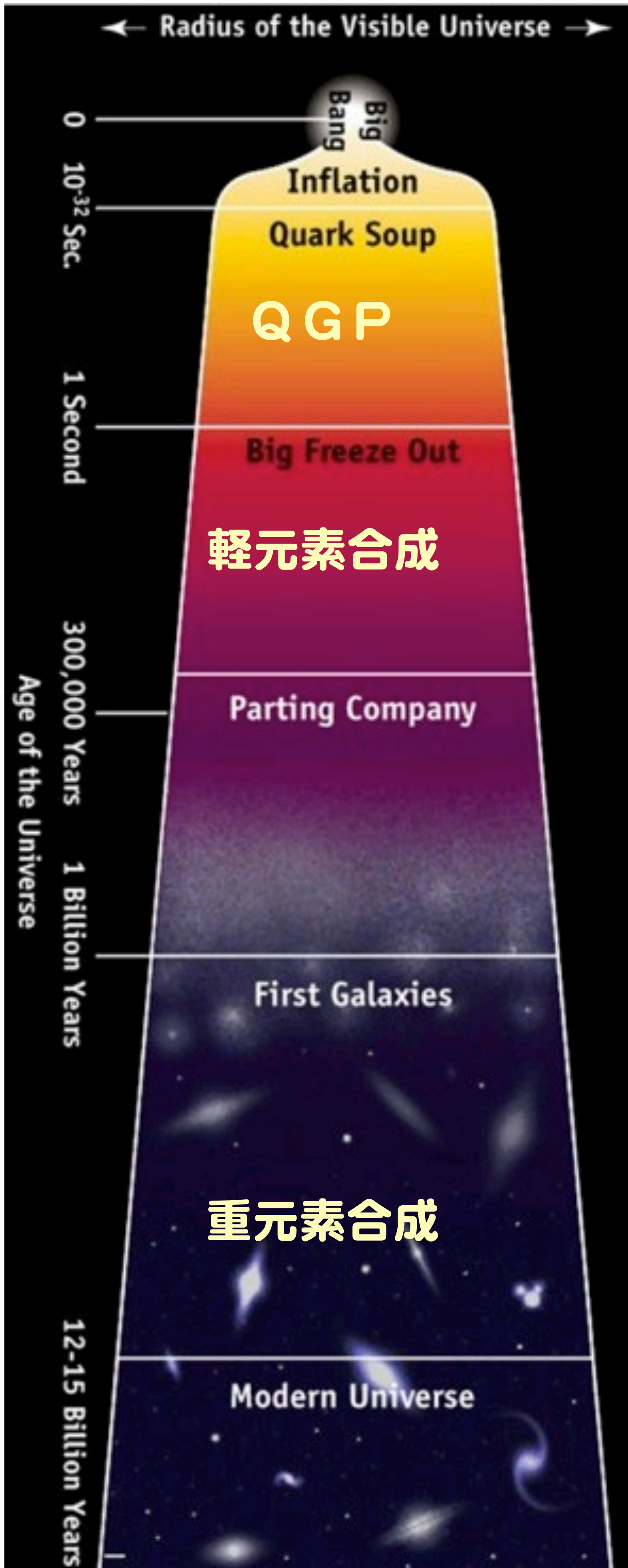


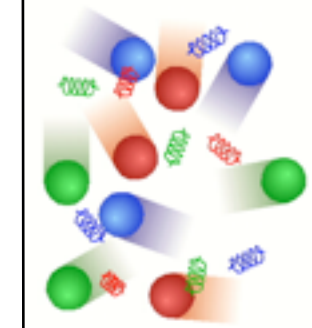

Nuclear Physics at Univ. of Tsukuba

- Two Major Activities;
  - Nucleosynthesis at Tandem & RIBF
  - Quark Gluon Plasma at RHIC & LHC

Yasuo MIAKE, Univ. of Tsukuba
三明康郎、筑波大学



Nuclear Physics and History of Universe

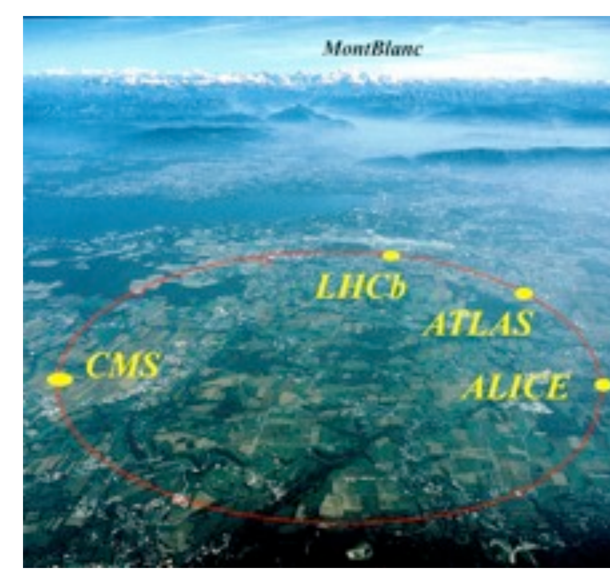


- ✦Quark-Gluon Plasma in early universe
- ✦Nucleosynthesis right after the big bang or in a super nova

✓Important to have common view point in research/education

✓Main facilities we use are,

- ✦Tandem van de graaf at Tsukuba,
- ✦RIBF at Riken,
- ✦RHIC at BNL,
- ✦LHC at CERN

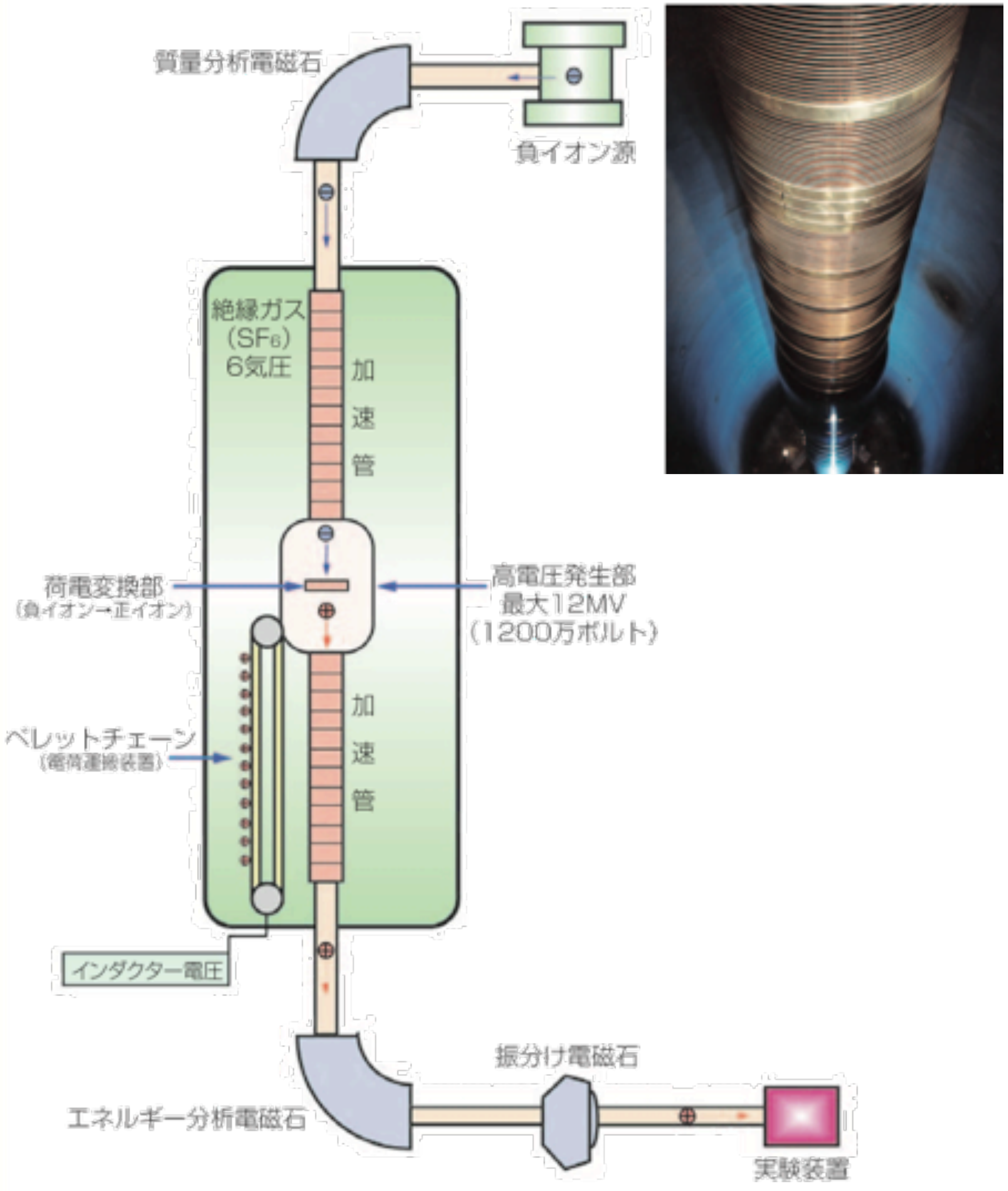


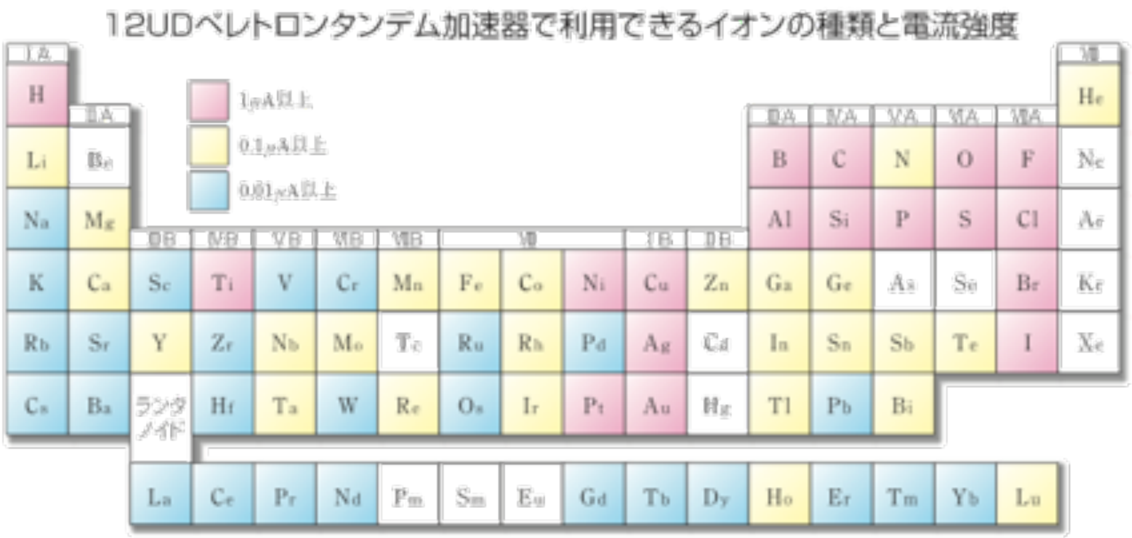
Members @ Tsukuba

	Low Energy Group (nucleosynthesis)	High Energy Group (QGP)
Staff	Akira Ozawa 小沢顕	Yasuo Miake 三明康郎
	Ichiro Arai 新井一郎	Shinichi Esumi 江角晋一
	Tetsuo Komatsubara 小松原哲郎	Tatsuya Chujo 中條達也
	Kimikazu Sasa 笹公和	
RA/PD	Hiroshi Suzuki 鈴木宏	Maya Shimomura 下村真弥
	Daisuke Nagae 長江大輔	Takuma Horaguchi 洞口拓磨
G.S.	10	14

Tandem van de Graaf (12MV)

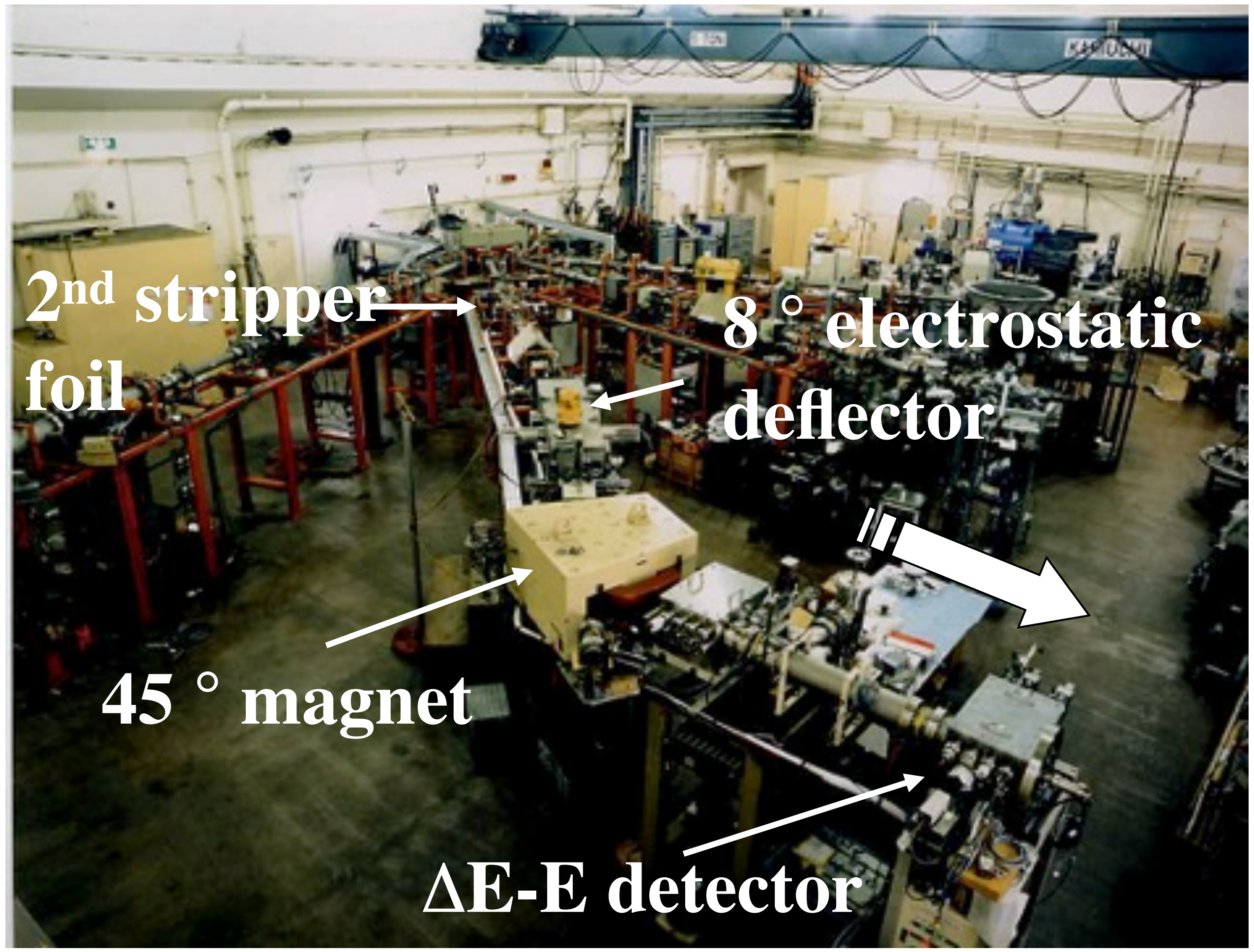
筑波大応用加速器部門





- ✓ **Nuclear physics**
  - Magnetic moment ^{20}F, ^{40}Sc, $^{25}\mathrm{Al}(\mathrm{p},\gamma)^{26}\mathrm{Si}$
- ✓ **Test beam facility**
  - Detector R&D
- ✓ **Analysis Tools**
  - Elementary analysis
    - ➡ Accelerator Mass Spectr.
  - Hydrogen analysis
    - ➡ Elastic Recoil Coinc. Spectr.
    - ➡ Proton Induced Xray Emission

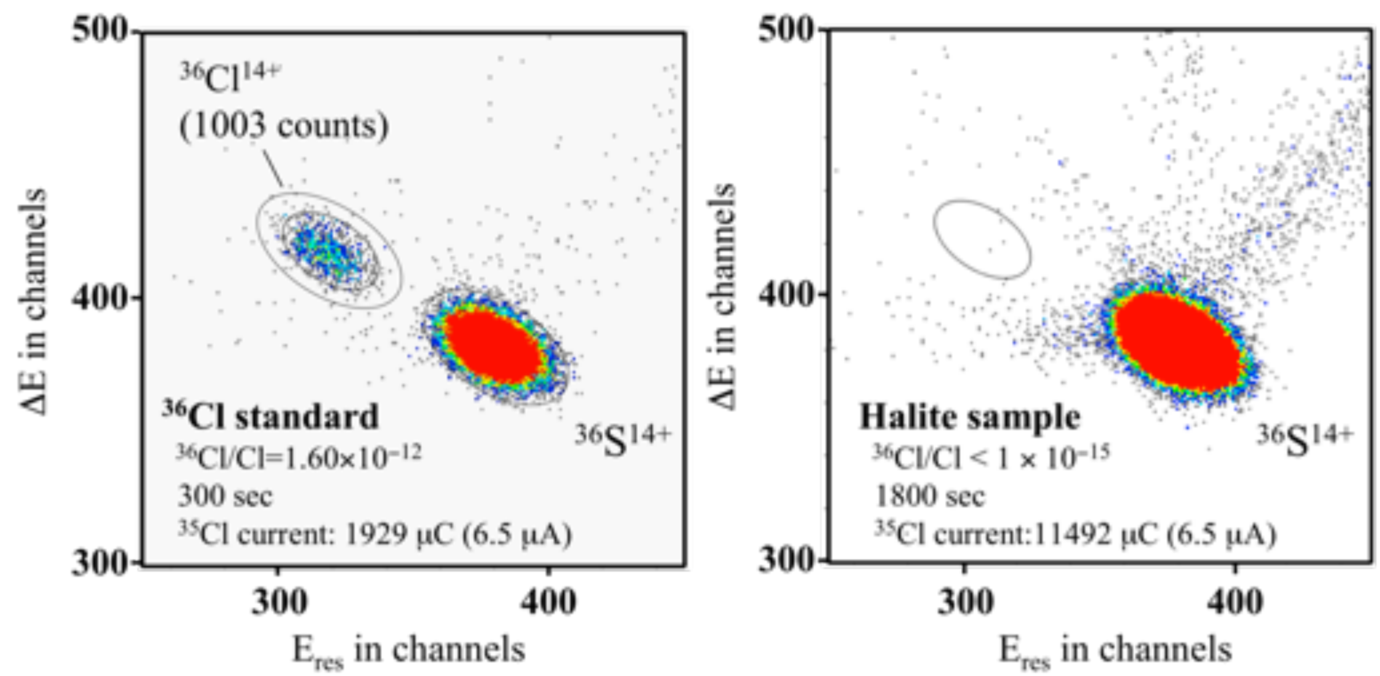
Accelerator Mass Spectrometer using Tandem VDG



Gas ΔE- SSD E detector

K. Sasa

Iso-butane
gas flow ~670 Pa



宇宙線生成核種 ^{36}Clの測定スペクトル

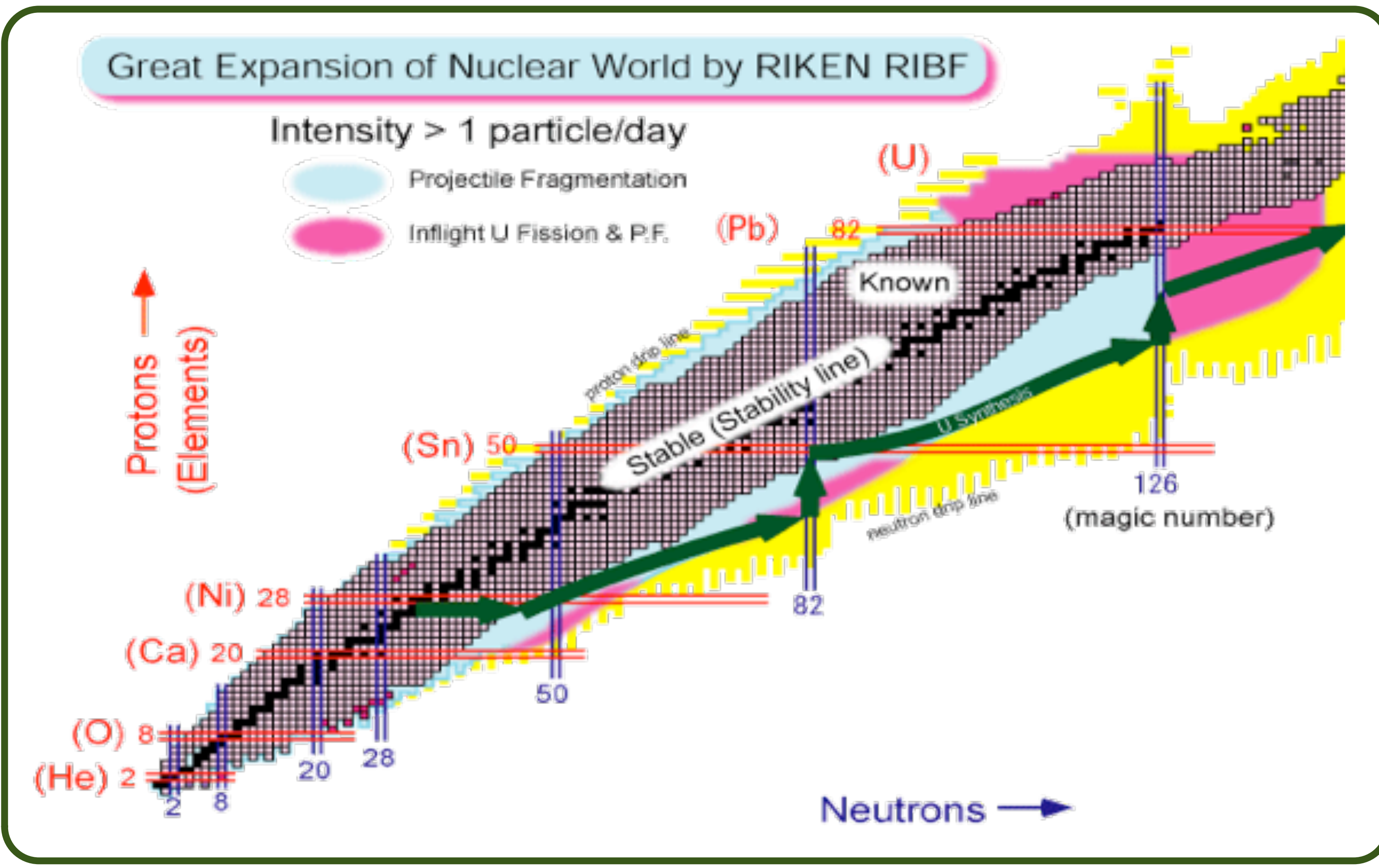
同位体比　^{36}Cl/Cl~10^{-16}の測定

✓ Nuclei by cosmic ray induced reaction

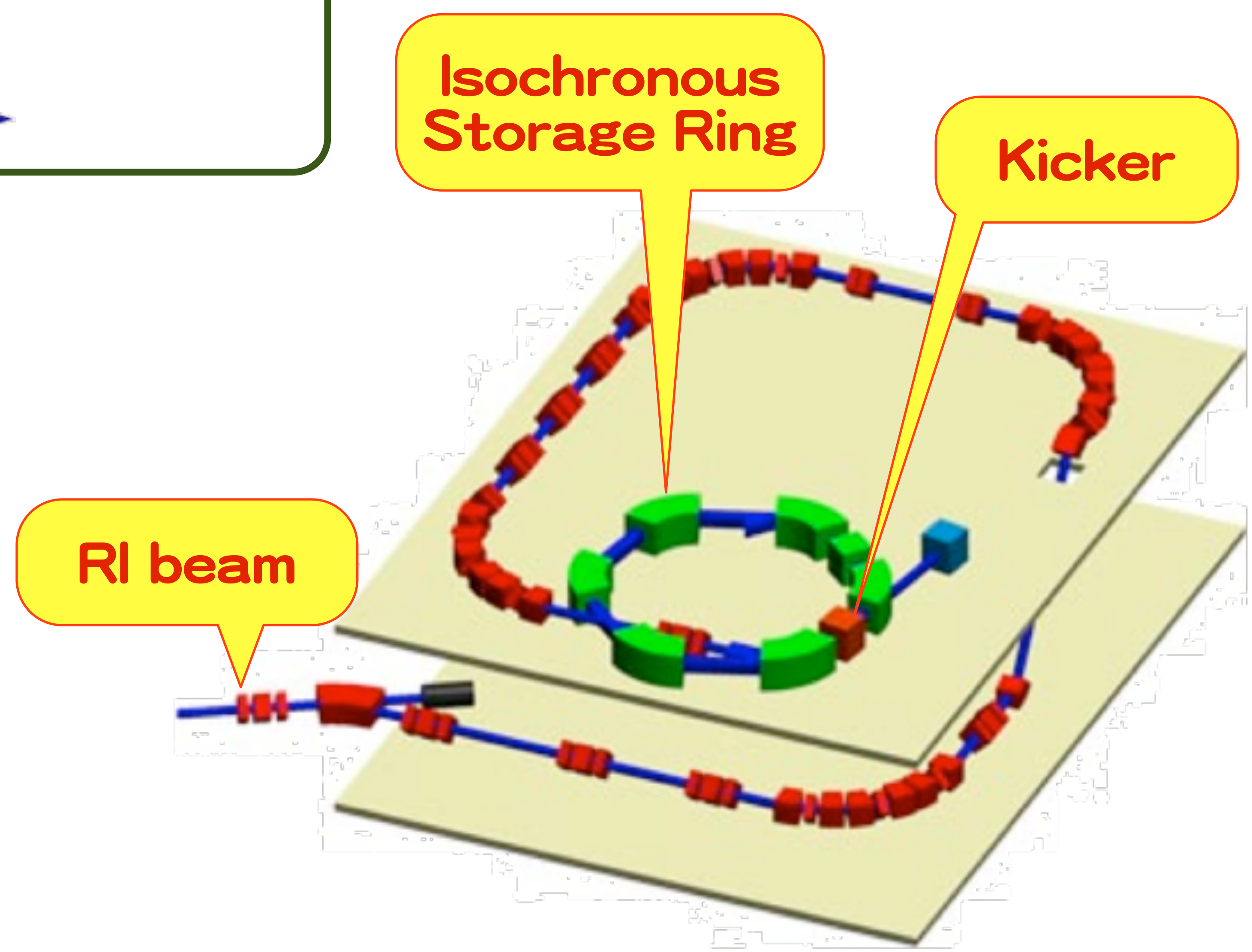
- ^{14}C ($T_{1/2}$= 5,730 yr), ^{26}Al (701 kyr), ^{32}Si (140 yr),
- ^{36}Cl (301 kyr), ^{41}Ca (103 kyr), ^{129}I (15.7 Myr), ...

Rare RI Ring Project

Akira OZAWA

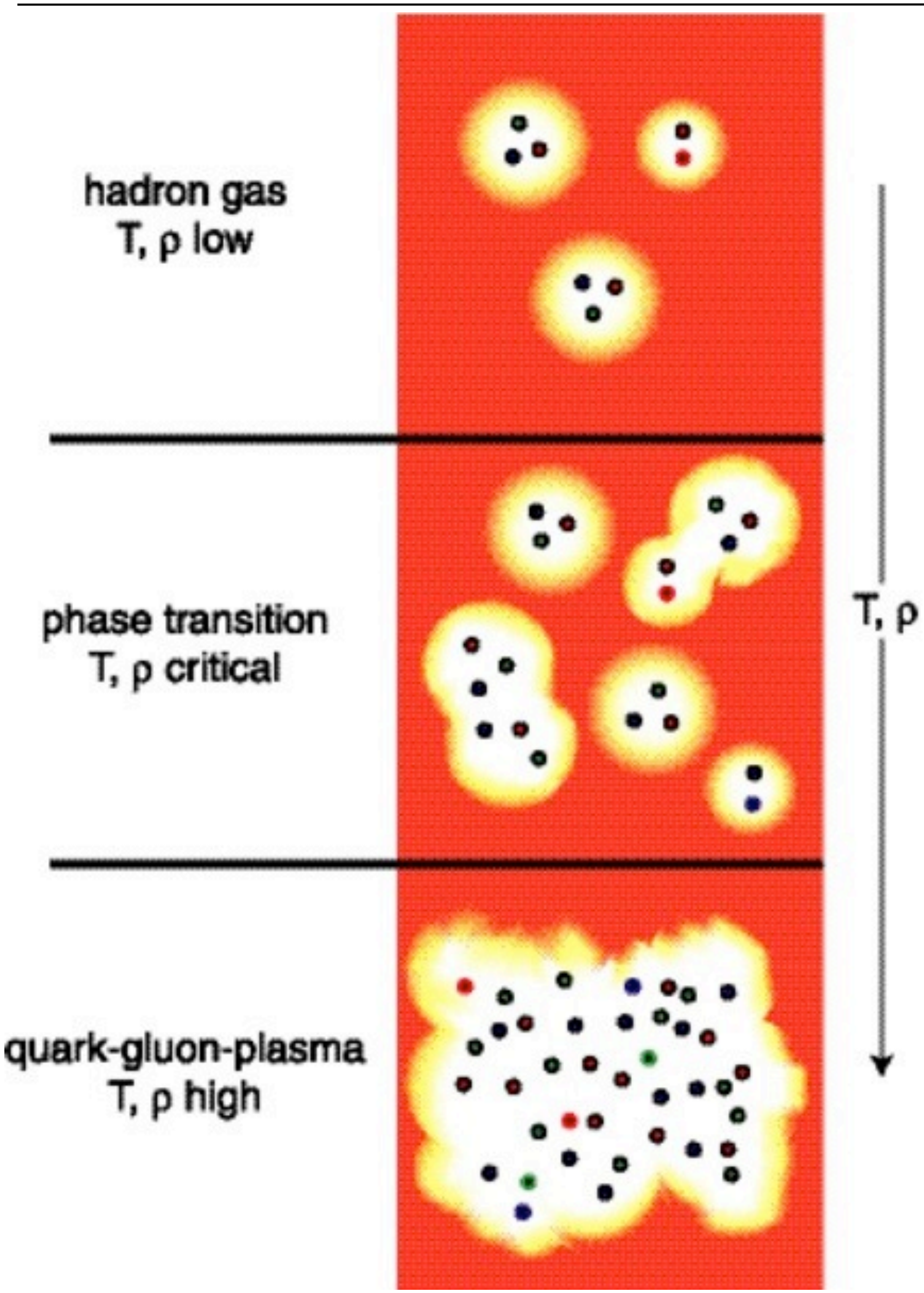


- ✓ Precision measurement of mass of rare isotope using isochronous storage ring
- ✓ Study of Rapid process of Nucleosynthesis
  - Design works, simulations and detector R&D in progress



Yasuo MIAKE, October, 2010, ISNPA

Quark-Gluon Plasma



RHIC(200GeV)
since 2000

LHC(5.6TeV)
soon

- ✓ **Physics of QCD in extreme T, ρ and small x**
- ✓ **Nucleus-Nucleus collisions**

What we learned at RHIC

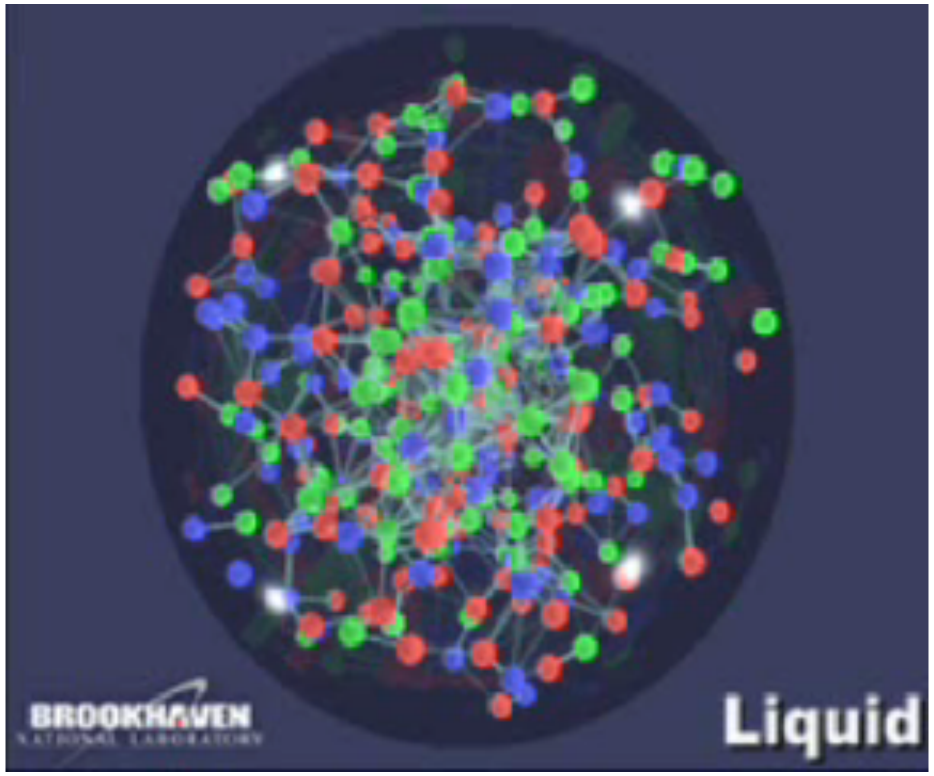
$$\epsilon_{\text{QGP}} \sim 2 \ [\text{GeV}/\text{fm}^3]$$

$$< n_{q,\bar{q}} > \sim \frac{\epsilon_{\text{QGP}}}{< m_T >} \sim \frac{2\text{GeV}}{0.4\text{GeV}} \sim 5$$

$$\lambda_q = \frac{1}{n\sigma_{qq}}$$

$$\sim \frac{1}{5 \times 0.4} = 0.5 \ [\text{fm}]$$

$$\lambda_q \ll R_{\text{system}}$$



- Strongly interacting QGP
- Statistical nature & space/time evolution of collisions well established
  - ➡Hadro-chemical equilibrium (T, μ)
  - ➡Kinematical equilibrium (T, β)
  - ➡Universal pt&azimuthal distributions of quarks (Quark coalescence model)

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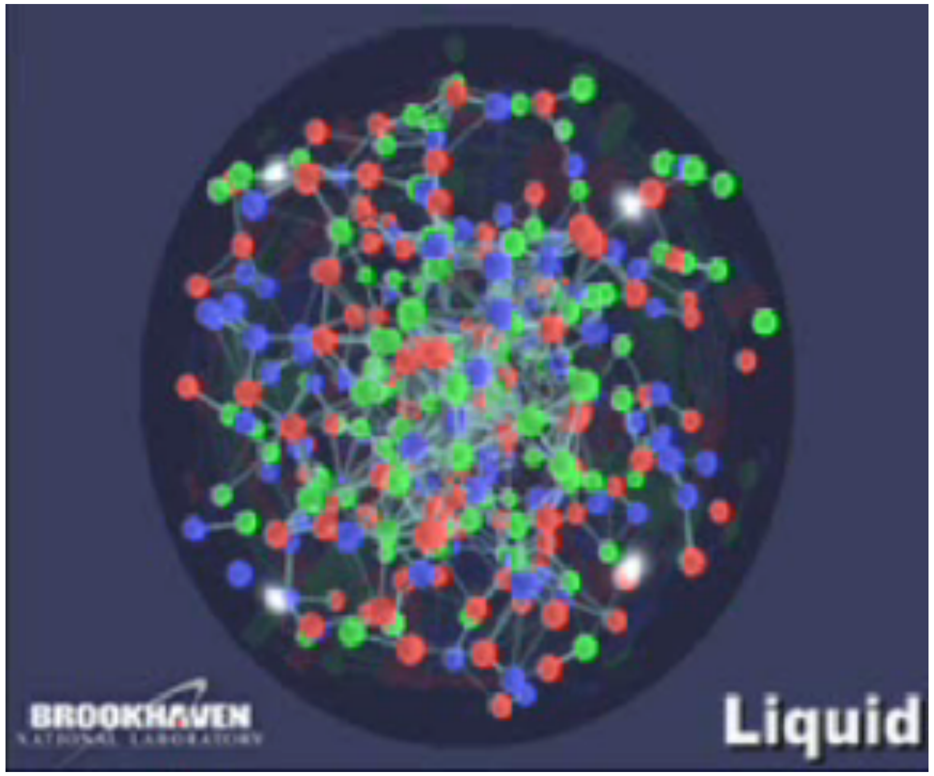

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Soft physics well understood (I think)

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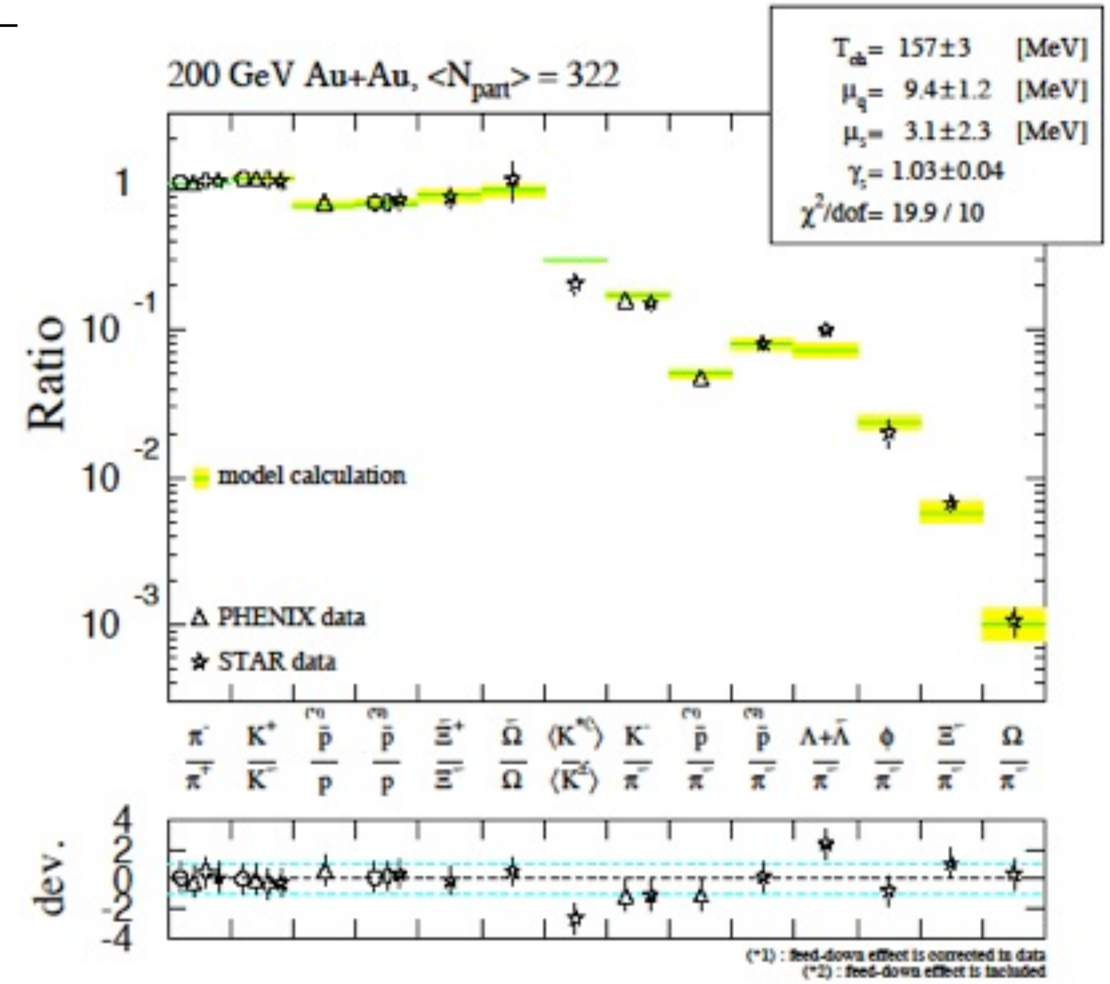

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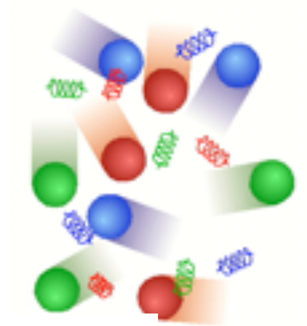

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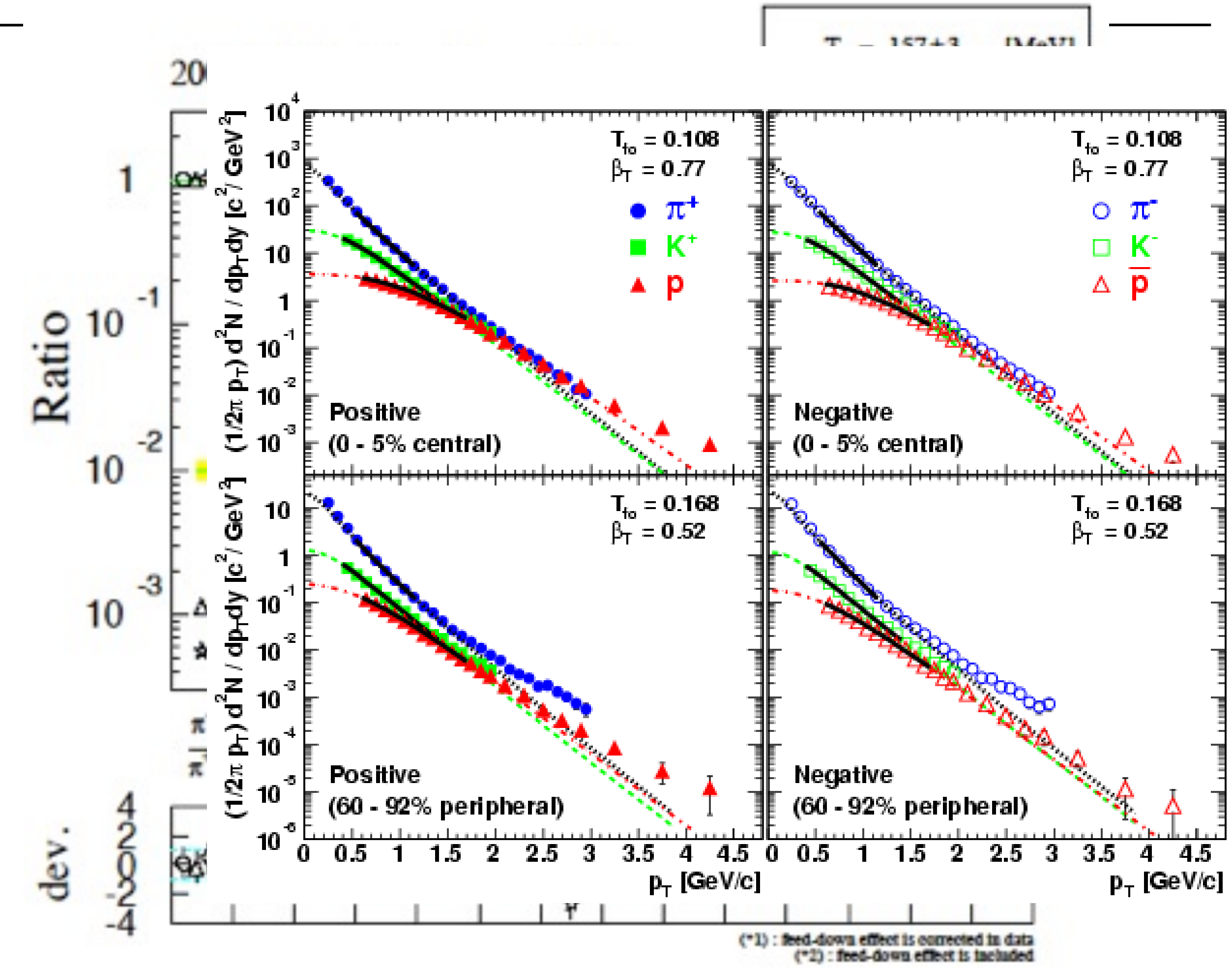

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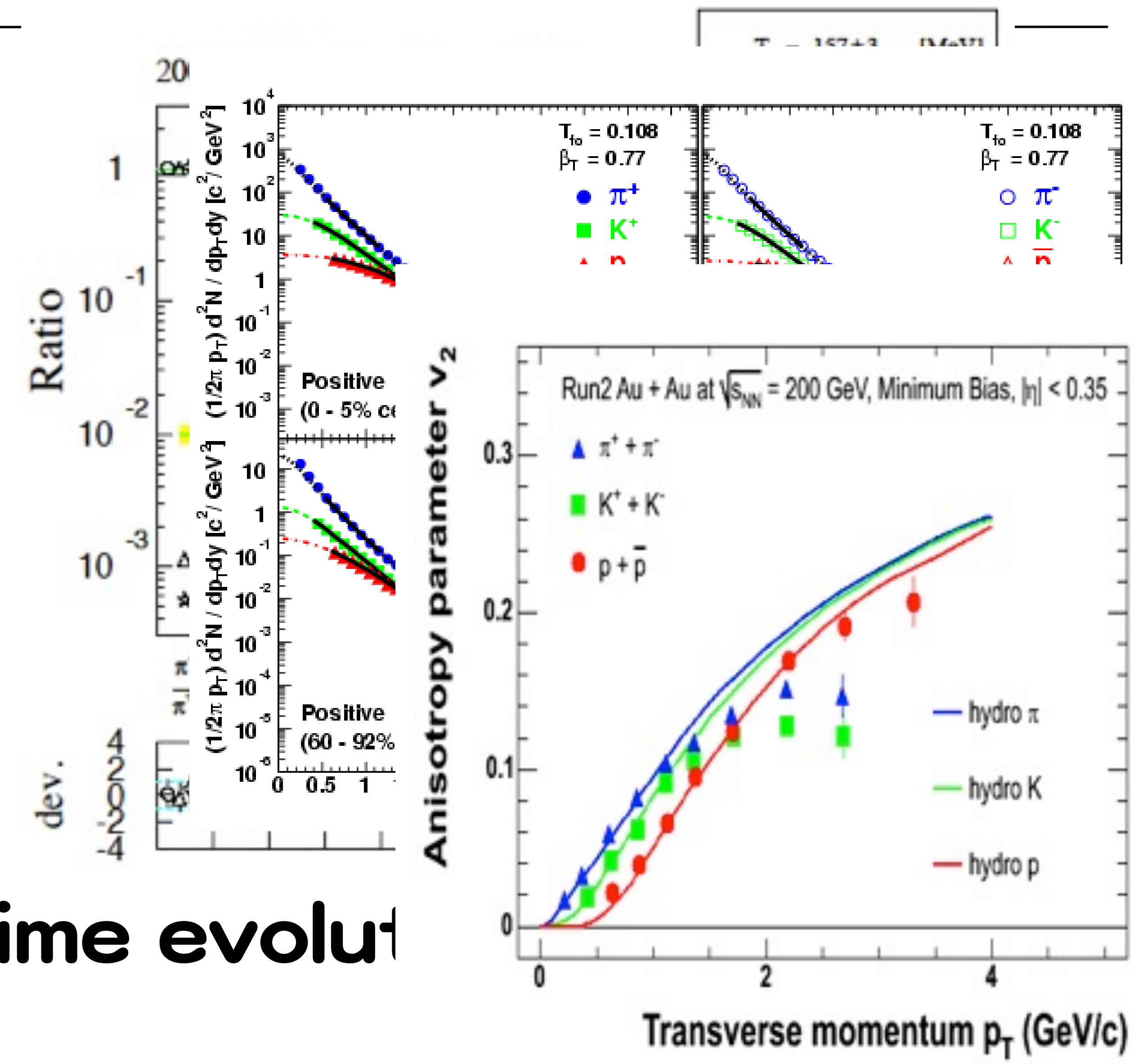

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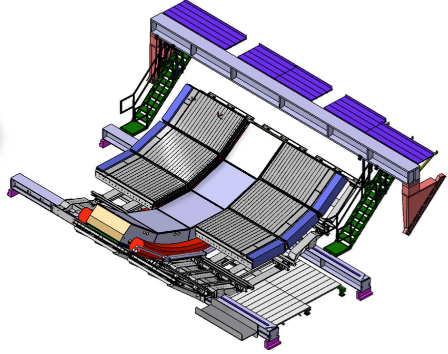
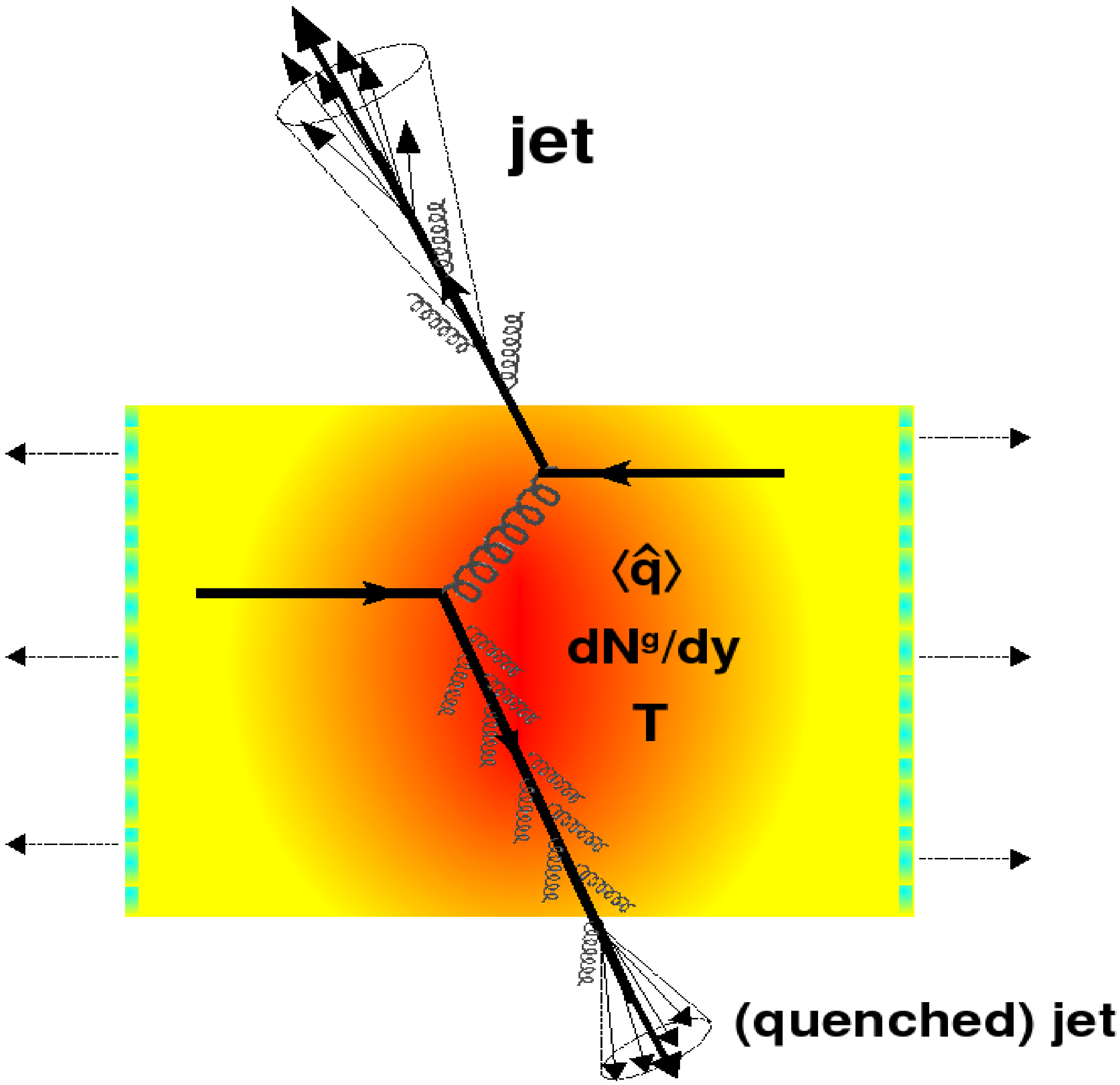
Big surprise! “Jet Quench”

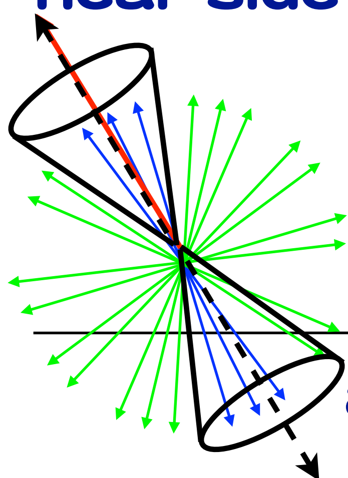


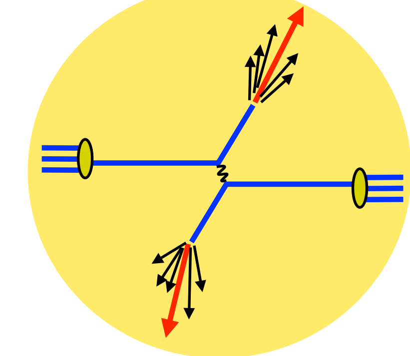


“Jet quenching” in nucleus-nucleus collision.

- ✓ Two quarks suffer a hard scattering in AA collision
  - One goes out to vacuum creating jet,
  - but the other goes through the QGP suffering energy loss due to gluon
- ✓ Manifestation:
  - attenuation/ disappearance of jet
  - suppression of high pt hadrons
  - modification of jet frag.

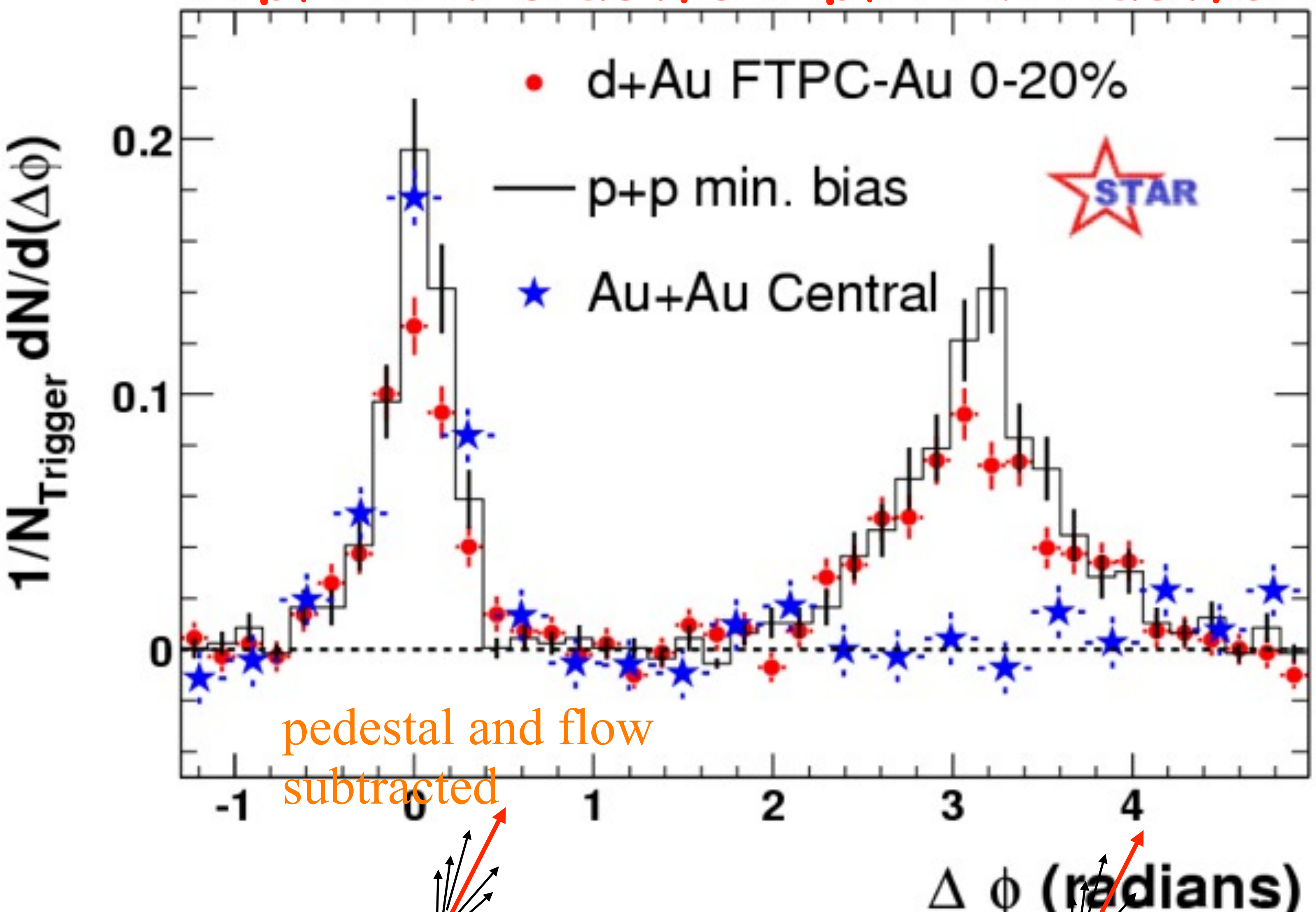
Modification of back-to-back corr.

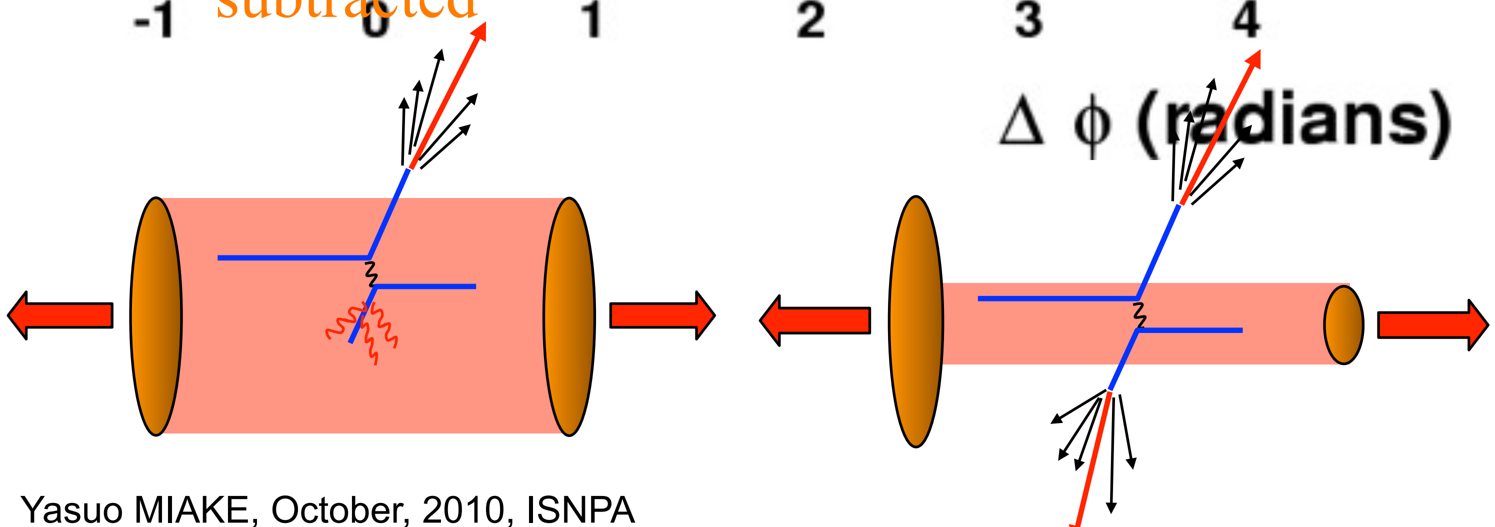




Star; P.R.L. 91, 72304 (2003)

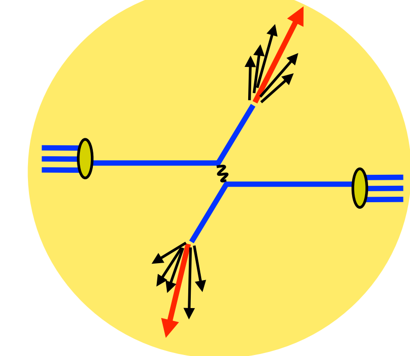
p_T^{trig} = 4~6 GeV/c × p_T^{assoc} > 2 GeV/c





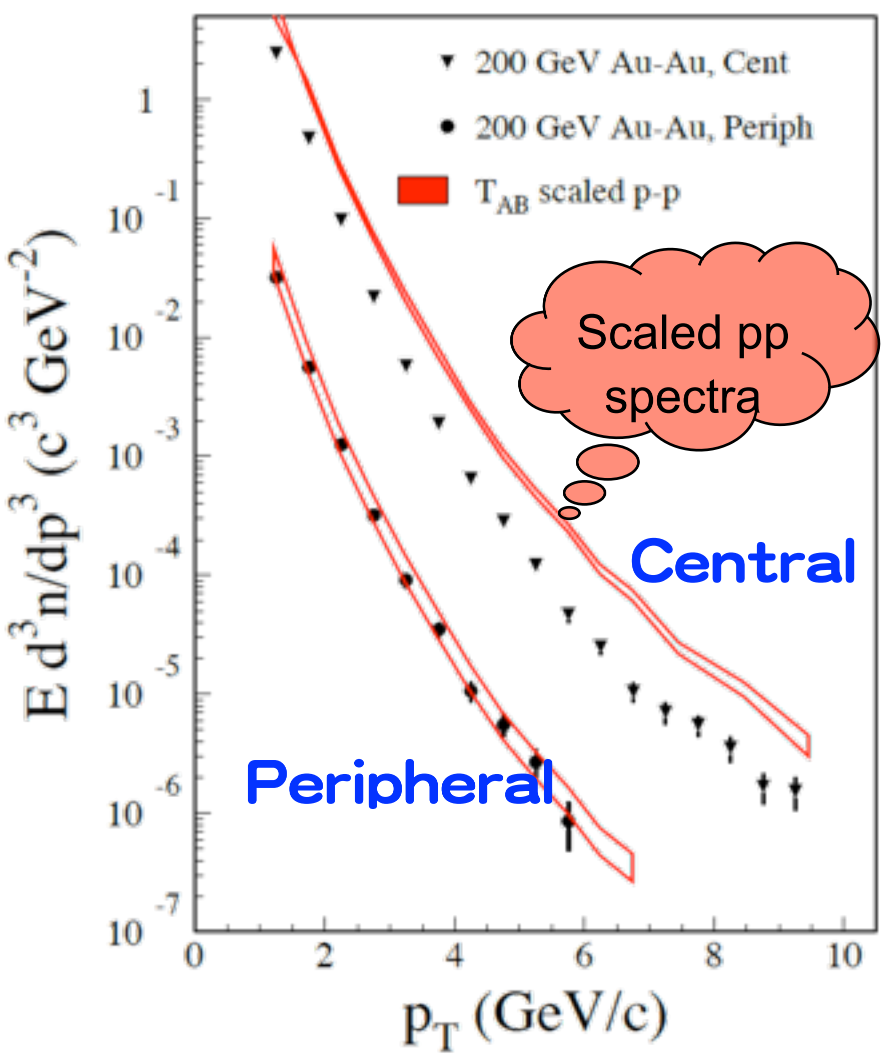
- ✓Direct evidence of loss of 'jet'
- ✓Azimuthal correlation w.r.t. high pt leading particle (trigger).
  - pp ; clean di-jet
  - dAu; similar to pp
  - Au+Au; Similar on the same side (suggesting jet-like mechanism), but b-to-b disappeared
    - Effect is not in initial but in final stage
    - Energy loss of partons in dense matter created in Au+Au

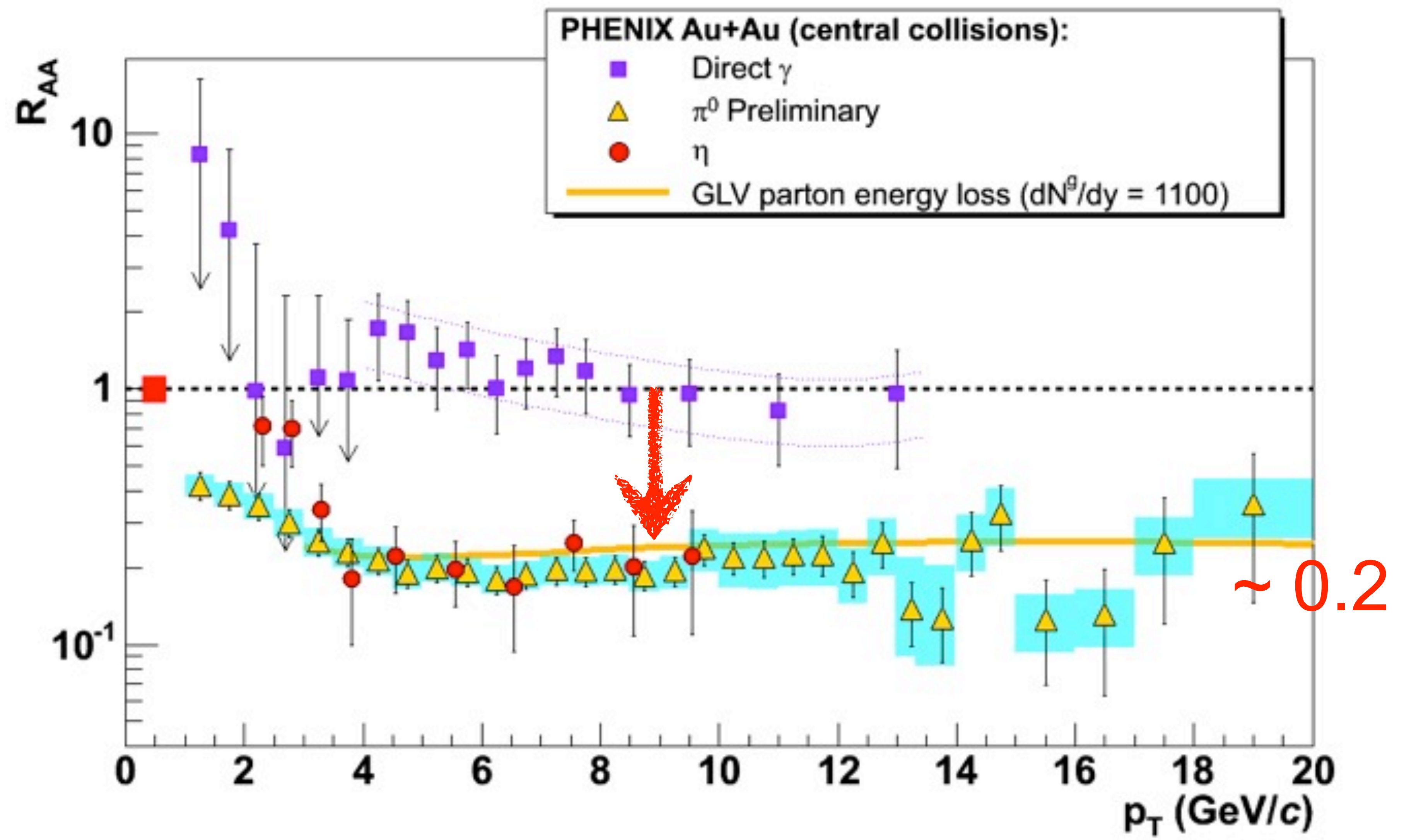
Suppression of high p_t particles



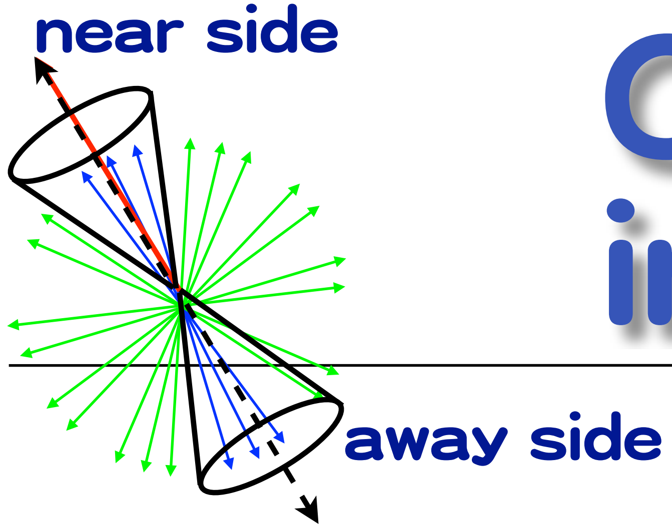
Nuclear Modification Factor

$$R_{AA} = \frac{\text{"hot/dense QCDmedium"}}{\text{"QCD vacuum"}} = \frac{dn_{AA}/dp_T dy}{\langle N_{binary} \rangle \cdot dn_{pp}/dp_T dy}$$

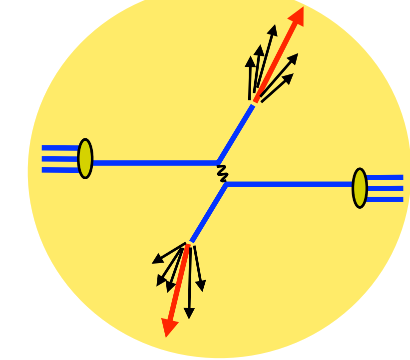




✓ **Pions are suppressed, direct photons are not**

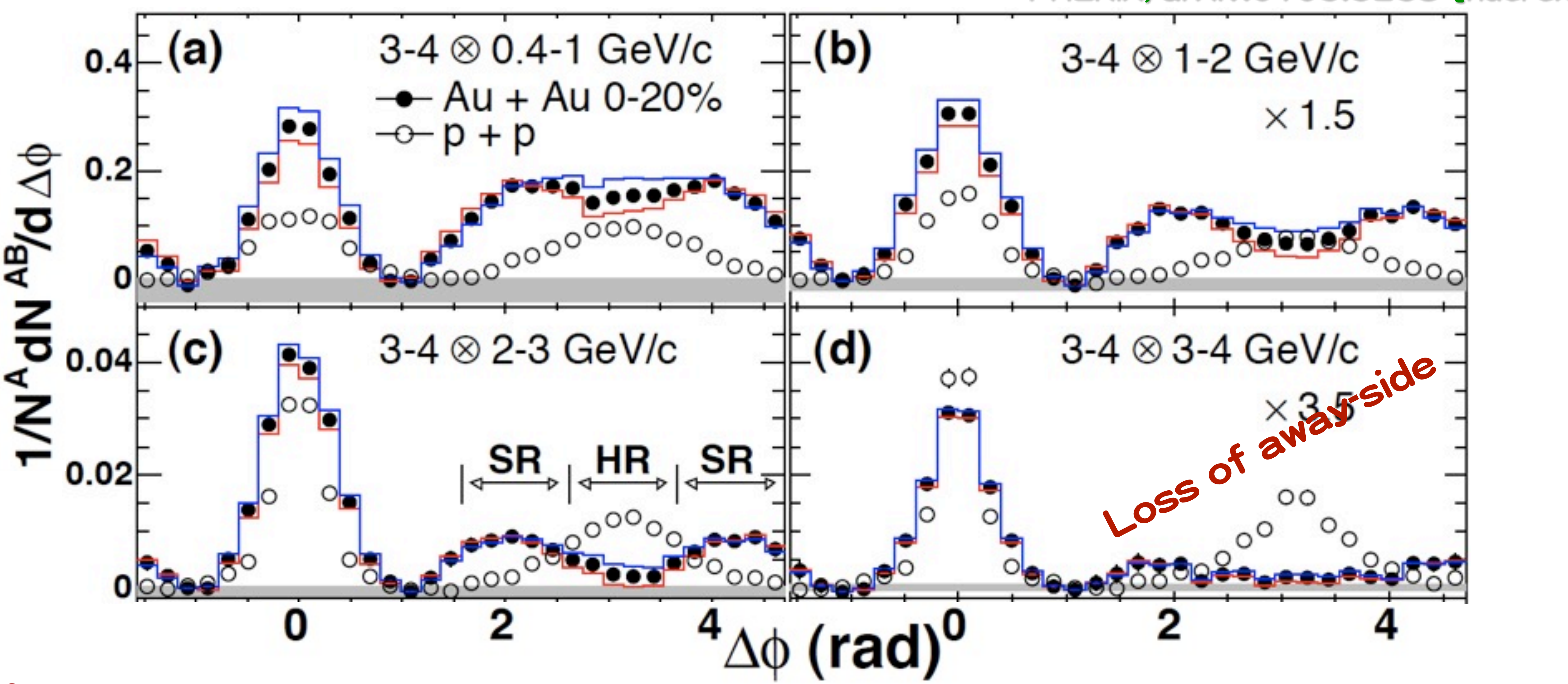


Change of shape in the away-side



p_T^{trig} = 3~4 GeV/c × p_T^{assoc}

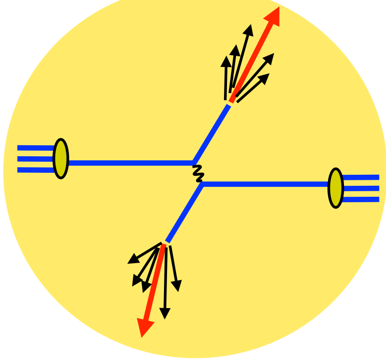
PHENIX, arXiv:0705.3238 [nucl-ex]



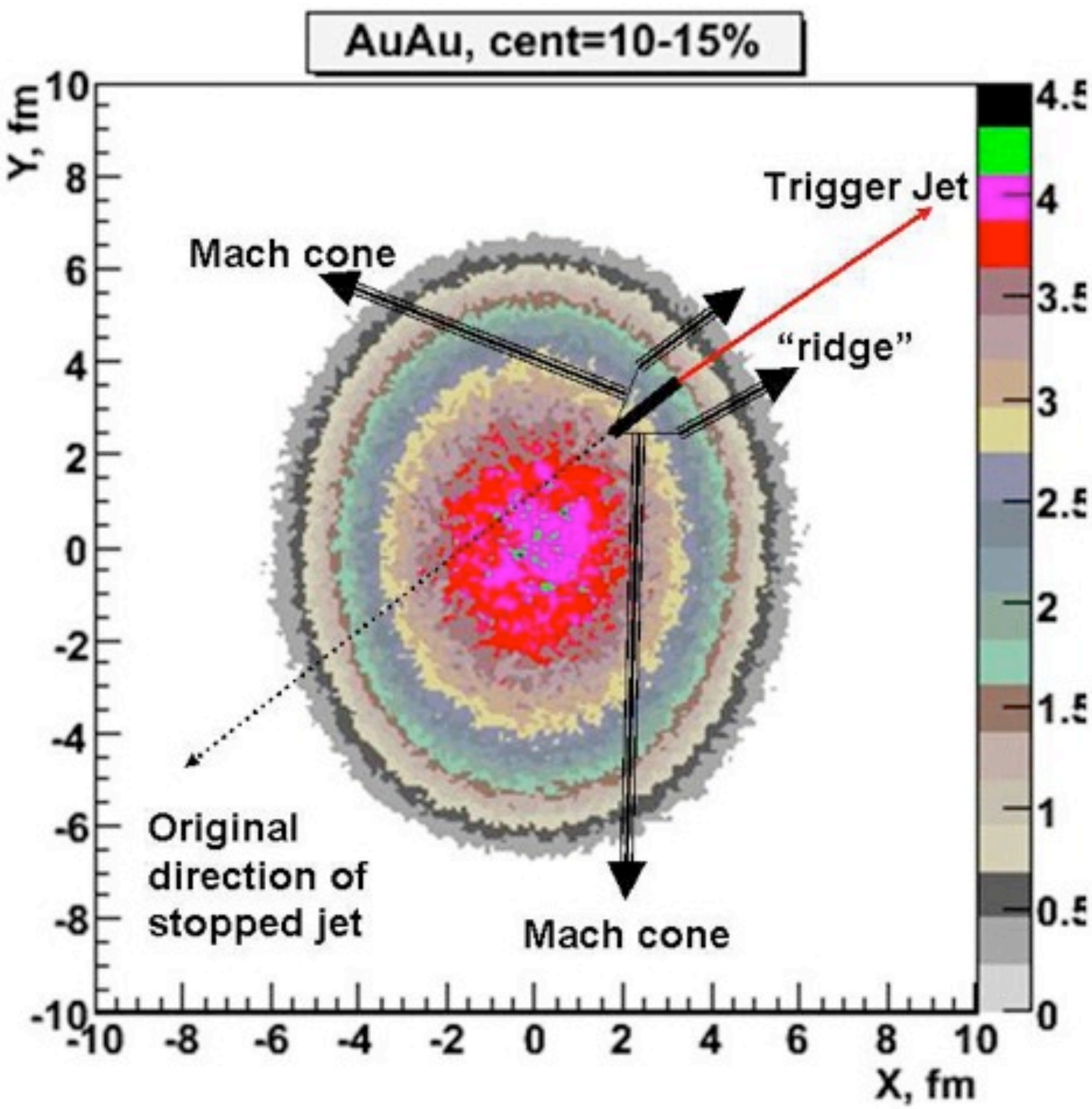
✓From broad/none to distinct two shoulders at $\Delta\Phi = \pi \pm 1$ with decreasing momentum

- Discussed in terms of Mach Cone, Cherenkov Em.

Jet quench as a homework to LHC

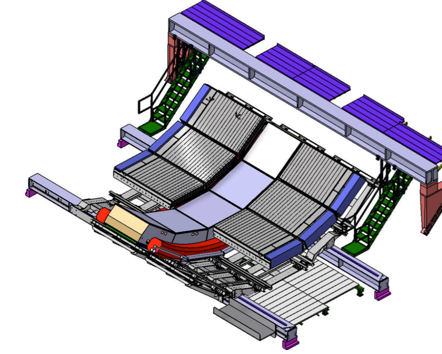


V.S. Pantuev, arXiv:hep-ph/0701.1882v1

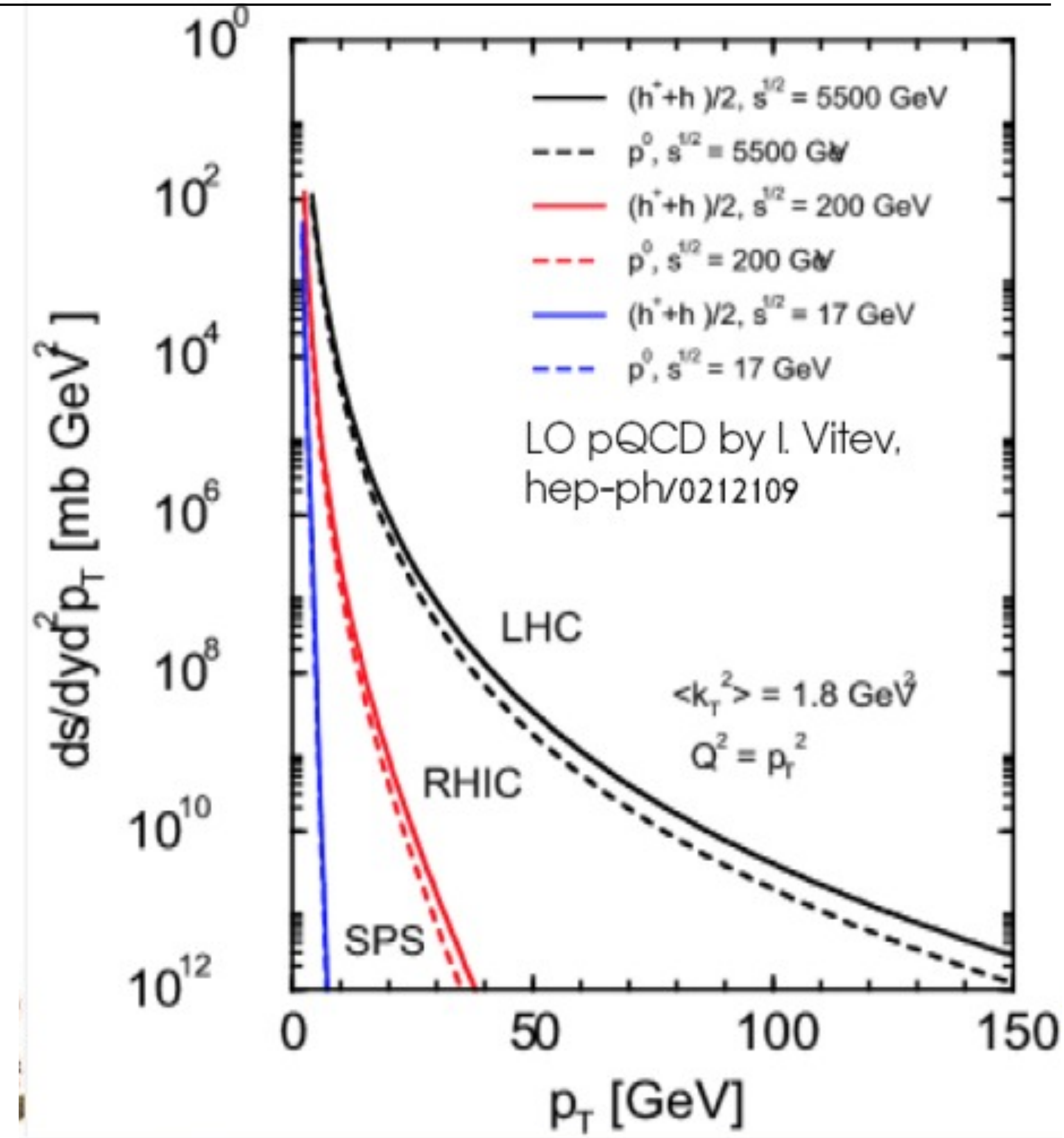


- ✓ Is it indeed a Mach cone?
- ✓ What is "ridge"?
- ✓ Jets at RHIC are too low.
  - Effects are 1-3 GeV regions where many QCD backgrounds
- ✓ Jet Quench as a homework to LHC
  - CMS@LHC claims ridge structure in high mult. pp.

RHIC vs LHC



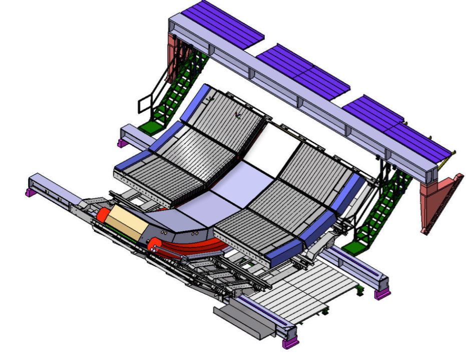
	RHIC	LHC
$\sqrt{s_{NN}}$ (GeV)	200	5500
T/T_c	1.9	3.0-4.2
ε (GeV/fm^3)	5	15-60
τ_{QGP} (fm/c)	2-4	>10



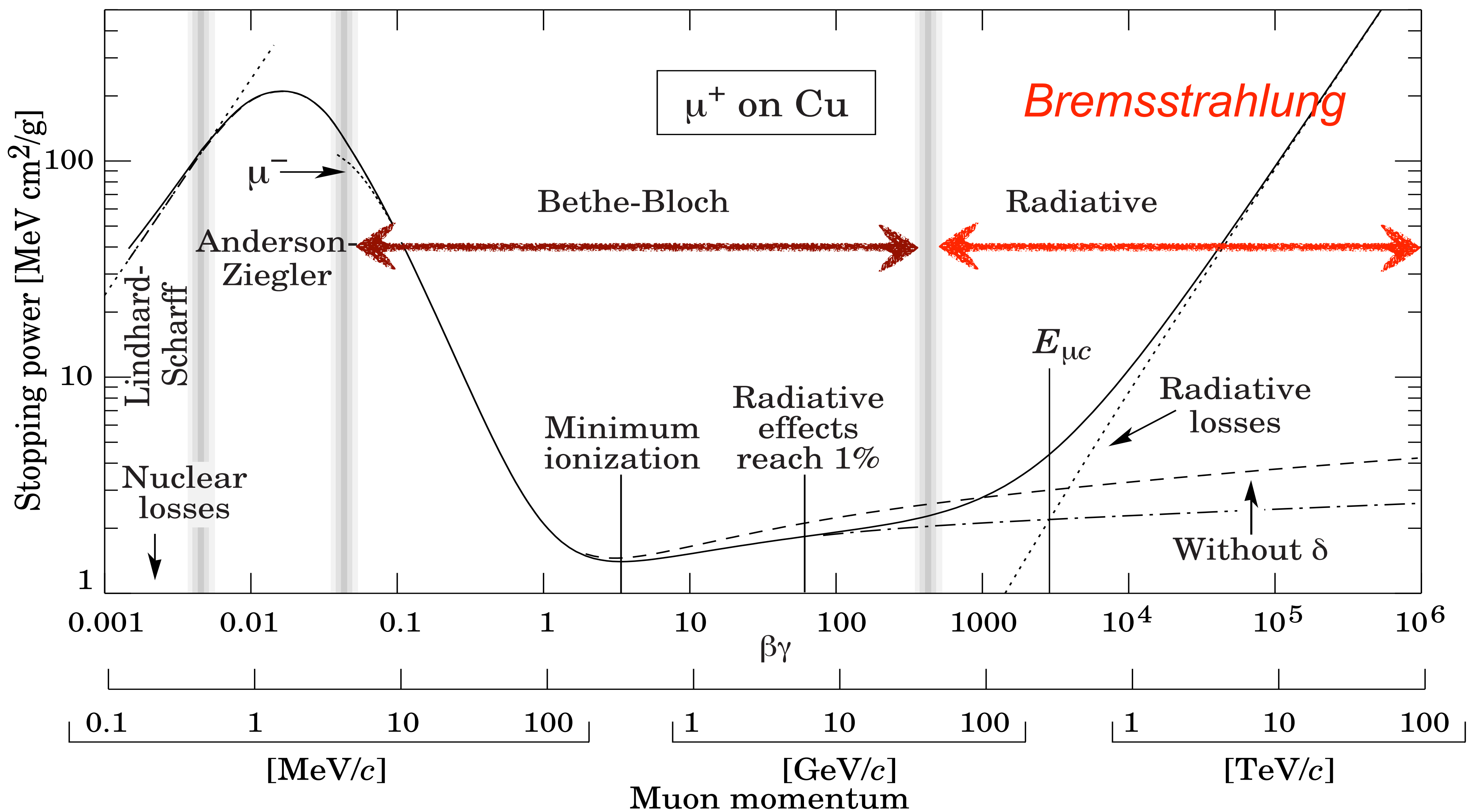
✓ **Home work to the LHC, physics of jet quench**

➡ **LHC has superior advantage in hard probes**

Energy loss in QED



Energy loss of charged particle in a matter



Collisional

- ✓Bethe-Bloch

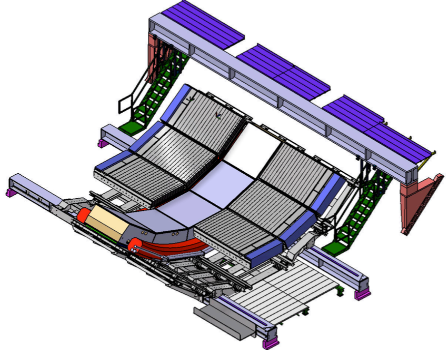
Radiative

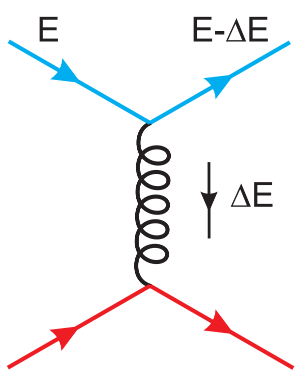
- ✓Bethe-Heitler (thin; $L \ll \lambda$)
- ✓Landau-Pomeranchuk-Migdal (thick; $L \gg \lambda$)

✓Measurements of dE/dx gives prop. of matter

- **Energy loss in QED plasma gives T & m_D info.**

Energy Loss in QCD





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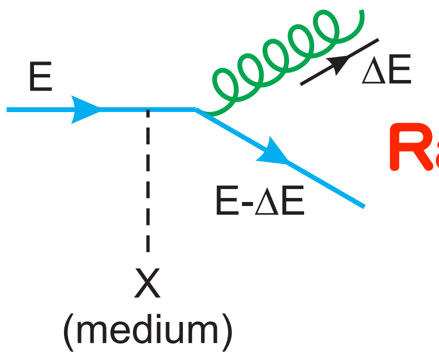
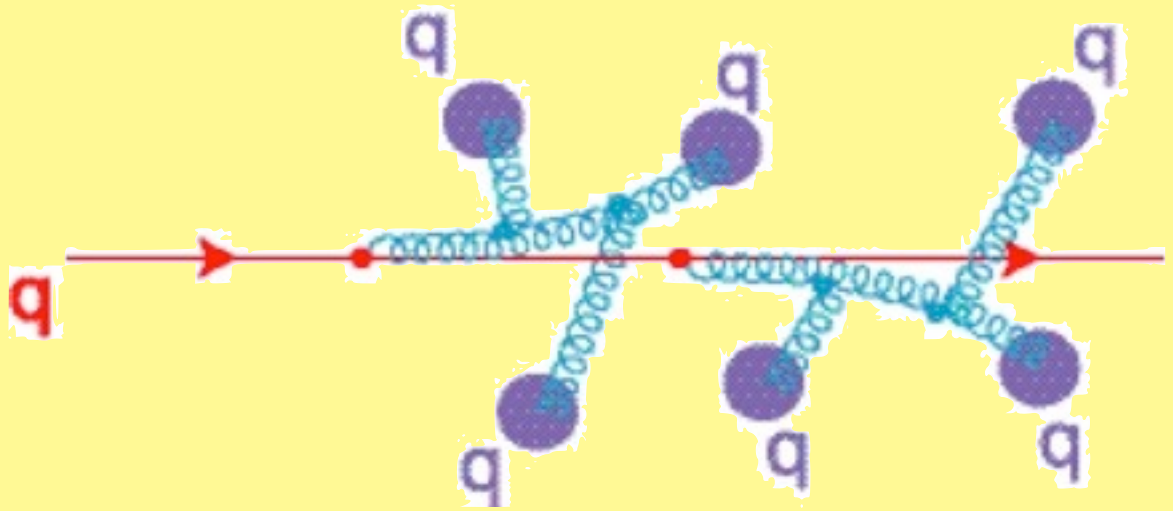


Radiative

- ✓ Many theories on
  - Collisional loss
  - Radiative loss
    - ➡Bethe-Heitler regime
    - ➡LPM regime
    - ➡ "dead-cone" effect



$$\Delta E \propto \alpha_S C_{\mathrm{R}} \langle \hat{q} \rangle L^2$$

(Executive) Summary

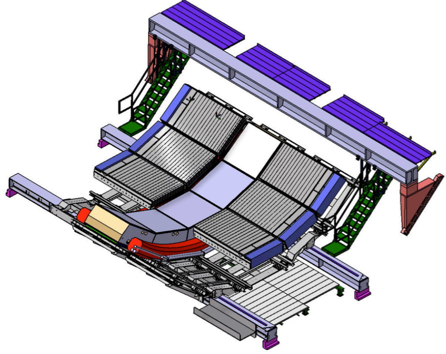
Radiative loss is dominant

Effects are;

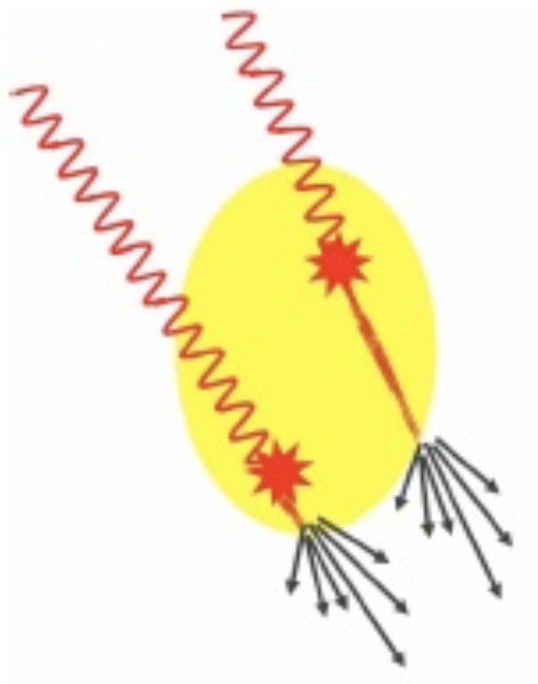
- suppression of high pt hadron
- unbalanced back-to back
- modification of jet fragmentation
  softer, larger multiplicity,
  angular broadening

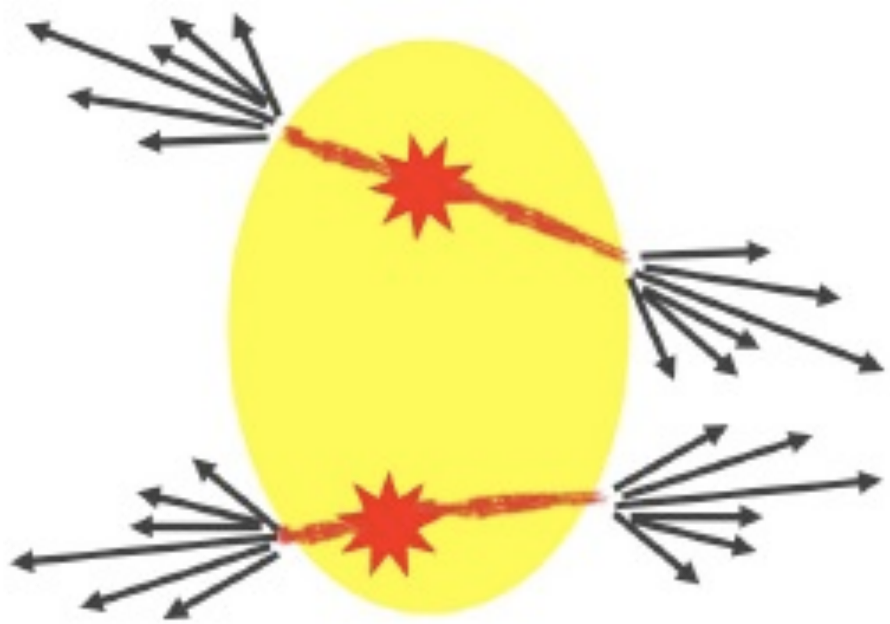
$$\Delta E_{\mathrm{gluon}} > \Delta E_{\mathrm{quark}} > \Delta E_{\mathrm{charm}} > \Delta E_{\mathrm{bottom}}$$

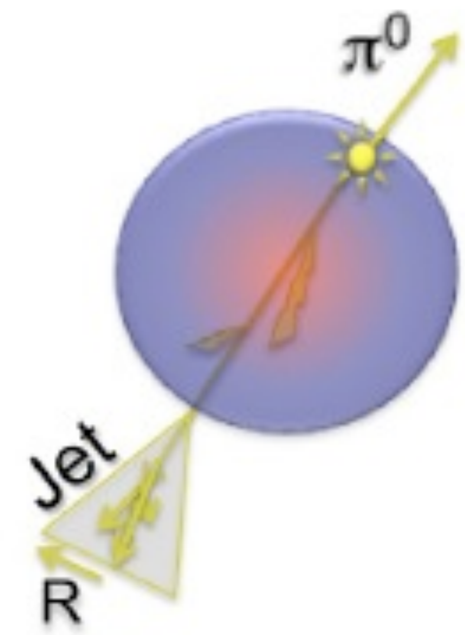
Probes for the study



γ-Jet	Di-jet	π^0-Jet







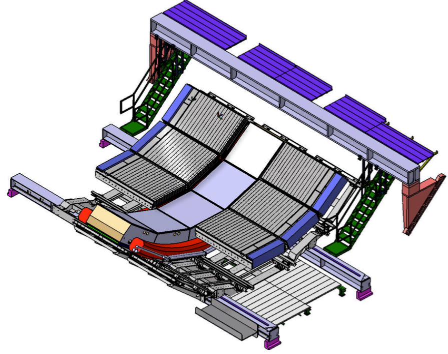
- ✓ **Quark Jet**
- ✓ Small Xsection
- ✓ Experimentally challenging

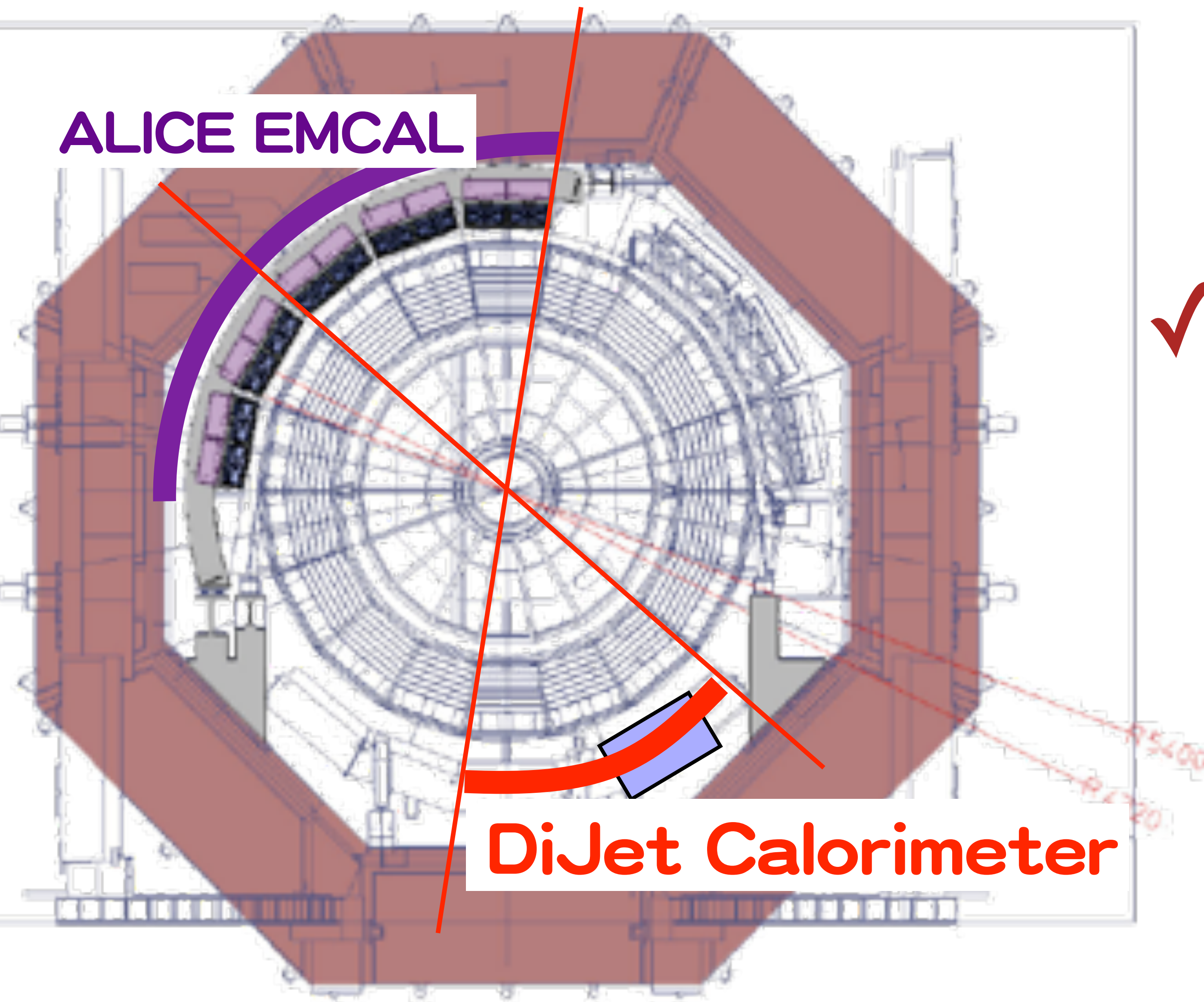
- ✓ Mostly **Gluon Jet**
- ✓ Larger Xsection
- ✓ Interpretation is complicated

- ✓ Clean π^0 trig
- ✓ Large Xsection
- ✓ Important for DCal

Systematic meas. of these processes for model comparison provides at high precision level.

DiJet Calorimeter@ALICE initiated by Tsukuba-Wuhan





✓For better performance of back-to back capability

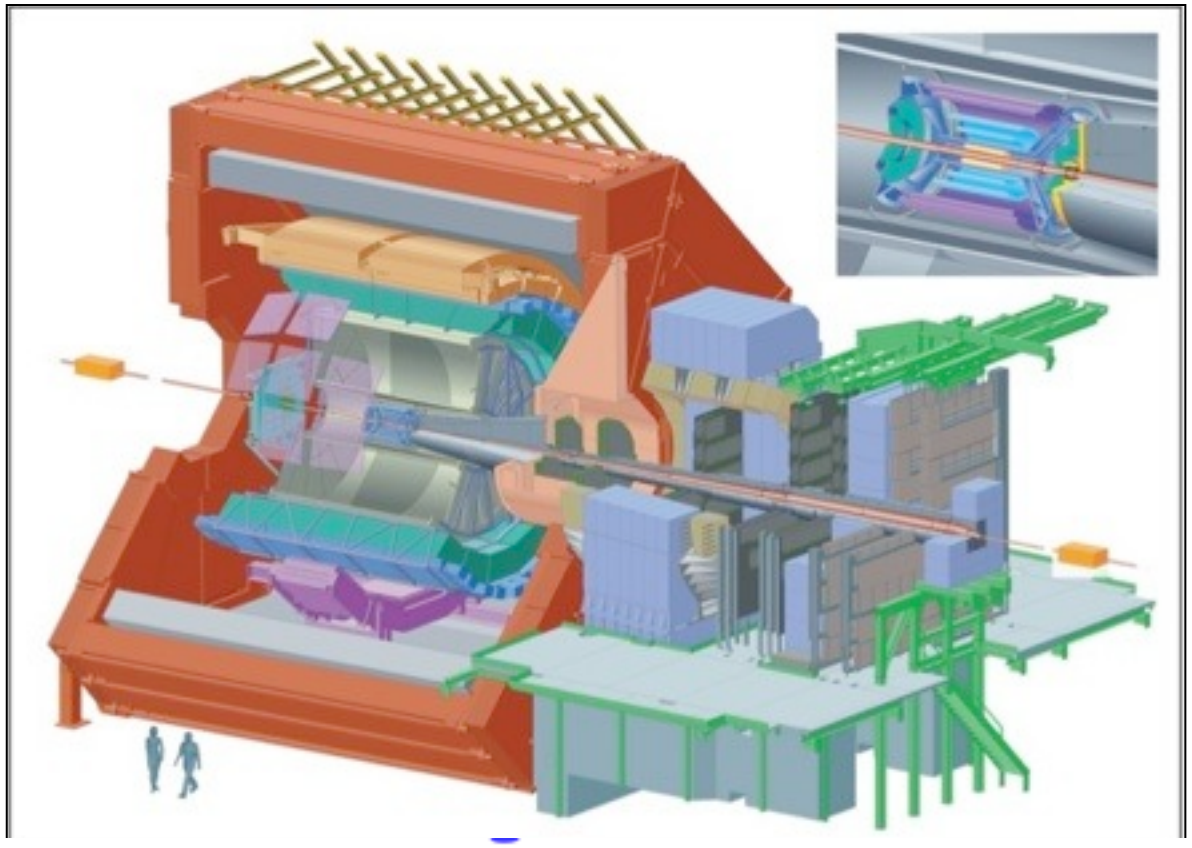
- ➡Define back-to back jets
- ➡Trigger back-to back jets

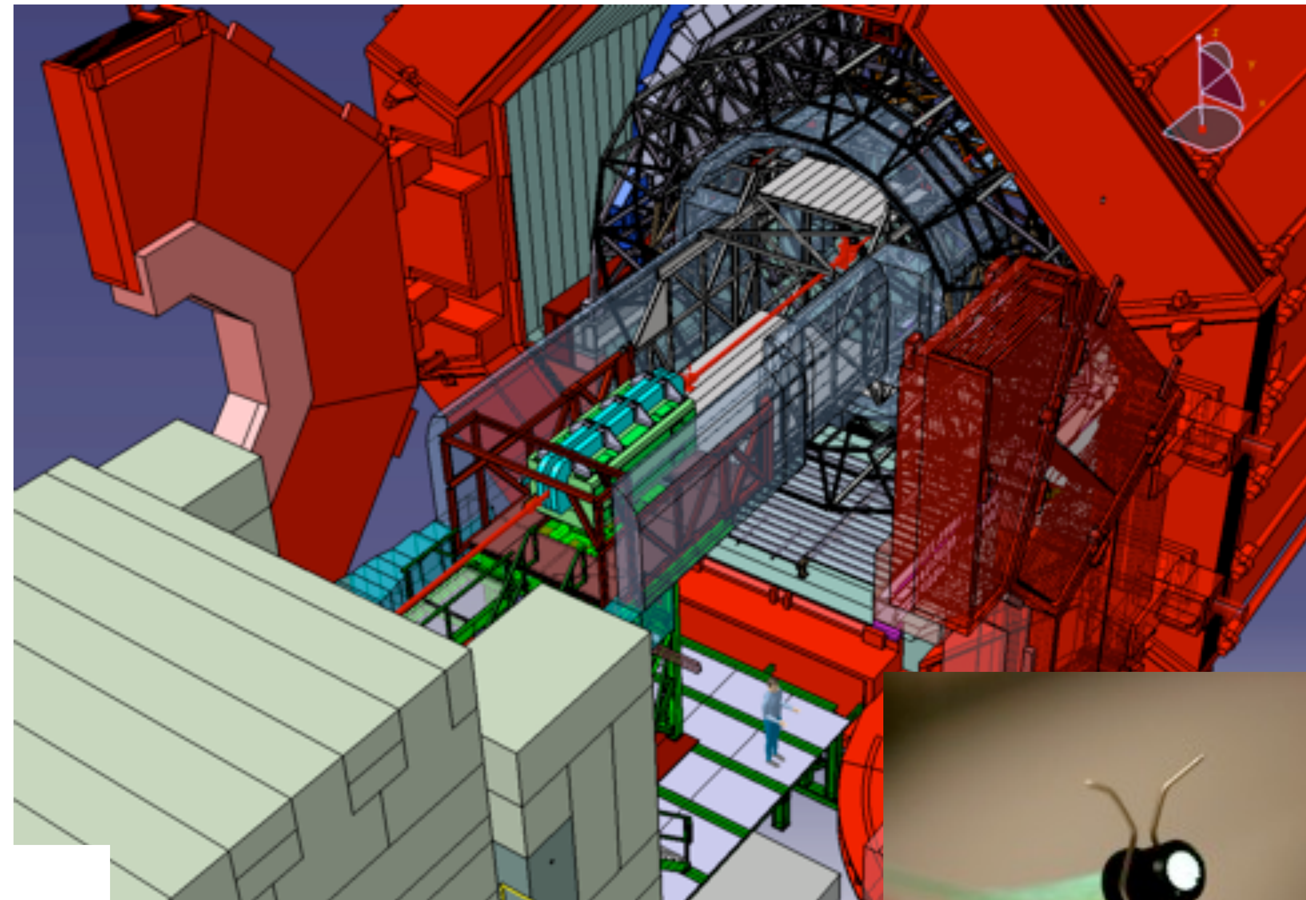
✓Progress

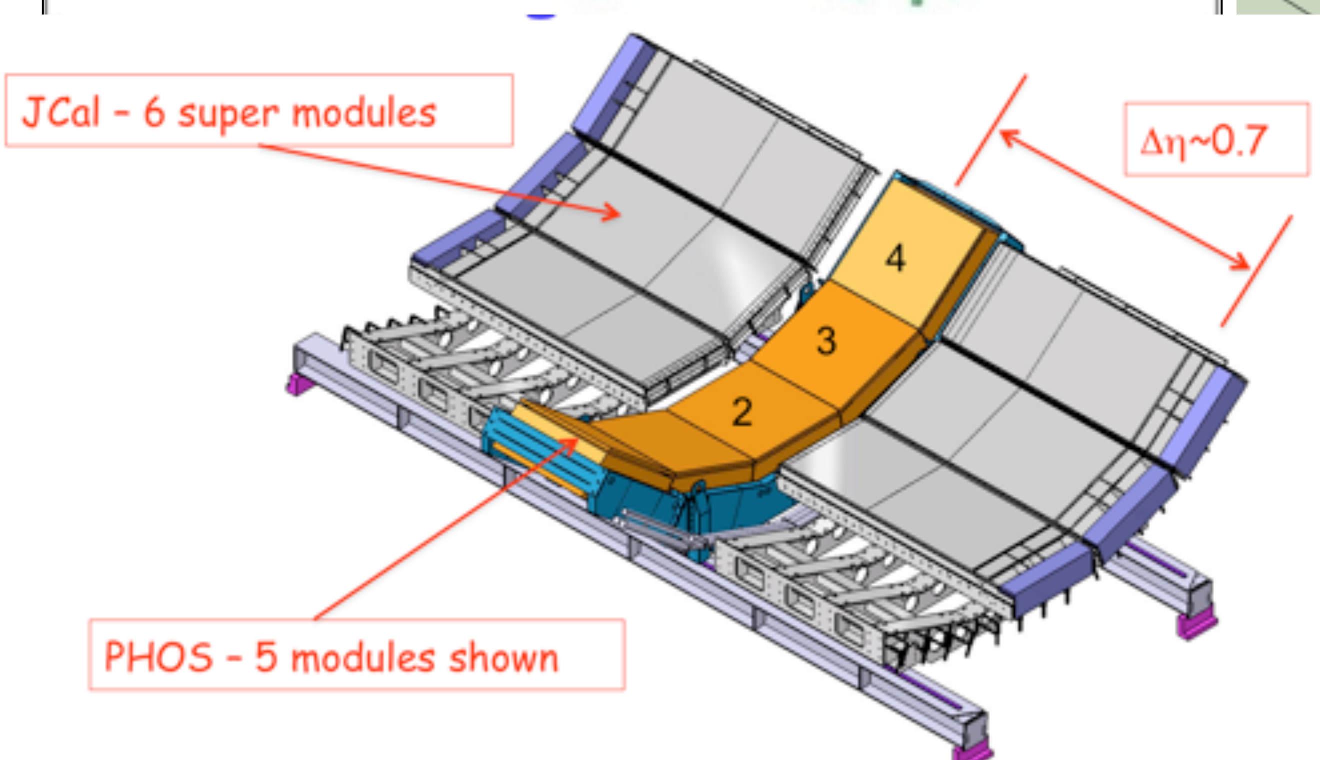
- Proposed in Feb.,09
- Discussed w. IN2P3 in May, 09
- Discussed in March,09
- Proposal in May, 09
- Partial approval in July, 09
- Full approval by ALICE in Oct. 09

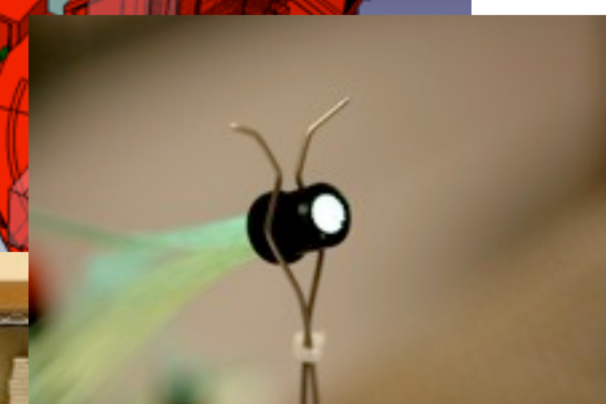
✓Construction started !

DiJet Calorimeter now with Japan-China-France-Italy-USA



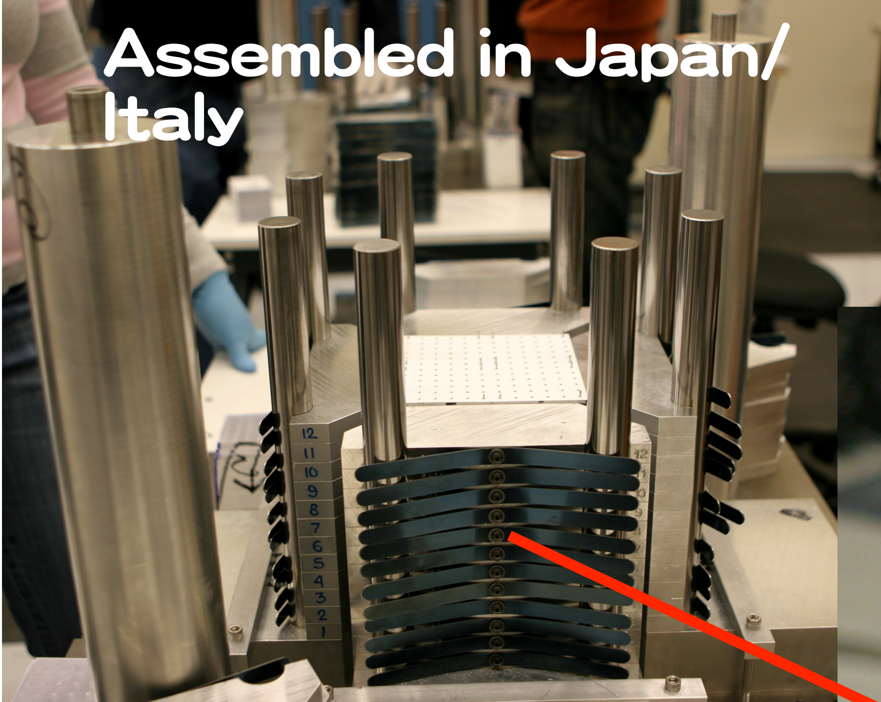


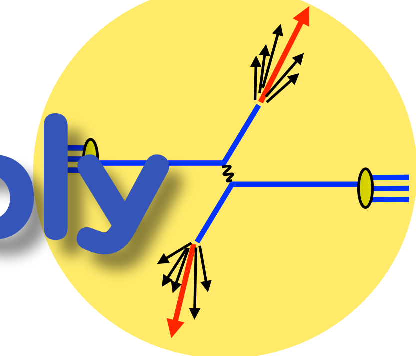


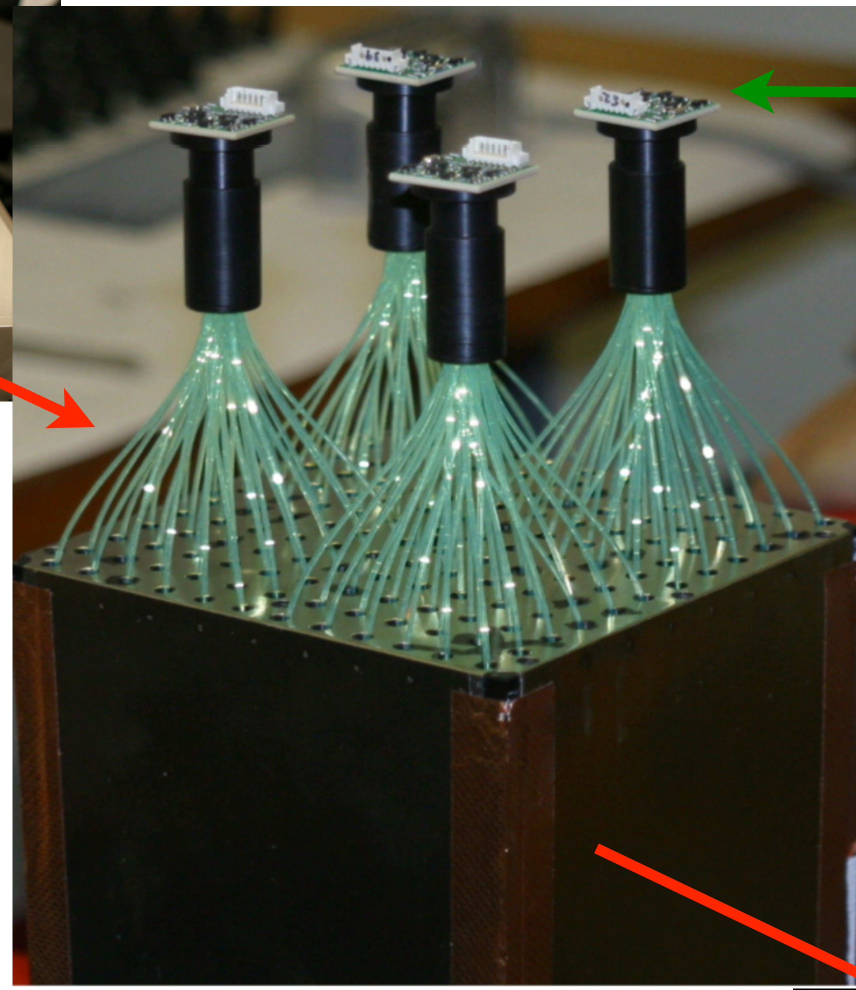


科研費基盤S(三明)

Dijet Cal assembly







APD tested in Italy

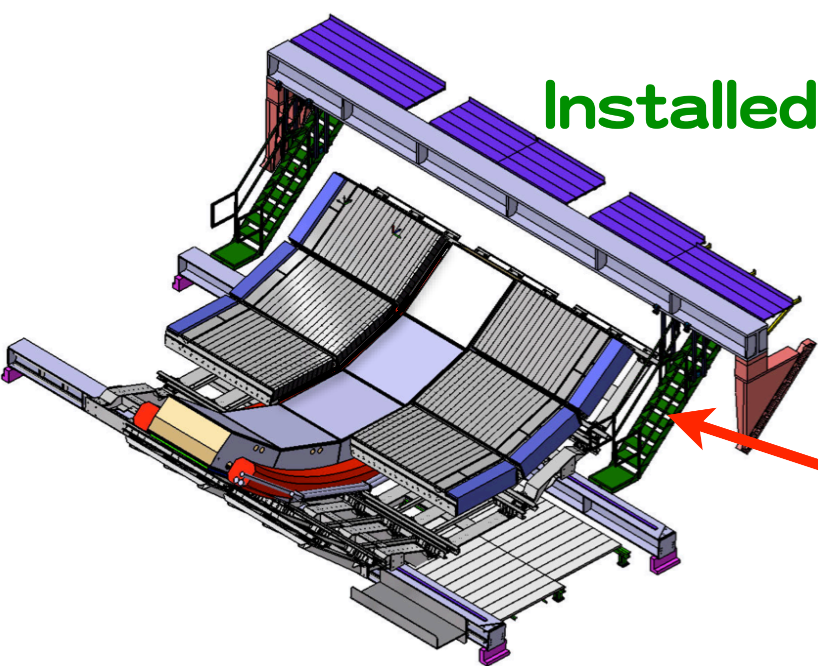
Parameter	Value
Tower Size (at η=0)	~6.0 × ~6.0 × 24.6 cm^3
Tower Size	$\Delta\phi \times \Delta\eta = 0.0143 \times 0.0143$
Sampling Ratio	1.44 mm Pb / 1.76 mm Scint.
Layers	77
Scintillator	Polystyrene (BASF143E + 1.5%pTP + 0.04%POPOP)
Absorber	natural Lead
Effective RL X_0	12.3 mm
Effective MR R_M	3.20 cm
Effective Density	5.68 g/cm^3
Sampling Fraction	1/10.5
Radiation Length	20.1

Stack and press 77 scintillators/lead tiles

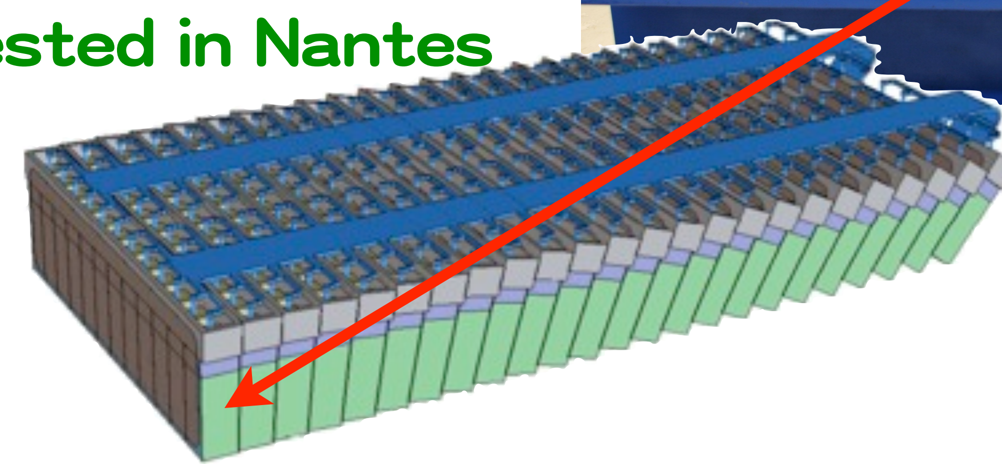
~1 stack/day

Tsukuba ~300 modules

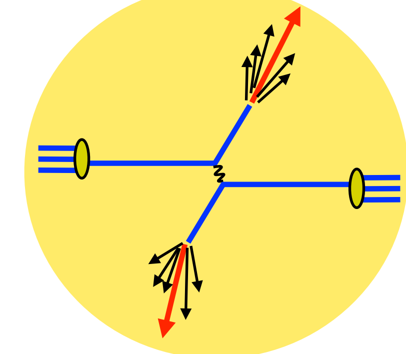
Installed at CERN

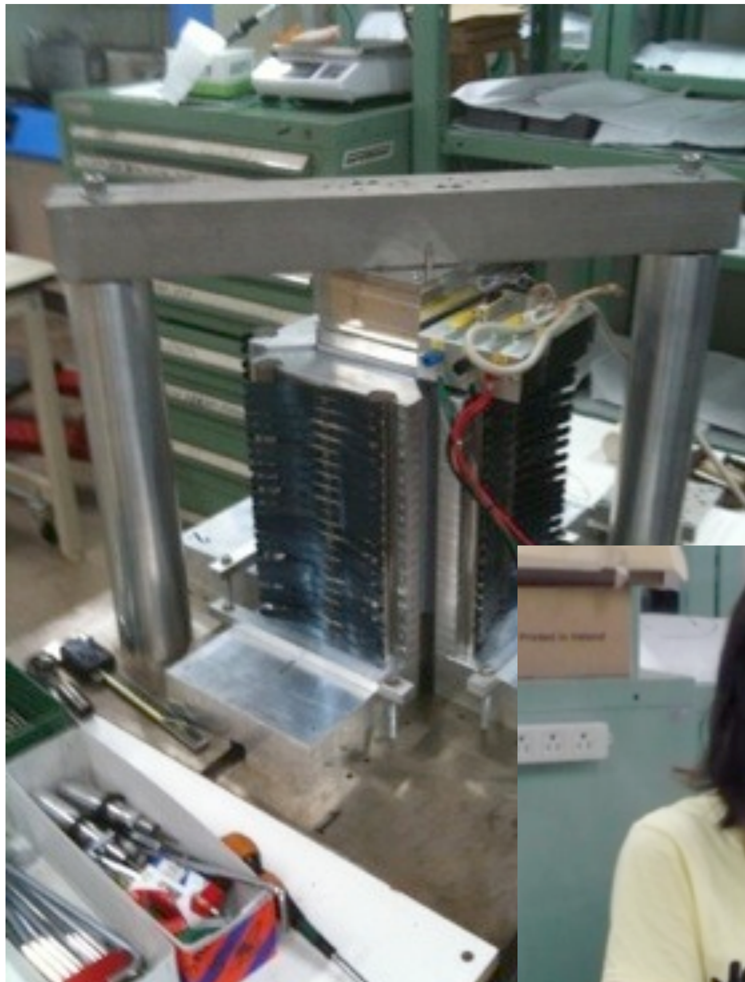


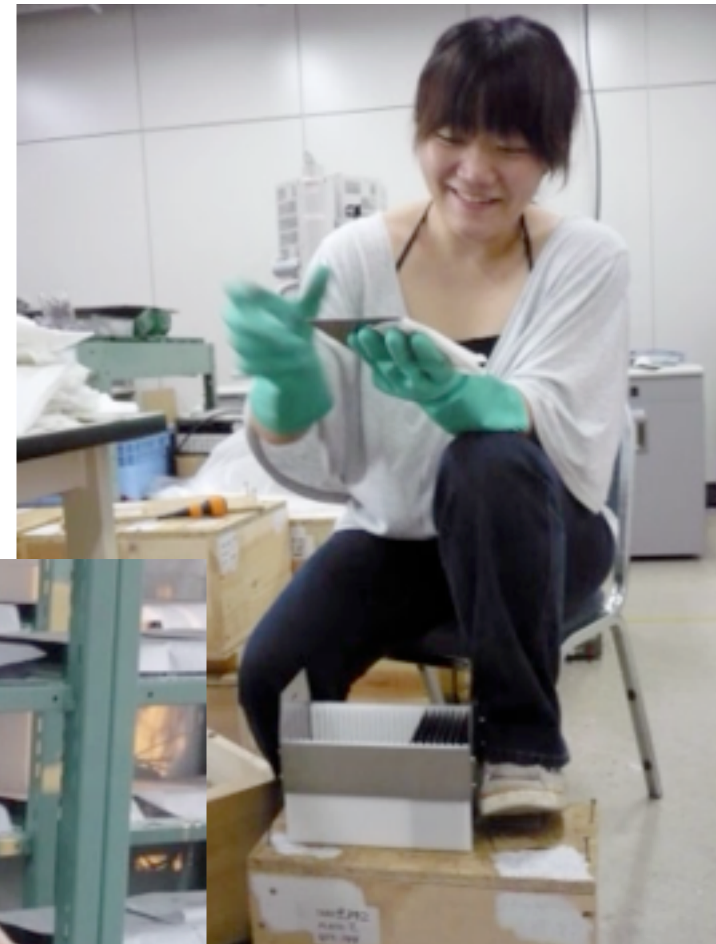
Tested in Nantes

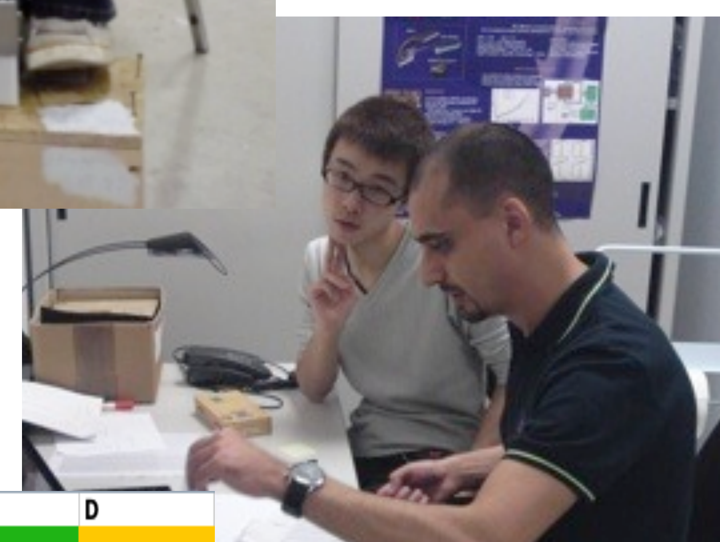


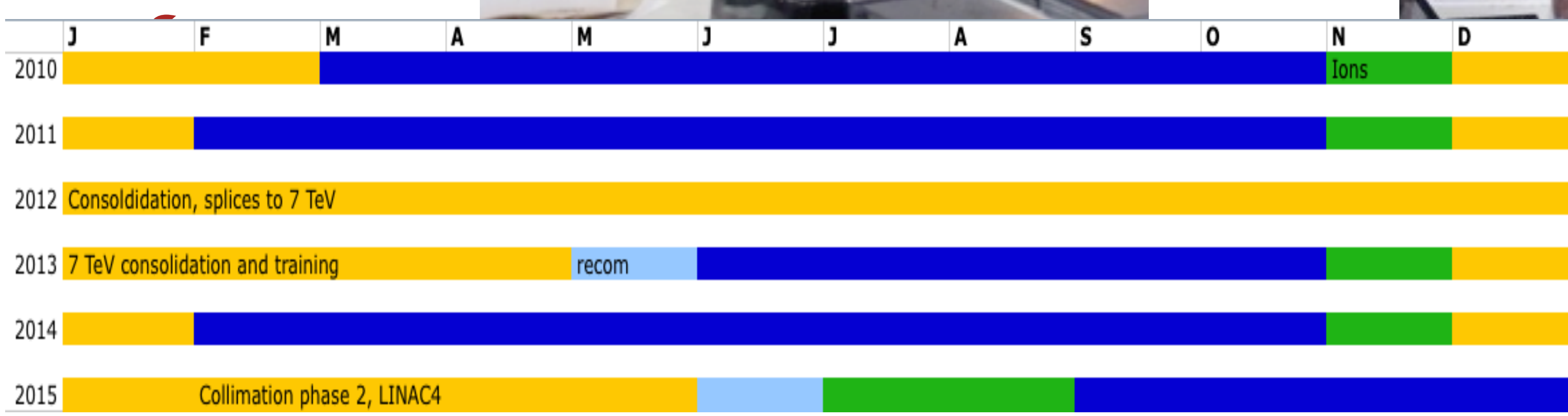
Our works at Tsukuba & Catania



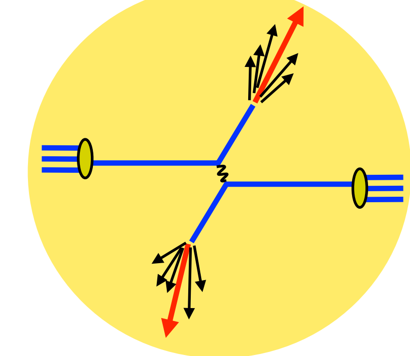








Summary



大学間協定・部局間協定

GENERAL MEMORANDUM FOR ACADEMIC EXCHANGE AND COOPERATION BETWEEN GRADUATE SCHOOL OF PURE AND APPLIED SCIENCES, UNIVERSITY OF TSUKUBA, JAPAN AND COLLEGE OF SCIENCES, YONSEI UNIVERSITY, THE REPUBLIC OF KOREA

The Graduate School of Pure and Applied Sciences of the University of Tsukuba, Japan and the College of Sciences of Yonsei University, the Republic of Korea, hereinafter referred to as "the two parties", hereby agree to foster academic exchange and cooperation between the two parties.

1. The two parties shall encourage the following activities in the field of natural sciences and related fields:

   (1) Exchange of professors and researchers;

   (2) Exchange of graduate students;

   (3) Collaborative research and scientific meetings; and

   (4) Exchange of scientific materials, publications and information.

2. The aforementioned activities shall be realized by means of consultation and the exchange of information between the two parties.

3. This Agreement shall become effective immediately upon being signed by the official representatives of the two parties and shall remain valid for a period of five (5) years. This Agreement may be renewed for a further period of five (5) years by mutual agreement prior to the date of expiry.

4. This Agreement may be amended by the two parties by mutual agreement.

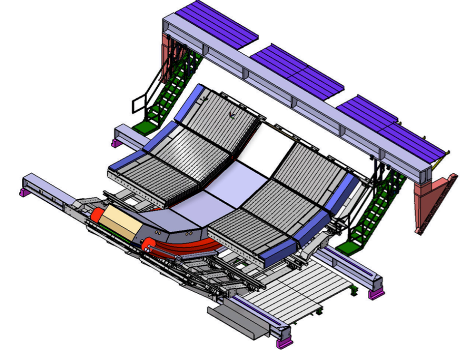
5. This Agreement is made in English, which is the authentic text.

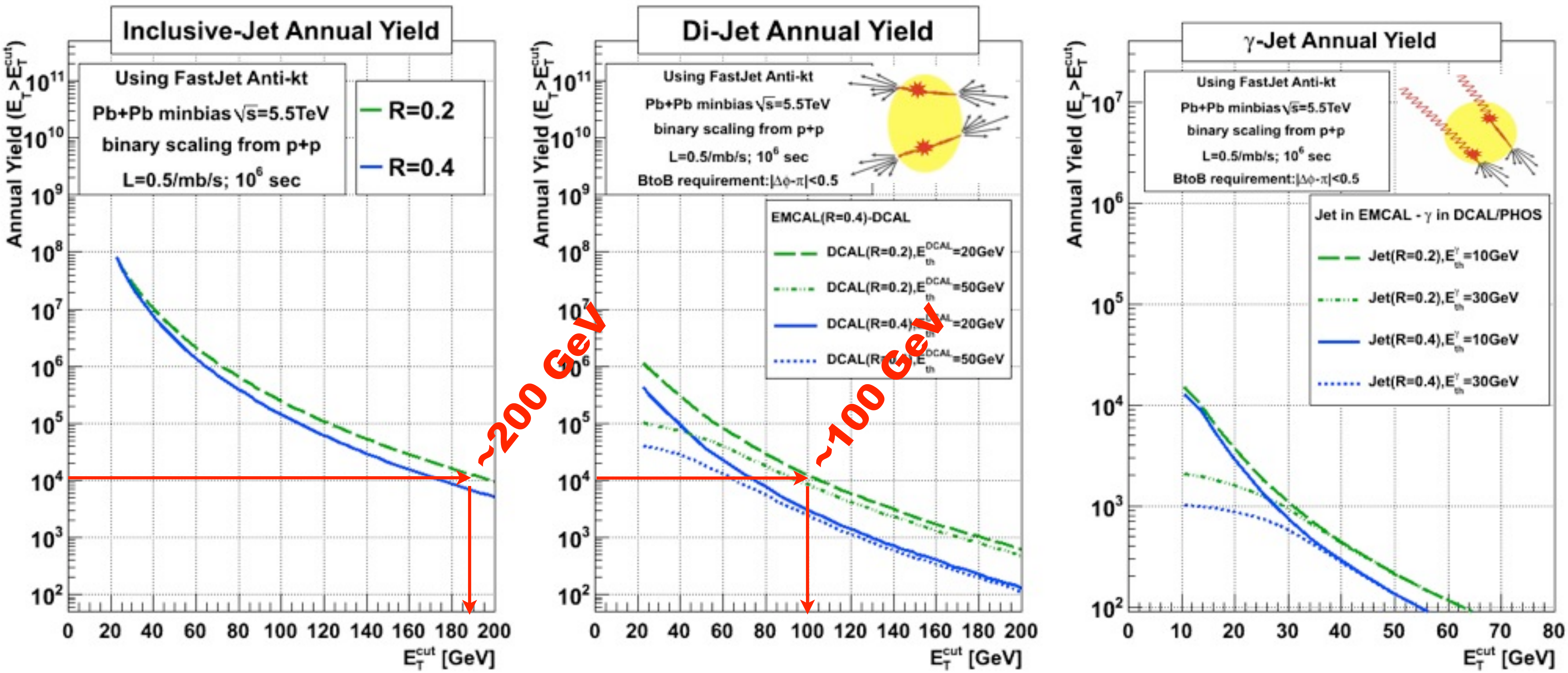
Date: October 1, 2005	Date: October 1, 2005
Hiroshi Mizubayashi	[signature]
Prof. Hiroshi Mizubayashi	Prof. Young Min Kim
Provost	Dean
Graduate School of Pure and Applied Sciences	College of Sciences
University of Tsukuba	Yonsei University

- ✓ We like to collaborate in Tandem, RIBF and/or LHC.
- ✓ Let us start with an agreement between Universities.
  - pure academic
  - no money issue
  - no obligation

    ➡still useful to start up

What we expect; Reach of Jet Energy

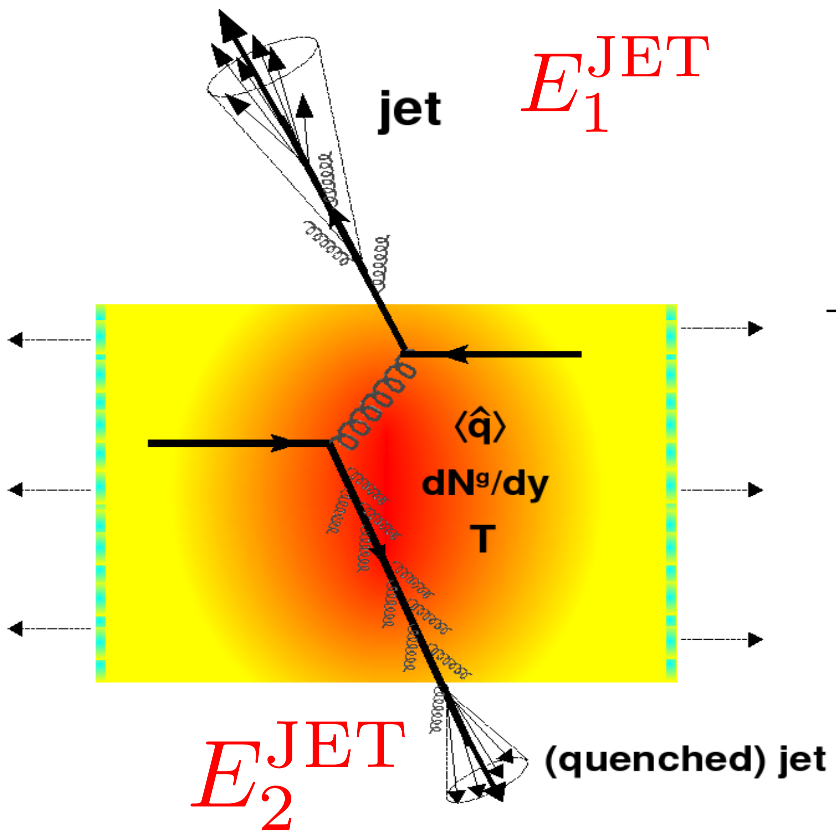


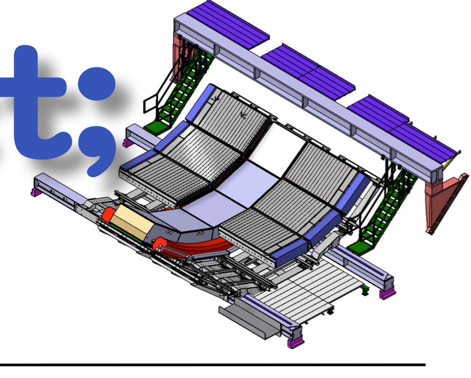


✓ For 10^4 events/year in Pb+Pb@5.5TeV,

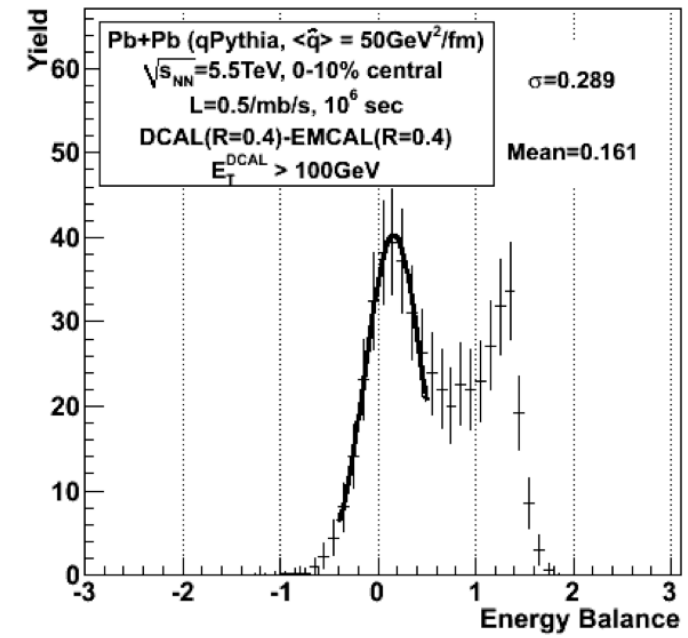
- Inclusive jet up to 200 GeV
- Di-Jet to 100 GeV

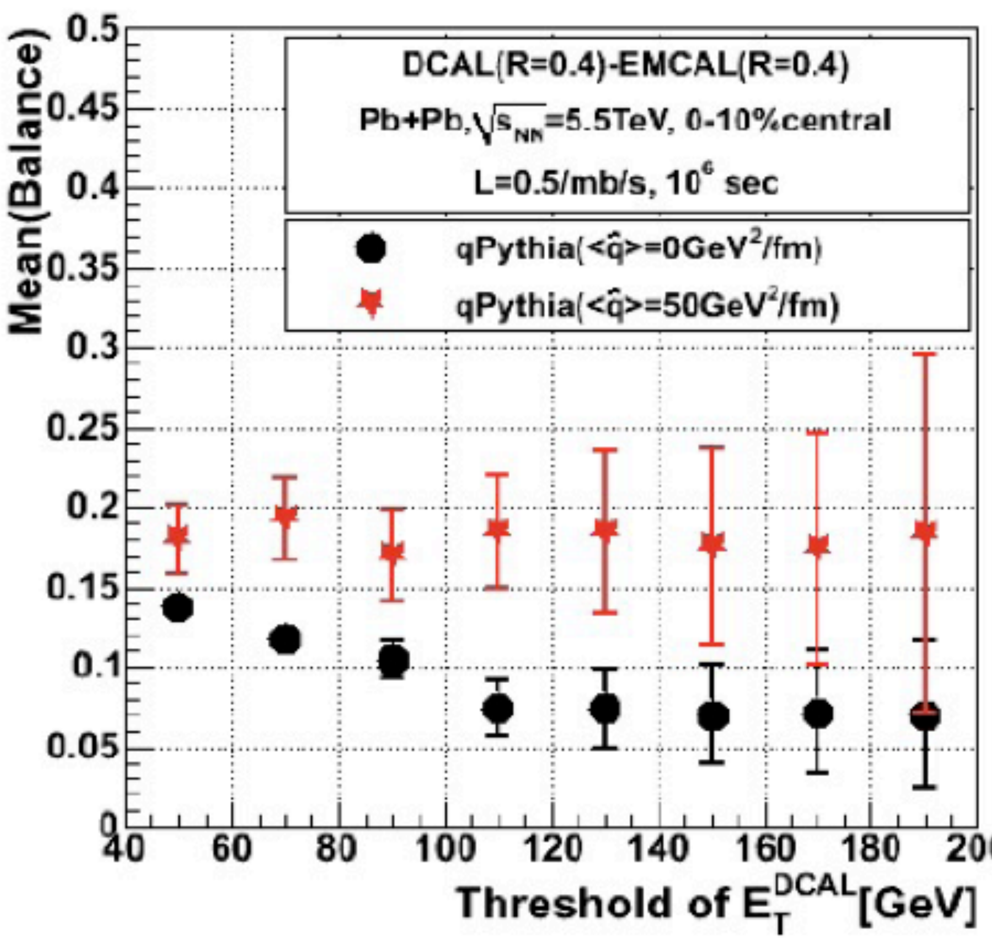
What we expect; sensitivity

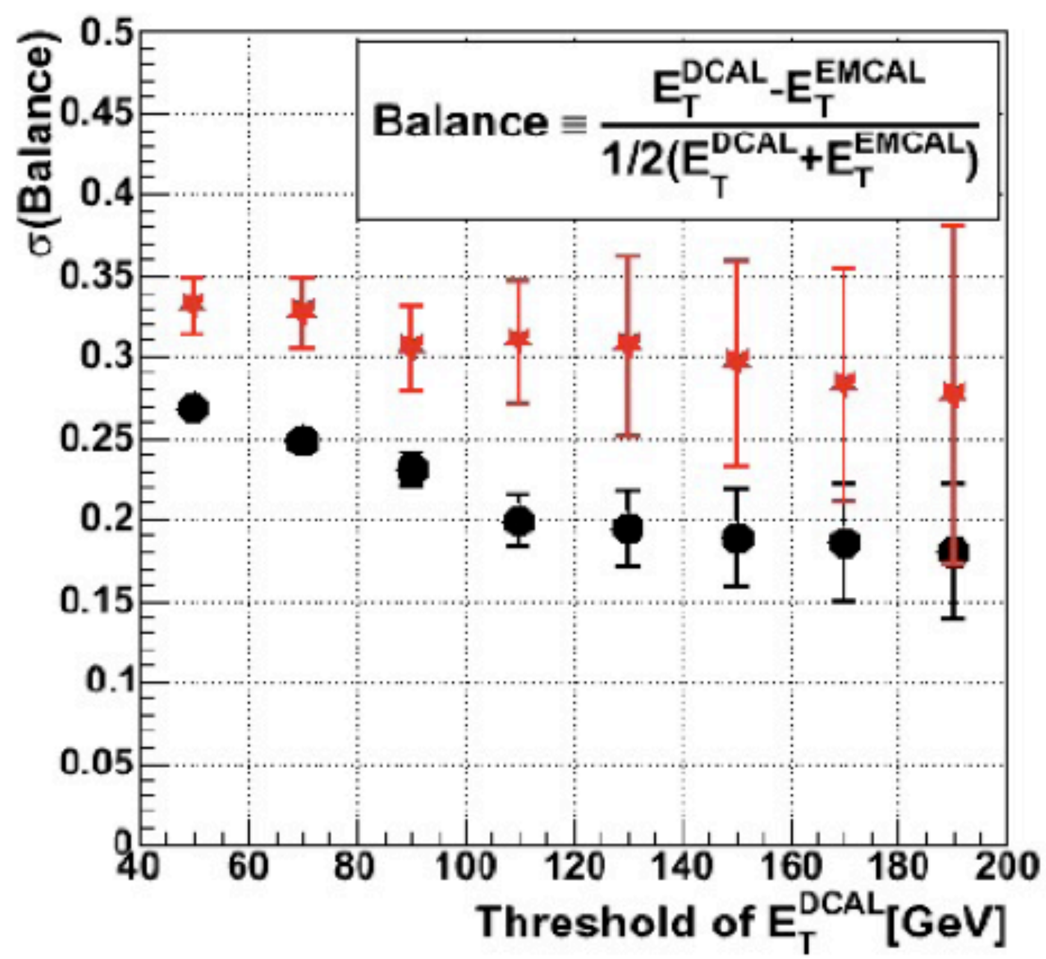




$$\mathrm{Balance} \equiv \frac{E_1^{\mathrm{JET}} - E_2^{\mathrm{JET}}}{1/2(E_1^{\mathrm{JET}} + E_2^{\mathrm{JET}})}$$







✓ Sensitivity in data of 1 year

Good textbook on QGP!

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