

June 22, 2023  
25<sup>th</sup> Anniversary of RBRC Center



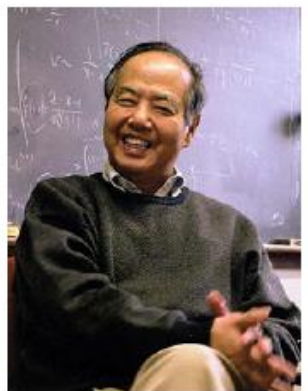
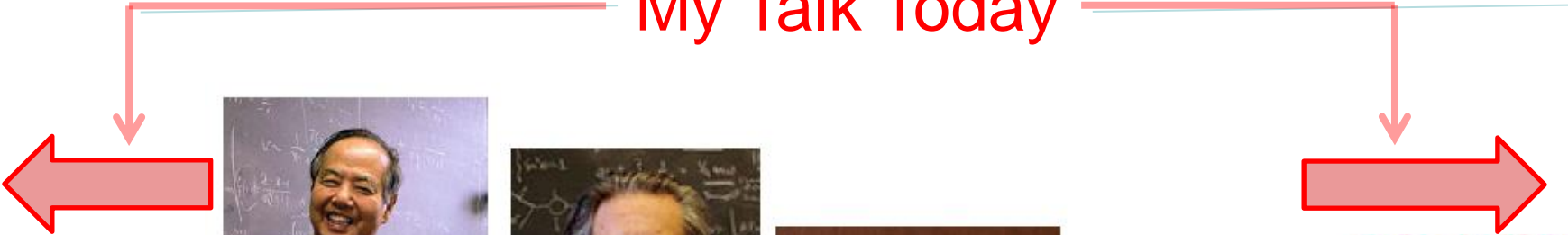
# Before the Birth of RBRC and the Future

**Shoji Nagamiya**

**RIKEN**



# My Talk Today



**Tsung-Dao Lee**  
1997-



**Nick Samios**  
2004-



**Samuel Aronson**  
2013-

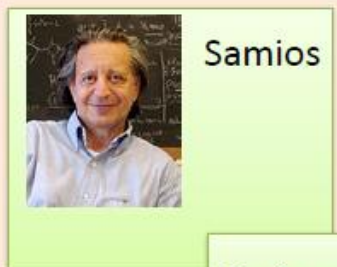


**Hideto En'yo**  
2017-

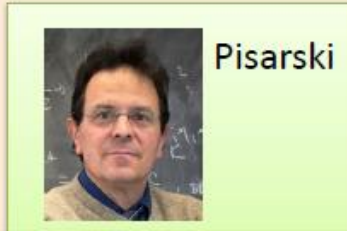


**Robert Tribble**  
2023-

## RBRC Deputy Directors



Samios



Pisarski



Morrison

En'yo 2001-2017 Associate Director

~1985  
at AGS



Yasuyuki  
Akiba

Toru  
Sugitate

Kazu  
Kurita

Yoahi  
Takahashi

Kenta  
Shigaki



Masa  
Asakawa

Junsei  
Chiba



Yasuo  
Miake



Hideki  
Hamagaki

Myself

Ryu  
Hayano

Shige  
Hayashi

Yuu  
Ikeda

Hiro  
Sakurai

**1990: Workshop on July 4<sup>th</sup> (holiday) at BNL for RHIC.**

**Converged (?) into 7 working groups on various detector proposals**

**1991: Four Proposals  
STAR ( $4\pi$ )... Approved**

**OASIS (di-electron+photon)  
Dimuon (dimuon)  
TALES/ SPARHC  
(di-eleron)**

**... Advised  
to combine**

**We thought  
three were  
trashed.**



Courtesy of W. A. Zajc



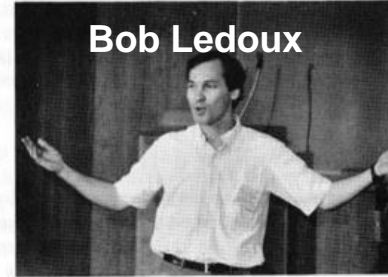
**Workshop on Experiments and Detectors for RHIC:  
Issues and Ideas  
Amid July 4 Fireworks**

The fourth workshop on experiments and detectors for RHIC was held at Brookhaven during the first week of July. Beginning on Monday and winding up at noon on Saturday. A gathering of nearly 200 soon-to-be users of the RHIC facility assembled for an intensive week of discussions and working groups focussed on the preparation of letters of intent for experiments at RHIC. As announced in the April edition of the RHIC Bulletin, these Letters are due September 28, 1990, and are the first step in a sequence of events which will lead to the first round of experiments for the collider.

At the core of this summer's workshop was the activity of seven working groups, each developing its concept for a RHIC detector. In concert with this activity, the workshop participants also addressed a number of issues related to the implementation of an experimental program at RHIC. Among these issues, the major topics of discussion were related to the detailed configuration of the collision regions at RHIC, including the existing experimental halls and machine questions such as possible luminosity upgrades, and the plans for detector R&D.

The meeting took place amid local celebrations of the Independence Day holiday, and fireworks lit the skies in surrounding communities as the workshop participants toiled into the night. Although the week of

(Continued on page 2)



**Bob Ledoux**



**Wit Busza**

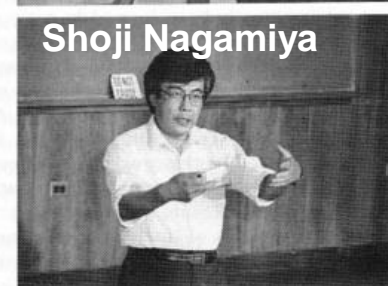


**Satoshi Ozaki**



**John Harris**

Photos by Roger Stoutenburgh



**Shoji Nagamiya**

Making their points at the RHIC workshop: clockwise from top . . . Bob Ledoux, MIT; Wit Busza, MIT; Satoshi Ozaki, RHIC Project Head; Shoji Nagamiya, Columbia University; John Harris, Lawrence Berkeley Laboratory.

## 1991.09. Rebirth of 3 Proposals

- DOE covered \$30M, KEK covered \$10M for di-electron, but \$10M was missing for di-muons.
- 1992.02.: Sam and I visited RIKEN to see if RIKEN could fund a muon arm, but our effort failed (according to M. Ishihara).

## 1992.03. SN was appointed as a PHENIX spokesperson.

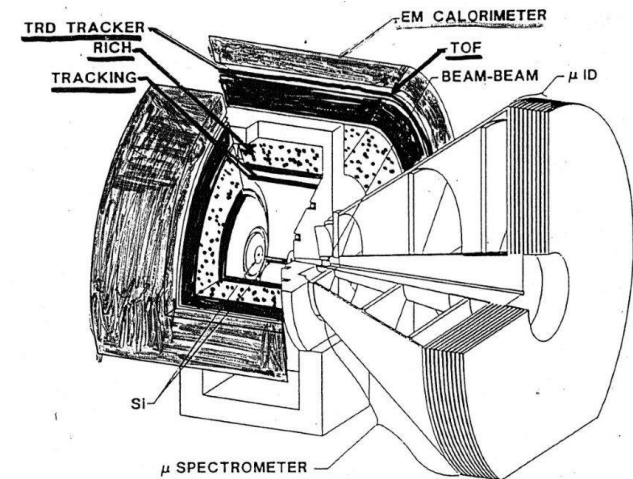
- 1992.06: pCDR of 260 pages published.
- 1992.11: Muon arm deferred from the baseline. I, therefore, decided to seek for new money.

## 1993: RIKEN started discussing Spin Program by Ishihara grp.



DOE .. \$30M  
KEK .. \$10M  
\$10M missing

**PHEONIX? Photon, Hadron, Electron  
muOn Nucl. Ion eXperiment ???**



PHENIX Detector

**PHENIX Pioneering High Energy  
Nuclear Ion eXperiment**

## 1993.12. RIKEN Proposal on Spin Physics was almost finalized.

- Included were Snakes and Spin rotators for PHENIX and STAR.
- 1994.04.: AEE Proposal submitted.



**RIKEN  
Chief  
Scientist,  
Ishihara**

## 1994.12. Spin and an additional Muon Arm funding approved for RIKEN.

## 1995.01 NSAC strongly supported the AEE fund (for additional muon arm + level-2 trigger for PHENIX).

**Two muon-arms became realistic:  
One from RIKEN and the other from DOE.**

## 1995.05. Unification of Heavy-Ions and Spin Programs in PHENIX.

**Major Event For PHENIX.**

## 1995.10. RIKEN-BNL MoU Signed.

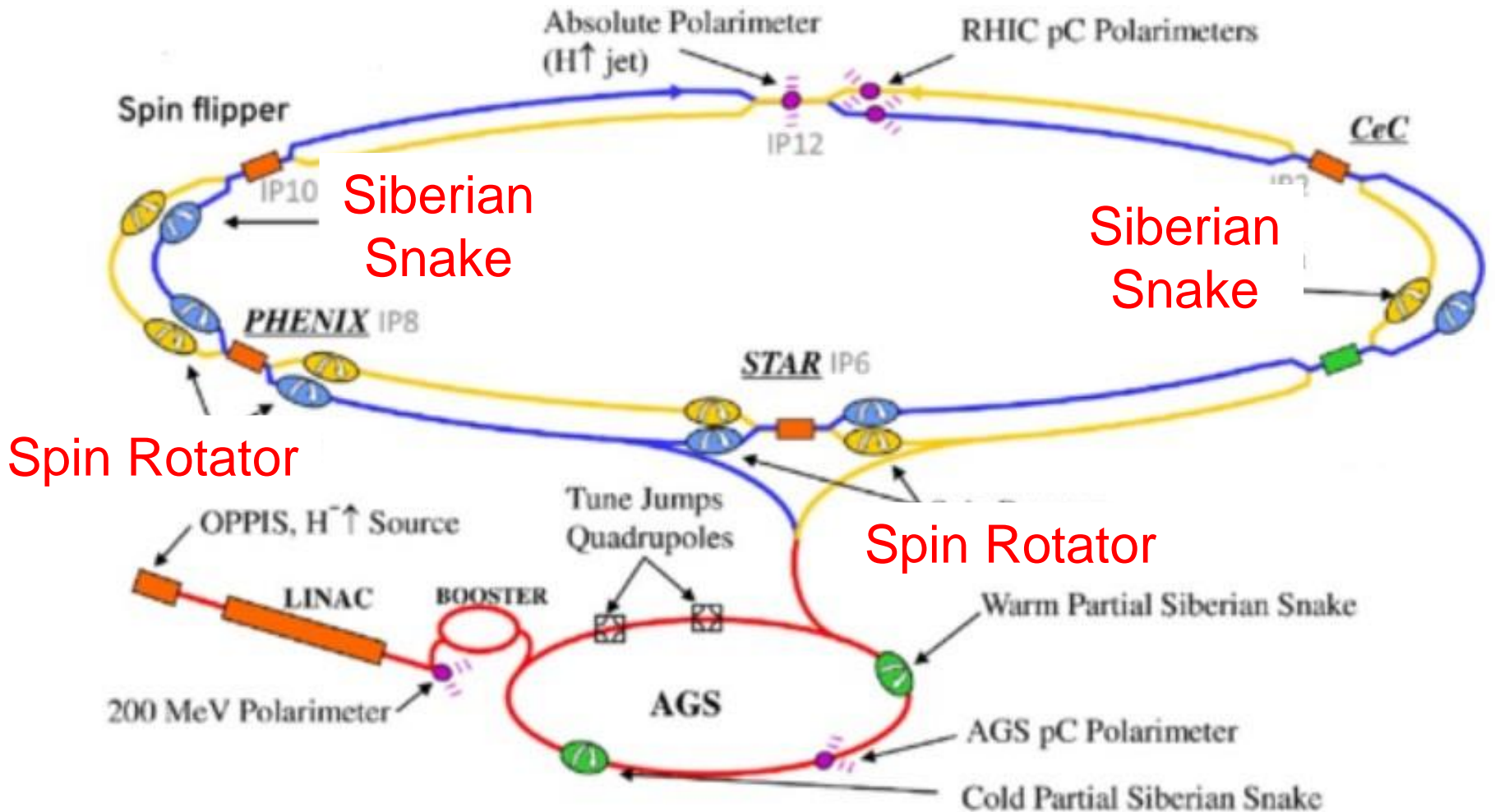
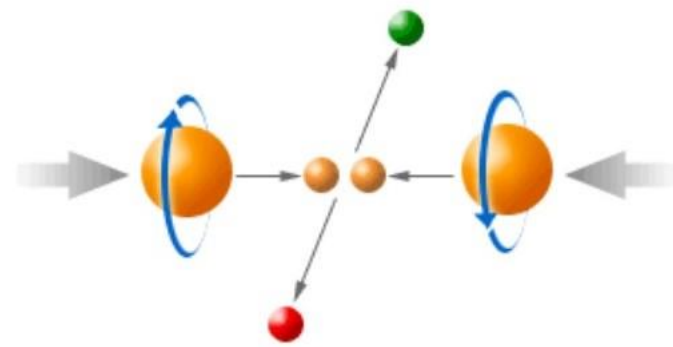
## 1996. 04. RIKEN Steering Committee on Phase II Budget

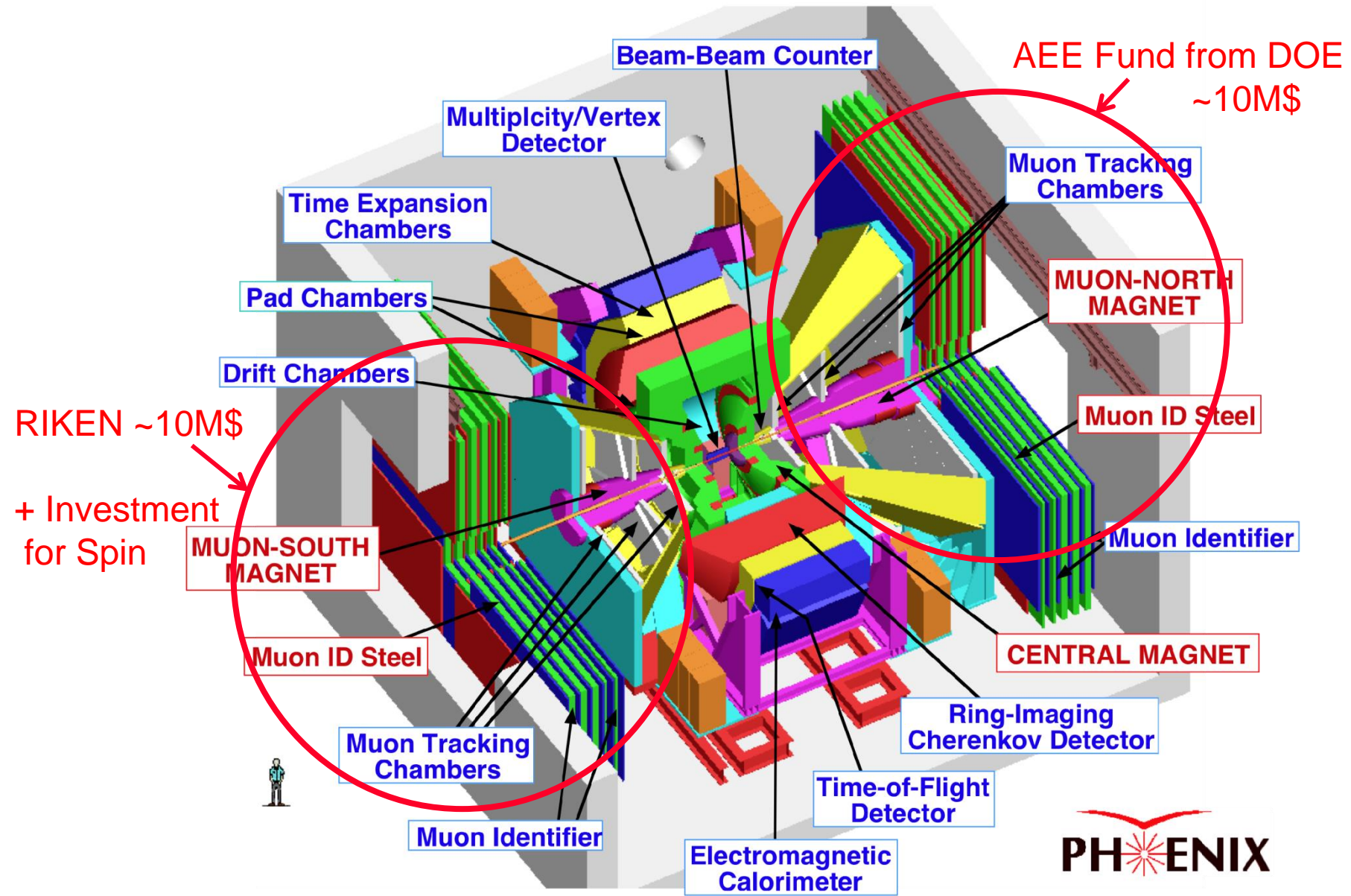
## 1996. 12 RBRC officially approved.



**(2001 - )  
En'yo  
succeeded  
Chief  
Scientist**

# Siberian Snake and Spin Rotator for both STAR and PHENIX







**Funding for Muon Arms**

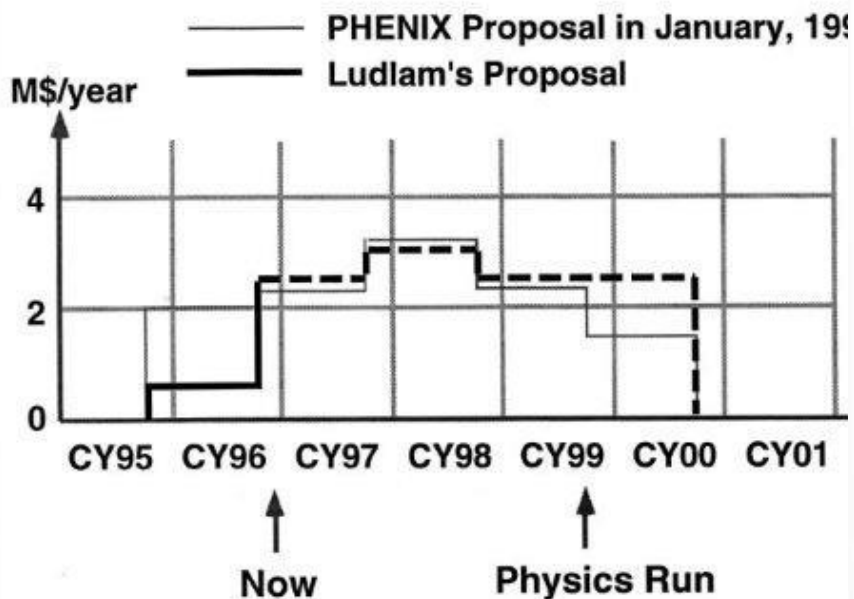
**1. Muon Arm North (AEE)**

[BNL's proposal for AEE]

	FY95/96	FY97	FY98	FY99	FY00	FY01
SVT	1.45	2.00	1.50	1.05		
EMCal	0.30	0.60	1.20	2.15	2.50	1.75
Muon-N	0.75	2.65	3.00	2.50	2.50	11.4 M\$
High-pT		0.25	0.30	0.30	1.00	1.9 M\$
RCF	0.10	0.70	2.00	5.10		
<b>Total</b>	<b>2.60</b>	<b>6.20</b>	<b>8.00</b>	<b>11.10</b>	<b>6.00</b>	<b>1.75</b>

STAR  
PHENIX  
RCF

**AEE Funds for Muon North**

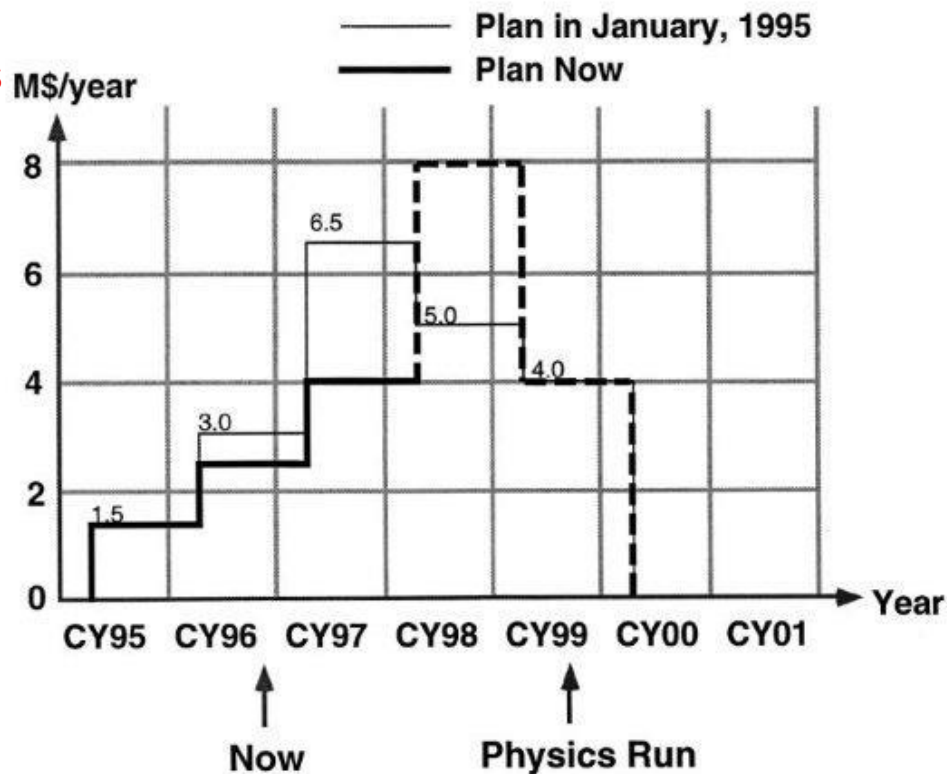


**2. Muon Arm South (RIKEN)**

	JFY95	JFY96	JFY97	JFY98	JFY99
Phase 1	\$1.5M	\$1.5M	\$2.0M		
Phase 2		\$1.0M	\$1.0M	\$3.0M	
Phase 3			\$1.0M	\$5.0M	\$4.0M

Total 20M\$ Incl. Siberian snakes & rotators

**RIKEN Funds for Spin**



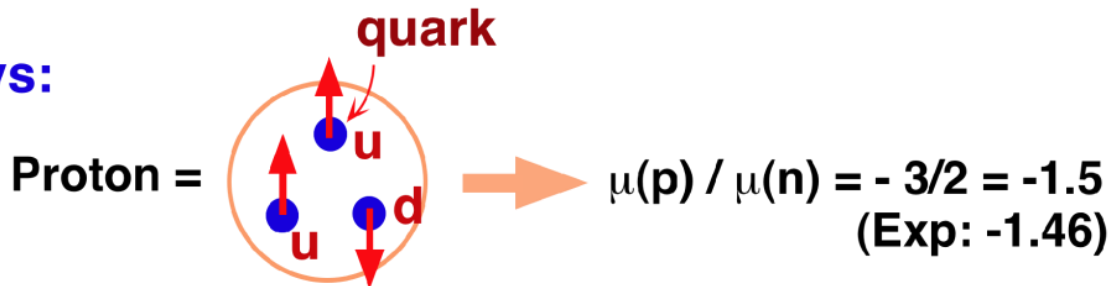
1. Significant delay for Siberian snakes and spin rotators.
2. No contingencies included. Also, \$1 > 100 Yen.

I (as a non-expert in spin physics) created the following two graphs when the spin program merged into PHENIX in 1995.

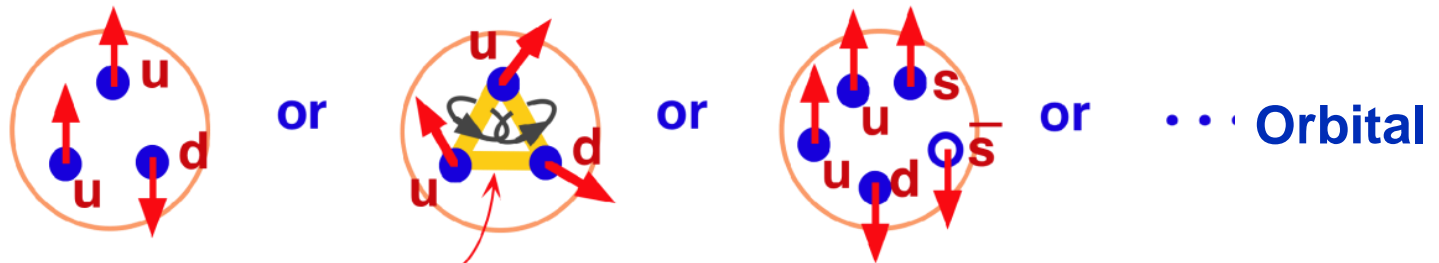


**Polarization of the Nucleon**

Old Days:



Recent Questions:



Only 30% of proton spin originated from quarks!

Remaining 70% ???

# Spin Physics at RHIC

1995



- Always compare



and measure asymmetry (to study the angular anisotropy).

- Polarization can be longitudinal or transverse.
- Single spin asymmetry (e.g.,  $p^\uparrow + p$  or  $p^\uparrow + A$ ) can also be studied.

## Typical Examples

- gluon + gluon  $\rightarrow$  jet + jet
- gluon + quark  $\rightarrow$  high-energy  $\gamma \leftarrow$
- quark + anti-quark  $\rightarrow \mu^+\mu^-$  (Drell-Yan)  $\leftarrow$ 
  - $\rightarrow W^\pm \rightarrow e^\pm$  (or  $\mu^\pm$ ) +  $\nu \leftarrow$
  - $\rightarrow Z^0 \rightarrow \mu^+\mu^- \leftarrow ?$

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2023



$A_{LL}$ ,  $A_L$  confirmed by STAR jet

PHENIX direct  $\gamma + \pi_0$

PHENIX  $W \rightarrow e, \mu$

STAR  $W \rightarrow e$

$A_N \sim 0$  (in midrapidity)

For example,

PHENIX direct  $\gamma$

○ STAR

○ PHENIX (+  $\pi_0$  also)

×

○ PHENIX(e +  $\mu$ ), STAR(e)

○ STAR ( $A_N$  alone,  $e^+e^-$ )



**Sam Aronson**

**Bill Zajc**

**Satoshi Ozaki**

**Nick Samios**



**Mel Schwartz**

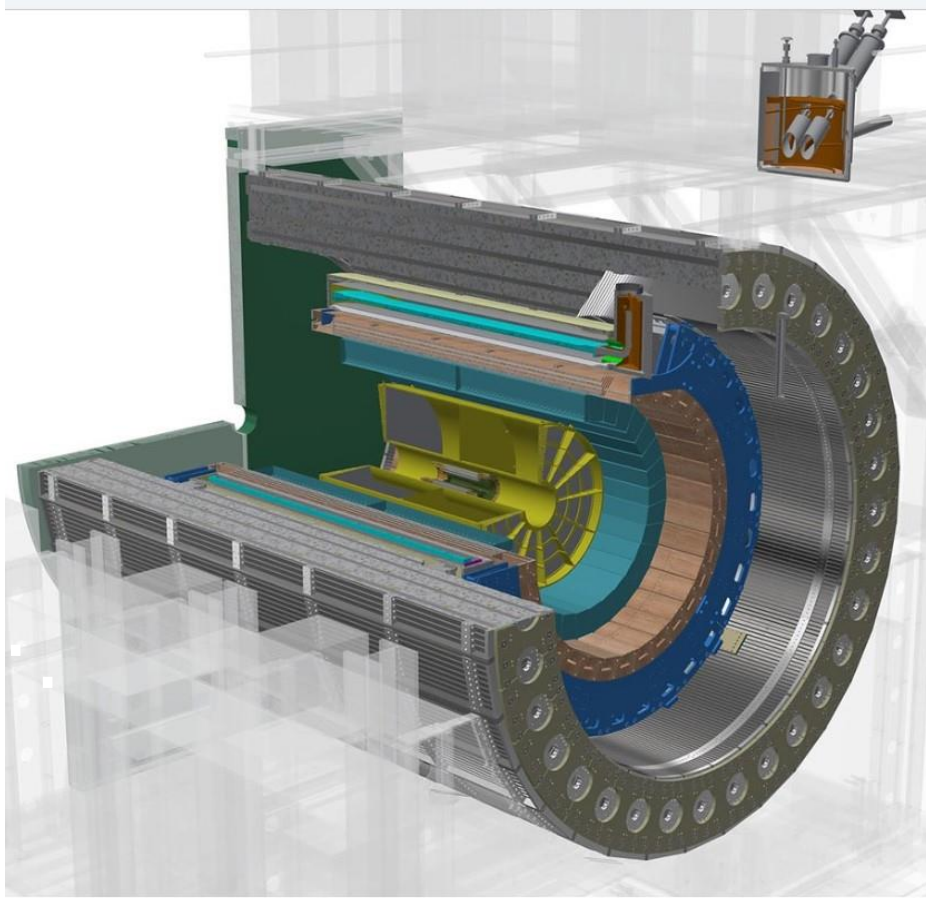
**T. D. Lee**



# Extremely Successful Operation of RBRC



- **T. D. Lee introduced a joint appointment system**
  - Many excellent physicists have been born from RBRC.
- **Siberian snake and spin rotator added a significant portion to RHIC**
  - Successfully achieved polarized proton beams for both STAR and PHENIX.
  - Powerful di-muons for PHENIX, in addition to di-electrons
- **In public, the most well-known and successful US-Japan Collaboration**
  - Based on substantial efforts by RIKEN staff members
- **DOE changed polarized proton physics into Nuclear Physics (before then, it was classified as High-Energy Physics at DOE)**



## sPHENIX Detector

Single jet, Jet-jet, Jet + Direct  $\gamma$  will be measured in addition to many others.

## Spin Programs at sPHENIX

Measured are:

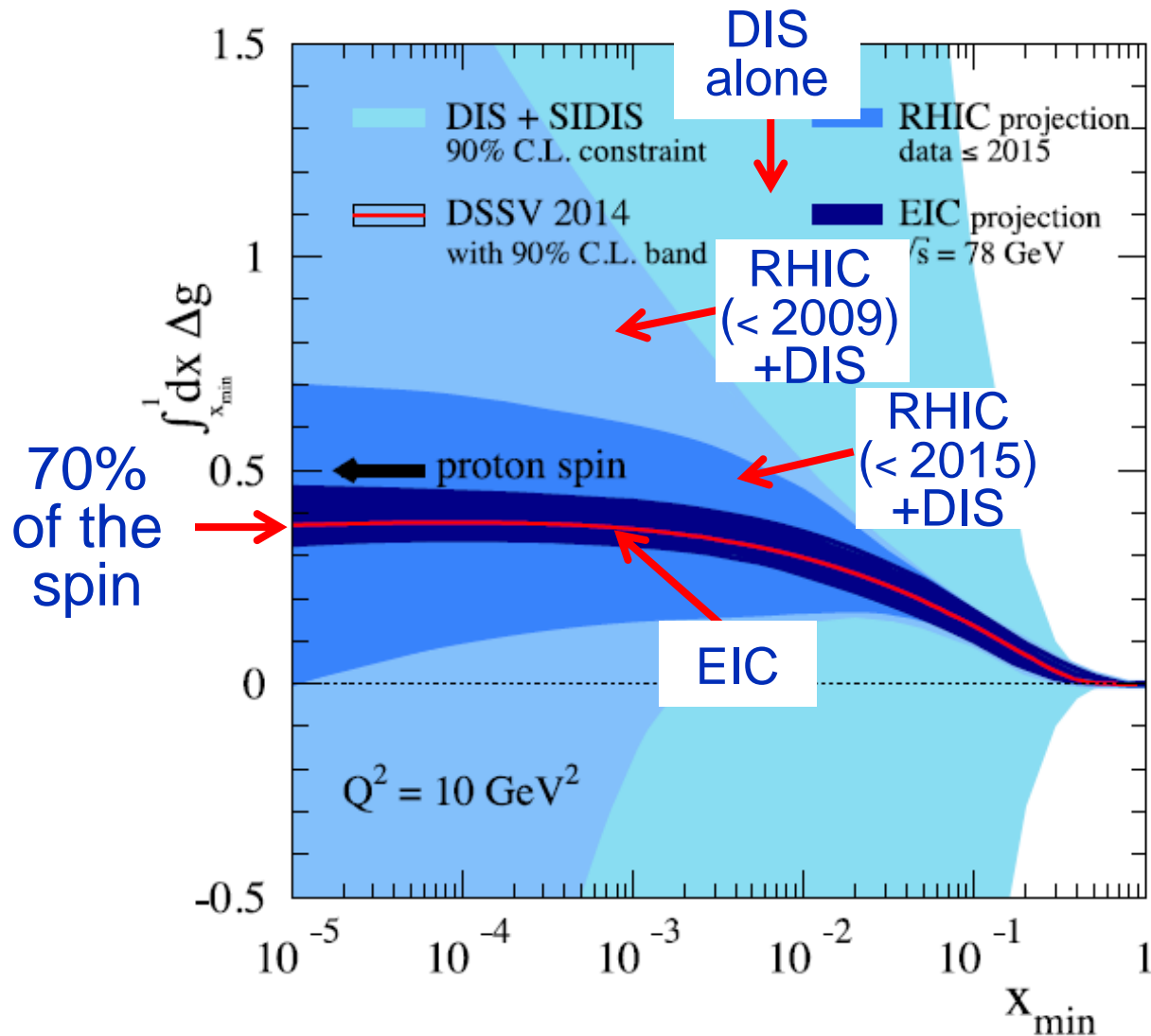
$$\begin{array}{c}
 \begin{array}{ccc}
 \begin{array}{c} \uparrow \\ \textcircled{p} \end{array} + \begin{array}{c} \uparrow \\ \textcircled{p} \end{array} & \text{vs.} & \begin{array}{c} \uparrow \\ \textcircled{p} \end{array} + \begin{array}{c} \downarrow \\ \textcircled{p} \end{array} \\
 p \uparrow + p & & p \uparrow + p \\
 p \uparrow + p \text{ or } p \uparrow + A
 \end{array}
 \end{array}$$

One of the objectives is the precise measurement of Transverse Momentum Dependence (TMD)

- This is related to the orbital contribution to the nucleon spin,  $A_N$ .
- Already, the PHENIX group has reported  $A_N \sim 0$  from direct  $\gamma$ .
- 50 times of statistics are expected at sPHENIX.



# Proton Spin from Gluons



DIS = Deep Inelastic Scattering

< 2009  
= p + p at 200 GeV

< 2015  
= p + p at 200 + 510 GeV

Taken from <https://arxiv.org/pdf/1602.03922>

Issues at EIC

In addition, the contribution from  $q$  and  $\bar{q}$  is  $\sim 30\%$ .

Is 70% from gluon correct? Or, other contributions?