm 0.226$
Pomeron spin flip amplitude

Introduce $t$ independent parameter $\tau(s)$

$$\phi_5(s, t) = \tau(s) \frac{\sqrt{-t}}{m} \phi_+(s, t)$$

Analogy to the non-flip scattering
$(pp$ elastic, dominated by $I=0$ exchange)$

$$\phi_5(s, t) = \frac{\sqrt{t}}{m} \{ \tau_P \phi_P(s) + \tau_f \phi_f(s) + \tau_\omega \phi_\omega(s) \}$$

$\phi_P(s), \phi_f(s), \phi_\omega(s)$ : form established

$\tau$’s are real numbers

Once these parameters are determined, $A_N(t)$ at any energy $(s)$ can be predicted

<table>
<thead>
<tr>
<th></th>
<th>$l=0$</th>
<th>$l=1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$pp$</td>
<td>$P,f_1,\omega$</td>
<td>$a_2,\rho$</td>
</tr>
<tr>
<td>$pC$</td>
<td>$P,f_1,\omega$</td>
<td></td>
</tr>
</tbody>
</table>

In hep-ph/0305085
from results $\tau$ $(e950)$ $(2eq.)$, and
the shape of $A_N$ at 100GeV $(Run2002)$ $(1eq.)$

$$\tau_P = -0.02, \quad \tau_f = -0.43, \quad \tau_\omega = 0.03 \quad \text{with large ambiguity}$$
Experimental Techniques
(Setup, Complex)
RHIC/AGS at Brookhaven National Laboratory

RHIC is visible from airplane
4km circumference
**RHIC varieties of components for pp-mode**

*Full Siberian Snakes*: Cold helical dipole magnets
- Avoid all spin resonances
- Keep polarization at store

*Spin Rotators*: Longitudinal spin direction at collision point

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Trilogy of CNI polarimetry

**RHIC – polarimeters**
Quick and stable measurements
Provide polarization info for experiments
Goal is $\Delta p/p = 5\%$, needs to be calibrated

**AGS – polarimeter**
Diagnostic device for the polarization in AGS acceleration

Hydrogen Gas JET target polarimeter
Consists of 95 $\%$ polarized H jet target and $pp \rightarrow pp$ elastic polarimeter
Provide beam polarization without ambiguity from theoretical model
*(firstly commissioned at Run-04)*

Inside the RHIC tunnel at IP12 area
Inside the AGS tunnel at C15
Event selection

- Strong correlation: Kinetic relation (TOF vs. Energy) of recoil particle
- Banana cut can identify the carbon (≡ mass cut)
- Background < a few %

non-relativistic kinematics

\[ \text{tof} = \sqrt{\frac{M_C}{2T_{\text{kin}}}} L \]

<table>
<thead>
<tr>
<th>Invariant Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_C \sim 11.17 \text{ GeV} )</td>
</tr>
<tr>
<td>( \sigma_M \sim 1.5 \text{ GeV} )</td>
</tr>
</tbody>
</table>

Prompts

Alpha

Carbon
Detector/Target layout for pC CNI

Ultra thin Carbon ribbon Target (3.5μg/cm², 10μm)

Si strip detectors (TOF, E_C)

Distance: optimized for bunch crossing period

45 degree Si : sensitive to vertical components

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The Atomic H Beam

Hyperfine state (1), (2), (3), (4)

(1), (2)

Pz+ : (1), (4) (SFT ON (2) → (4))
Pz- : (2), (3) (WFT ON (1) → (3))
Pz0: (1), (2), (3), (4) (SFT & WFT ON)

record beam intensity 100% eff. RF transitions focusing high intensity B-R polarimeter

Breit-Rabi polarimeter

holding field magnet
Recoil Si spectrometer

6 Si detectors covering blue beam

MEASURE
- energy (res. < 50 keV)
- time of flight (res. < 2 ns)
- scattering angle (res. ~ 5 mrad)

of recoil protons from \( pp \rightarrow pp \) elastic scattering

\[
A_N^{\text{beam}}(t) = -A_N^{\text{target}}(t)
\]

for elastic scattering only!

\[
P_{\text{beam}} = - P_{\text{target}} \cdot \frac{\varepsilon_N^{\text{beam}}}{\varepsilon_N^{\text{target}}}
\]

have “design”
- azimuthal coverage
- one Si layer only
  \( \Rightarrow \) smaller energy range
  \( \Rightarrow \) reduced bckgrnd rejection power

Si detectors from BNL Inst. and Hamamatsu

Electronics developed by BNL Inst. and Physics
Data acquisition with WFD (Wave Form Digitizer)

CNI polarimeter is **destructive** for beam
Dead time free DAQ system is indispensable

Characterize pulse with FPGA algorithm

dt \sim 1.2 \text{nsec}
dE \sim 50 \text{keV}
Sampling: 3x140MHz

Data Readout
- After Measurement (RHIC)
- Between Beam Injections (AGS)
- During Jet Polarization Flips (JET)

2D Memory map in WFD

Data stored in onboard memory
Synchronized to accelerator clock

High Statistics (20M /run)
High DAQ rate (~0.5M /sec)
**Raw asymmetry → Polarization**

\[
P_{\text{beam}} = \frac{1}{\langle A_N \rangle} \cdot \mathcal{E}_N
\]

\[
\langle A_N \rangle = \sum N(t_i) A_{th}^N(t_i)
\]

\[
A_{th}^N(t) : \text{Theoretical function fit to E950 data}
\]

L. Trueman hep-ph/0305085

\[
N(t) : \text{Cross section curve from data}
\]

- \( \langle A_N \rangle \) compensates the difference in acceptance, S/N between polarimeters
- Asymmetry calculation with Square-Root Formula

\[
\varepsilon = P_B \cdot A_N
\]

\[
P_B \sim 27\%
\]

\[
\langle A_N \rangle \approx 1.12
\]

400 < \( E_C \) (keV) < 1000

(From Run-03)

Recoil Carbon Energy (keV)

Results of square-root formula
- ○ 90 degree detectors
- ○ 45 degree detectors
- ● Mean of two

Line – hep-ph/0305085

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Recent results from Run-04
**RHIC... CNI measurements within a fill**

*In the last week of run*

- \( P(RHIC) / P(AGS) \)
  - 1.001±0.016 (expect 0.974), \( \text{pol.}=48.7 \pm 0.5\% \)
  - 0.952±0.019 (expect 0.993), \( \text{pol.}=48.6 \pm 0.7\% \)

- **Pol. Size is confirmed at RHIC & AGS CNI (assuming same \( A_N \) values)**
- **56 bunch mode** (alternating spin pattern)
- **4x10^{12} proton /ring**
RHIC… Bunch by bunch Asymmetry

Simple Left-Right asymmetry

\[ \varepsilon(i) = - \frac{N_L(i) - N_R(i)}{N_L(i) + N_R(i)} \]

recoil detection

- + / – bunches clear separation
- Luminosity / Acceptance asymmetry stable

typical run (not best)
RHIC… -t dependence

- -t dependence follows theoretical model
- False asymmetries (Cross, Radial) are clean
- Physics asymmetries 90°, 45° agree

L. Trueman’s curve

typical run (not best)
RHIC... Polarization history in pp run-04

Change in Si dead layer parameters
dlittle loss or none at the ramp
switch to horizontal target

Data Points
Black : 24GeV
Color : 100GeV

Jet data taking
dedicated
Non-dedicated

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RHIC… Issues on polarization profile

- Large polarization profile in vertical (small profile in horizontal)
- Observed position dependent fluctuation in pol measurements

H Scan -- horizontal scan with vertical target
V Scan – vertical scan with horizontal target

- Polarization
- Beam Intensity
RHIC... Ramp measurements

- 5 ramp measurements taken in Run-04 (Fill: 5159, 5169, 5170, 5199, 5332)
- Larger on-board memory, larger statistics
- All of them suffered large profile effects due to the beam motion along the ramp
- Found the depolarization point prior to the energy ramp (200MHz RF cavity magnet ramp)

May 12th fill 5332

- Beam Energy
- Event rate

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**JET... pp elastic data collected**

**JET Profile:** measured selecting *pp* elastic events
- FWHM ~ 6 mm
- As designed
- background
- 118 cts. subtracted
- Hor. pos. of Jet 10000 cts. = 2.5 mm

- recoil protons unambiguously identified!

- 100 GeV ~ 700,000 events at the peak of $A_N$ ~ 100 hours
  (~ 2 x 10^6 total useful *pp* elastic events)
- 24 GeV ~ 120,000 events at the peak of $A_N$ ~ 17 hours
  (~ 4 x 10^5 total useful *pp* elastic events)

**ToF vs $E_{REC}$ correlation**
- $T_{kin} = \frac{1}{2} M_R (\text{dist}/\text{ToF})^2$

---

**Si = 1 all chan**

- *pp* elastic events
- recoil protons elastic *pp $\rightarrow pp*
- background
- 118 cts. subtracted
- $\Delta$ ToF < 6 ns
- prompt events and beam gas
- $\alpha$ source calibration

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JET... Energy - Position correlations

\[ T_{\text{kin}} \propto \theta^2 \text{ (i.e. position}^2) \]

fully absorbed protons

punch through protons

reconstructed missing mass \( M_X^2 \)

\[ pp \rightarrow Xp \]

elastic: \( X \equiv p \)

FWHM \~ 0.1 \text{ GeV}^2

inelastic threshold

\[
M_X^2 = \frac{(\sin \theta_X - \sin \theta_{el})}{2P_{beam} \sqrt{|t|}} + m_p^2
\]
JET... "ONLINE" measured asymmetries & Results

"Target": average over beam polarization

"Beam": average over target polarization

Data divided into 3 recoil energy bins

an example: $750 < E_{REC} < 1750$ keV

\[ \frac{\chi^2}{\text{ndf}} = 57.84 / 53 \]
\[ P_1 = 3.826 \pm 0.1535 \]

1 run ~ 1 hour

\[ P_{\text{beam}} = 36.9 \% \pm 1.9 \% \]
\[ \langle P_{\text{beam}} (pC CNI) \rangle = 38.1 \% \]

No major surprises?

(statistical errors only !)

ONLINE $\equiv$ statistical errors only
no background corrections
no dead layer corrections
no systematic studies
no false asymmetries studies
no run selection

blue beam with alternating bunch polarizations: ↑↓↑↓↑↓ …

good uniformity from run to run
(stable JET polarization)
JET polarization reversed each ~ 5 min.

$P_{\text{beam}} = -P_{\text{target}} \cdot \frac{\varepsilon_{\text{beam}}}{\varepsilon_{\text{target}}}$
Issues and technical difficulties
**Important issue for the systematic (t determination)**

- **t** is estimated from recoil Carbon energy
  
  \[-t = 2MC_E^{\text{elastic}}\]
  
  \[E^{\text{elastic}} = E^{\text{deposit}} + \Delta E^{\text{target}} + \Delta E^{\text{deadlayer}}\]
  
  \[(\Delta E^{\text{target}} \sim 0.1 \times \Delta E^{\text{deadlayer}})\]

- Estimation with kinetic fit to banana
  
  \[T_{\text{of}}(\text{ns}) = \sqrt{\frac{MC}{2}} \cdot \frac{\text{Distance}}{\sqrt{E^{\text{elastic}}}} + t_0\]
  
  \[E^{\text{elastic}} = f(E^{\text{deposit}}, D^{\text{width}})\]

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**Silicons are from the same wafer**

The absolute values are similar

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**Once the dead layer issue solved, the jet-measurements will not be needed anymore ....**

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**IF NOT, calibration needed every year**

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**20µg/cm²**

**60µg/cm²**

**100µg/cm²**

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**In order to be Insensitive to Polarization Profile**
*(For stable and robust CNI measurements)*

- Definition of $P$ differs in measurements
  1) $pC$ CNI samples one point
  2) $pp$-Jet target covers whole beam profile
  
  \[
  \bar{P} = \sum_x N(x) P(x) / \sum_x N(x)
  \]

- Experiments head-on collisions
  \[
  \bar{P} = \sqrt{\sum_x (N(x) P(x))^2 / \sum_x (N(x))^2}
  \]

- The idea is to move the target across the beam in steps during regular runs
  - Online results $\rightarrow$ 2)
  - Offline results $\rightarrow$ 1), 2), 3)
**Induced current free silicon design**

No More Beam Induced Pickups...

New improvement in AGS CNI
- every second wire is ground line, from edge to edge.
- wide range of \(-t\) is available
- able to open the time window to very close to the beam crossing

\[ T_{\text{kin}} = \frac{1}{2} M R (\text{dist/ToF})^2 \]

non-relativistic kinematics

TOF, ns

**Carbon**

**Alpha**

**Prompts**

\[ E_C, \text{ keV} \]

To apply for RHIC CNI
- new vacuum ports
- new detector mounts (ceramics)
- R&D on the glue for the vacuum
- new RF shields
- add coolers
Plan of RHIC Spin

- On Polarimetry
  - \(pp, pC\) calibration → determine \(r_5\)
  - more precise calibration at 2005 (100GeV)
  - 250GeV calibration (2008)

- RHIC Spin General
  - Long physics run at 2005
  - \(W\) → flavor decomposition (2008)
Summary

- Successful Jet-target commissioning done
- Calibration from online result looks consistent with calibration by E950
- Efforts of extracting $pp$, $pC\ AN$ are in progress

- Final goal $\Delta P/P = 5\%$ will be obtained in run-05