宇宙史拠点実習 Ⅱ

期間：7/1/2008 – 8/1/2008
実施場所：CERN, France/Switzerland

Practical Info

ALICE ：計6名（原子核実験4名、宇宙観測2名）
ATLAS：計9名（素粒子実験9名）

- 参加者：
  素粒子実験1年（河内山、瀬賀、塙、林、松隈、三井）6名
  素粒子実験2年（武政、須藤、秦野）3名
  原子核実験1年（横山、浜田、梶谷）3名
  原子核実験2年（坂田）1名
  宇宙観測1年（秋山）1名
  宇宙観測2年（荒井）1名

- 現地の対応者 (ALICE側)： 金野、中條、三明、渡辺(D1)

- CERN ユーザー登録：
  手続き： 到着翌日 (7/2)の午後 、CERNユーザーズオフィス
  必要な書類： パスポート、在学証明書（英文）、旅行保険証、
  及び、記入済みのユーザー登録フォーム
  => アクセスカードの取得

- 計算機アカウントの申請
- 安全講習

Practical Info

- 宿泊先:
  自炊可能なアパート (Prevessin)、共同生活。

- 移動:
  ホテルはフランス、研究所はスイス、実験室はフランス。
  パスポートとアクセスカードを常時携行。
  レンタカー:　集団行動。運転する場合は国際免許証が必要。

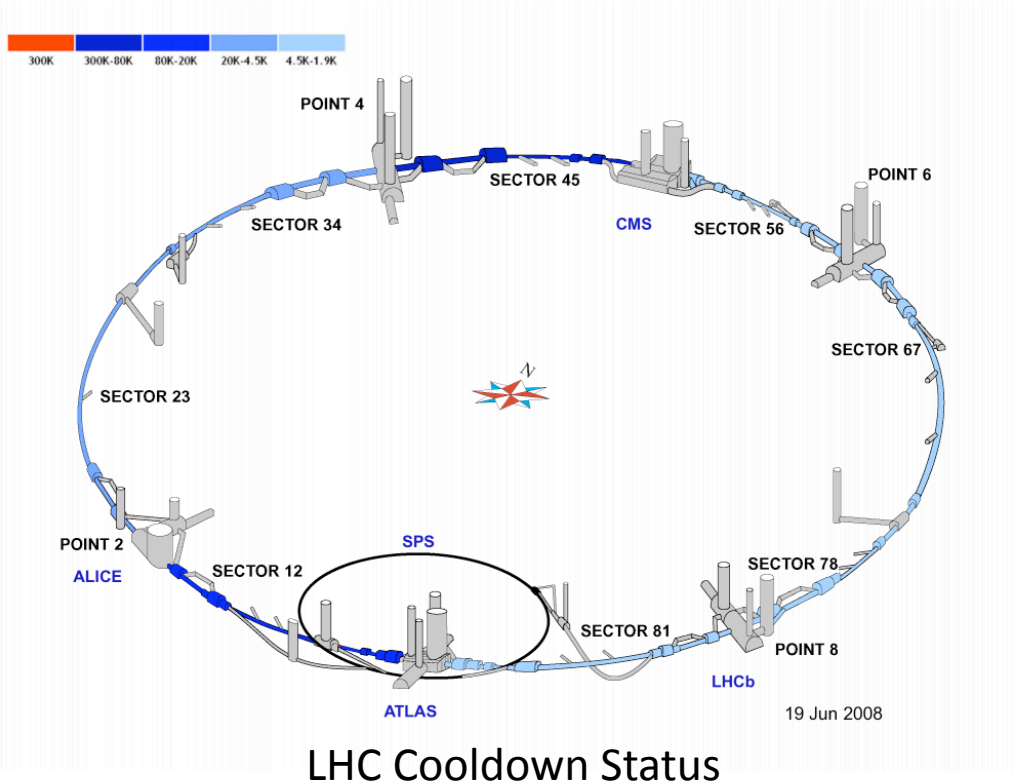
- 旅行保険は必須。保険の書類を携行。

- CERN での居室 (ALICE): 587-r-023, 13-r-002

- 各自ノートPCを持参すると便利。変換プラグ・変圧器も必要。

税金で実習費用が負担されていることを認識！

Large Hadron Collider



LHC Cooldown Status

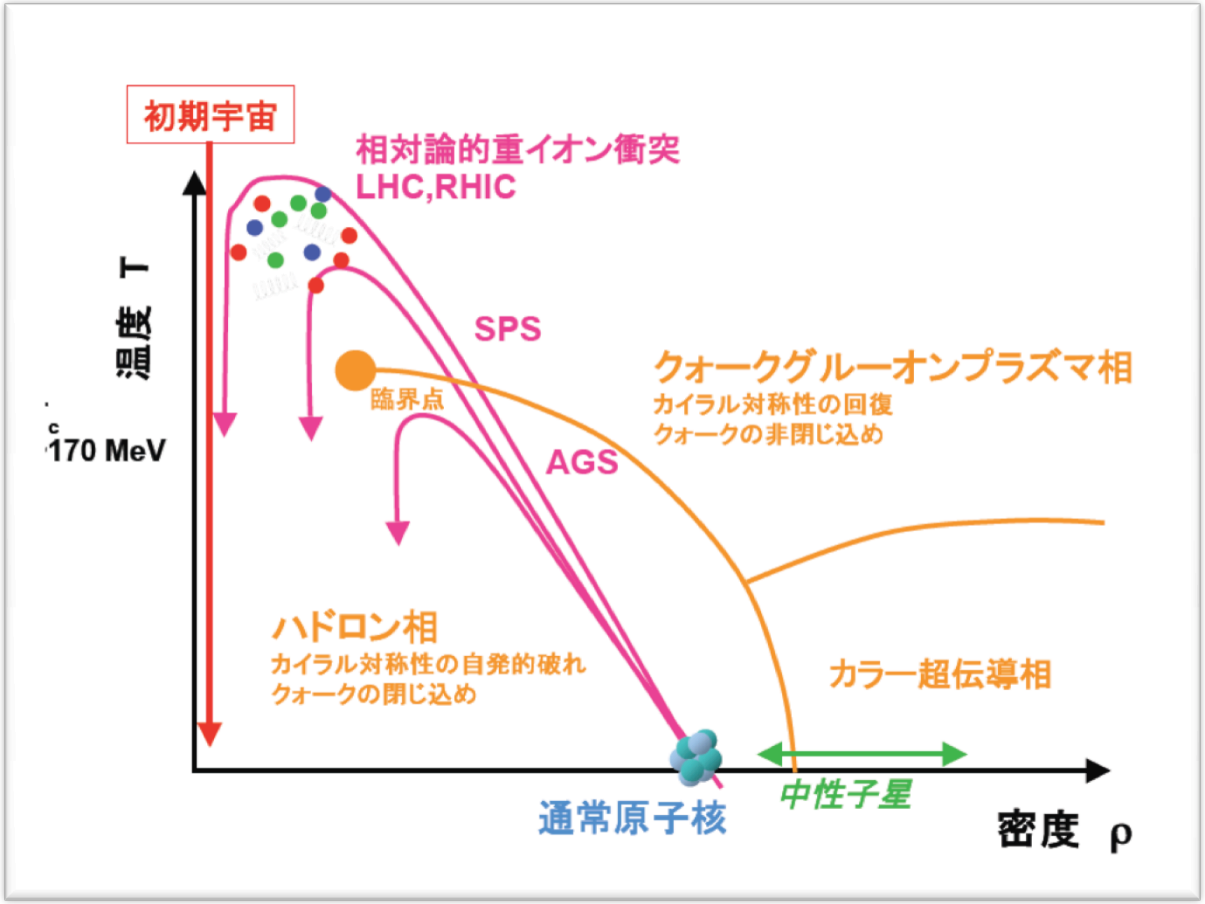
Large Hadron Collider (LHC)
- 周長：27 km、トンネル深度（地下）：50 – 175 m
- ビーム：protons at 7 TeV, heavy ions at 2.75 TeV
- 衝突点：ATLAS, ALICE, CMS, LHCb（4実験）

← 世界最高エネルギー

LHC Plan
- Cosmic run is ongoing for detector commissioning
- Early August/2008: first beam expected
- September/2008: fist collisions (p+p) expected

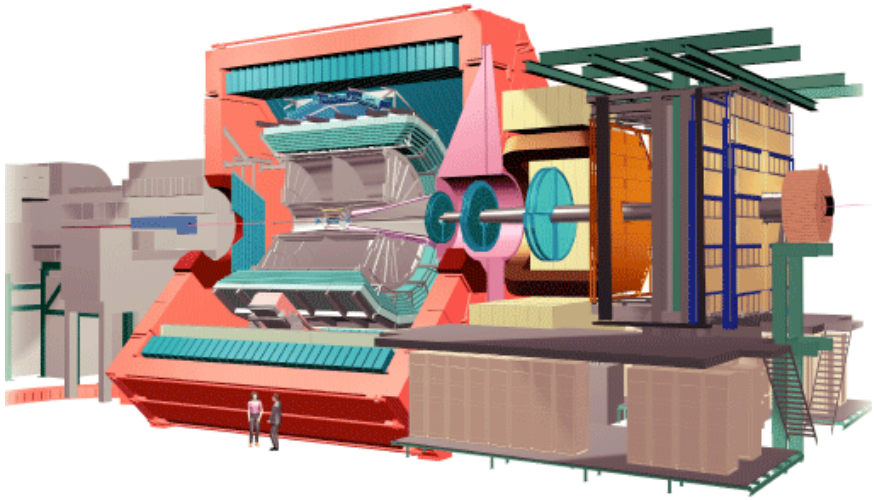
← Start Up Phase

What's the matter at LHC?

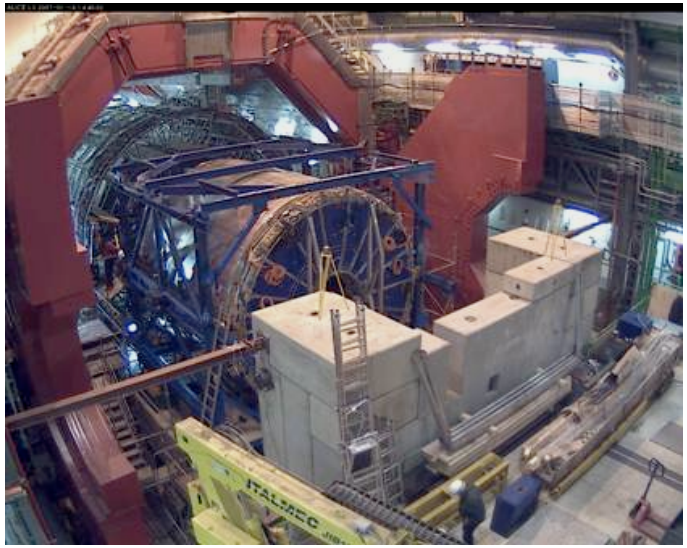


- Many physical properties to be measured, in order to characterize the matter produced at the relativistic heavy ion collisions. For example:
  - Initial Temperature, Energy density, Baryon chemical potential, speed of sound, shear viscosity/entropy ratio, gluon density, degrees of freedom, and Equation of State (EOS) ….
  - QCD material science.
- How can we measure them?
- How to map out the phase diagram of QCD?

ALICE Experiment

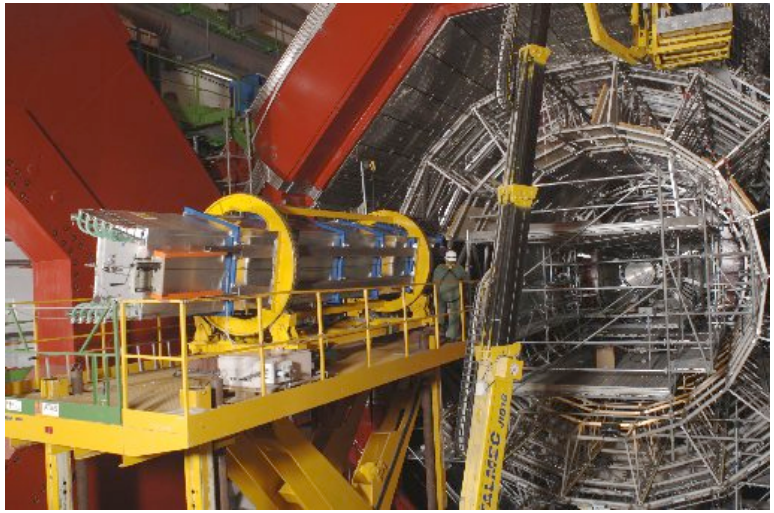


ALICE detector



TPC Installation

ALICE 実験
- 目的:高エネルギー密度状態での
  Quark-Gluon Plasma (QGP) 生成
- QGP物性の研究
  （これまでもCERN-SPSやBNL-RHICで様々な
  実験が行われてきた。RHICでは今も進行中。）
- 重イオン衝突に特化した検出器
- ハドロン・電子・ミュー粒子・光子を系統的に測定
- p+p 衝突でも稼働



TRD Installation

実習内容

＊ATLAS班とALICE班に分かれて実習

講義

- CERN Summer Student Lecture Programme（午前中）
  => レポート提出（8/31〆切）

共通実習

- ALICE Data Taking シフト（8時間/日、1週間）

テーマ実習

テーマを1つ
決めて取り組む

中間報告会（7/17頃TV会議）
最終報告会（7/31頃TV会議）

(1) ALICE 宇宙線データの解析、DCSの開発
- (1-a) 宇宙線データの解析
- (1-b) DCSの開発

(2) ALICE オフライン環境でのシミュレーション
- (2-a) ALICE実験におけるジェット事象の再構成
- (2-b) p+p 衝突におけるQGP的性質
- (2-c) ALICE実験における反応平面の可能性
- (2-d) Three-particle correlations
- (2-e) Initial temperature at LHC

(3) PHENIX 重イオン衝突データの解析
- (3-a) Run-7データを用いたΦ・Λの測定
- (3-b) Run-7データを用いたパイゼロ・光子の測定

CERN Summer Student Lecture Programme

- 7/2 (Wed.) – 8/8 (Fri.)
- 9:15 – 12:30, Weekdays

講義内容:
- Particle Physics, Nuclear Physics
- Astroparticle physics, Cosmology
- Accelerators, Detectors
- Experimental techniques

など

内容はとても充実している。

＊ https://hr-recruit.web.cern.ch/hr-recruit/summies/default.asp
＊講義スライドはWebに置かれ、ダウンロード可能。
＊午前中の講義でよく分からなかった点を記録しておき、
午後それらについて文献に当たったり、自分で計算をすると
理解が深まる。

セミナーやSummer Student Programなど様々な
催しがあるので積極的に参加して視野を拡げる。

ALICE Data Taking Shift – Cosmic Run

ALICE Data Taking Shift (24 hours a day, 7 days a week)

- Night shift　(00:00–08:00)
- Day shift　(08:00–16:00)
- Evening shift (16:00–24:00)

← 夕方の時間帯がベスト。

TRD&TPC Shift in ALICE Control Room

- 7/7 - 7/13
- 7/14 - 7/20
- 7/21 - 7/27

← 2人でペアを組んで
1週間のシフトを取る。
（前半/後半 or 1週間連続）

* TRD = Transition Radiation Detector
* TPC = Time Projection Chamber
* セイフティートレーニングとアクセスリクエストが事前に必要です。
* 初めの数日は金野・渡辺(D1)がヘルプします。

以下、個別テーマの説明。

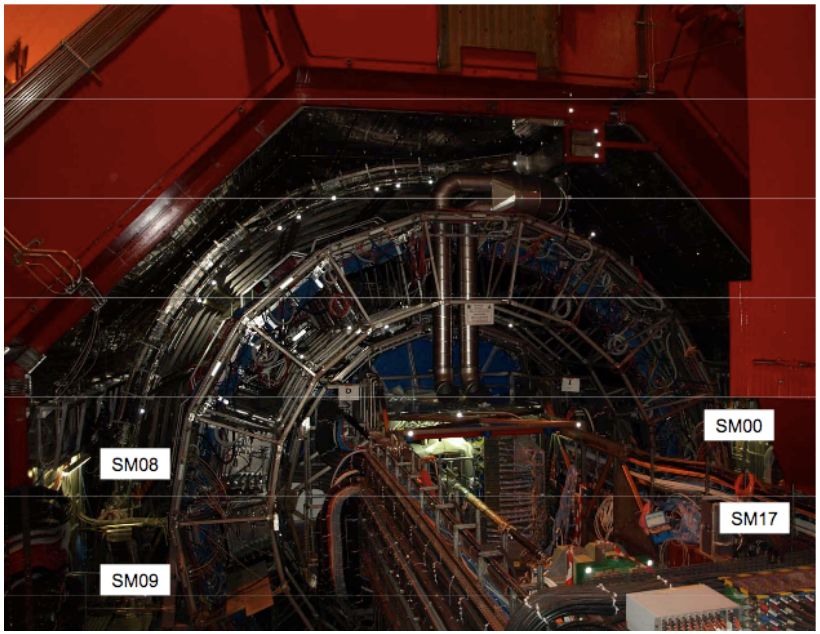
(1) ALICE宇宙線データの解析、DCSの開発

（ファーストコリジョンは見れないかも知れないけれど・・・）

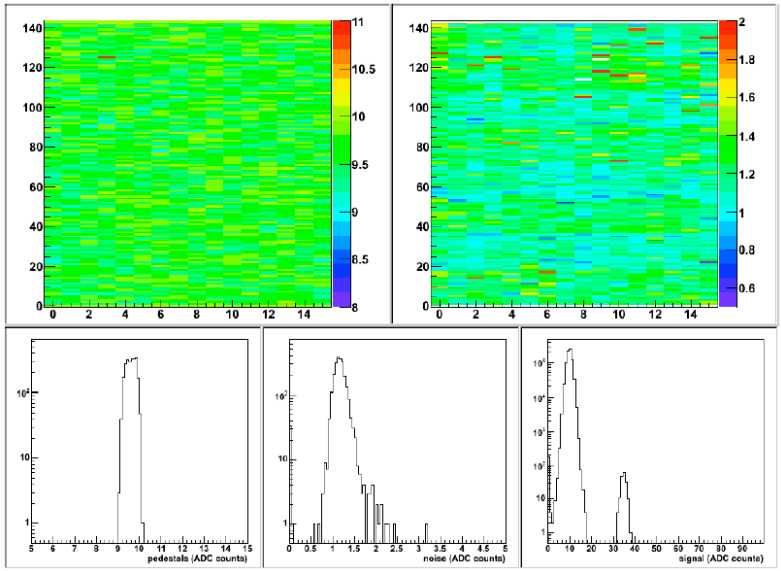
(1-a) 宇宙線データの解析 （担当：金野）

- Taking TRD shift for one week ← シフトは必須。
- Hardware/software debugging

  Readout, QA, Noise, ADC time bin data ; TRD raw data



4 TRD SM's installed

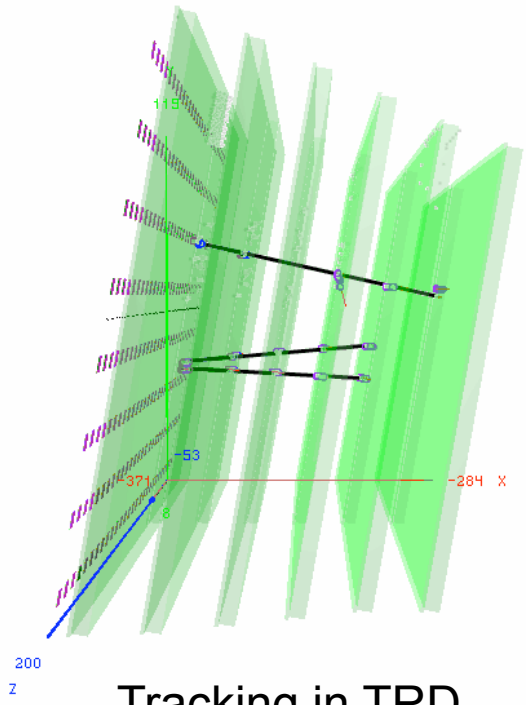


Monitoring plots

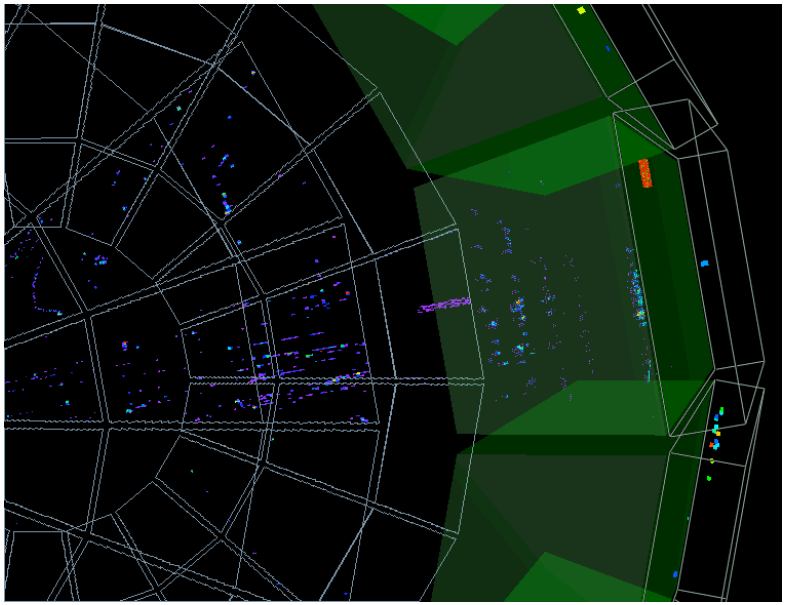
- Calibration
  - Pulse height distribution, Cluster position ; TRD
  - Prepare pedestal, gain tables for readout chips
  - HV setting (Anode, Cathode)

- Tracking, Alignment
  - Cluster position ; TRD/TPC

基本的にプログラミング。
取得したデータに触れます。
バグ取り。



Tracking in TRD



Shower event

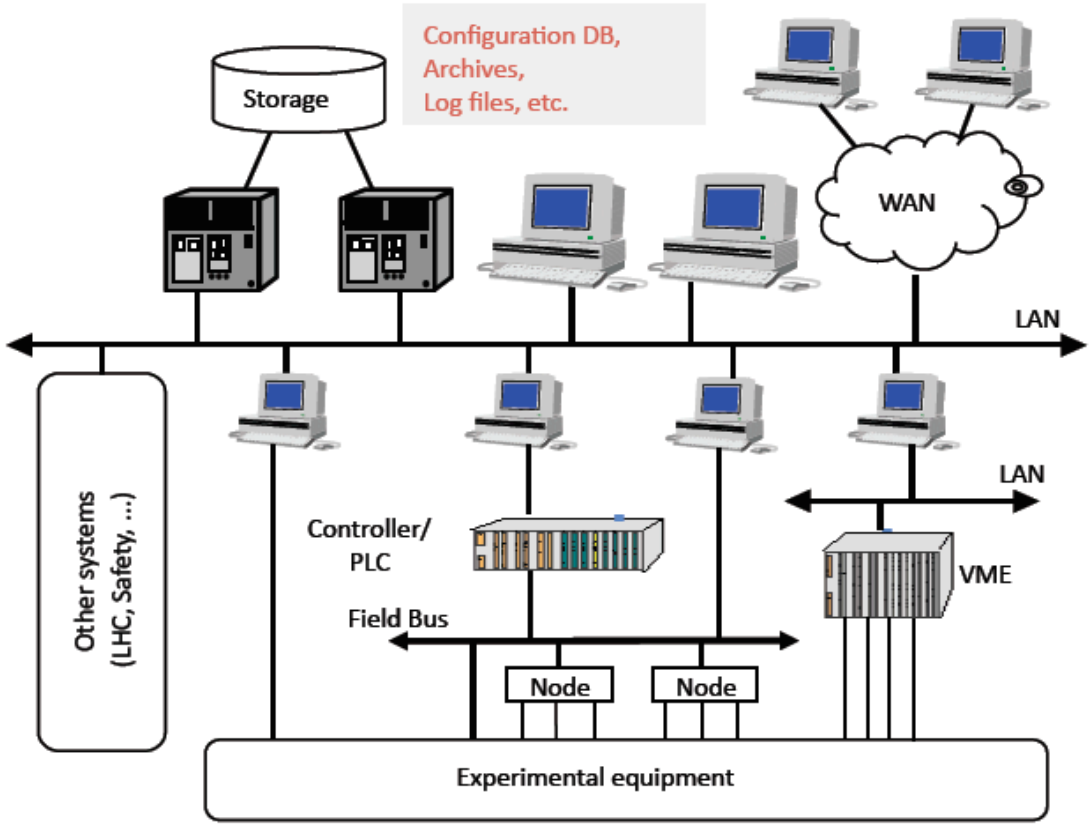
(1-b) DCSの開発

（担当：金野、渡辺）

実験全体の理解。

Detector Controls System (DCS)

-- To control and operate the experiment from a central operator workplace during all modes of operation.

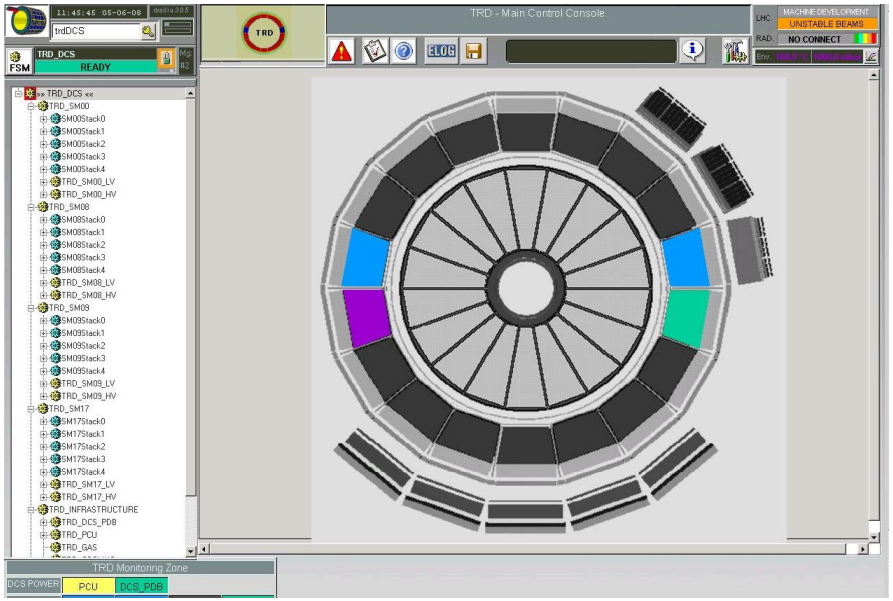


- Software, concepts:
  - PVSS (process visualization and control system)
  - FSM (finite state machine) etc.

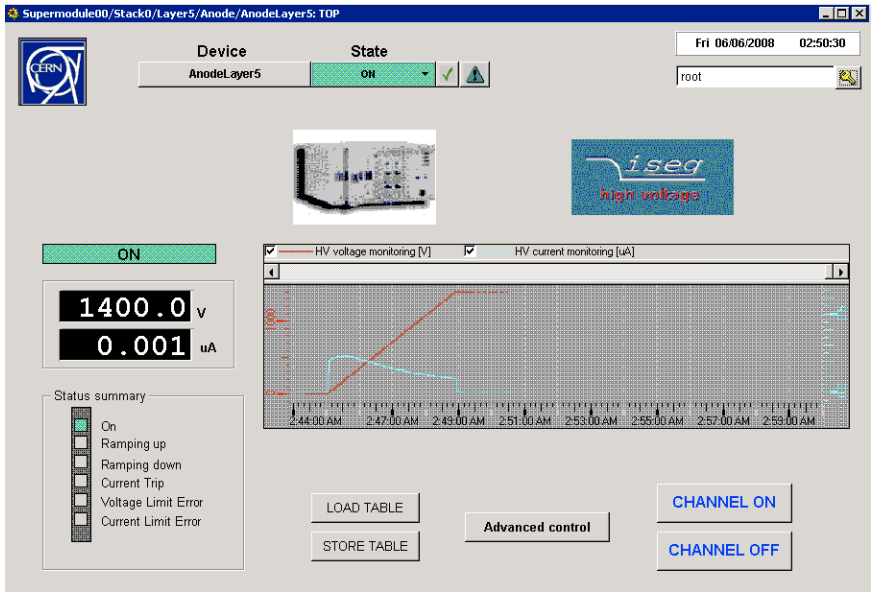
プログラミング自体は簡単。
概念や仕組みの理解が必要。

- Develop a part of the TRD DCS
  - HV control system
  - FSM states (routine, majority rules)

実際のTRD-DCSの
不足部分を補う。



TRD operator console



HV control panel

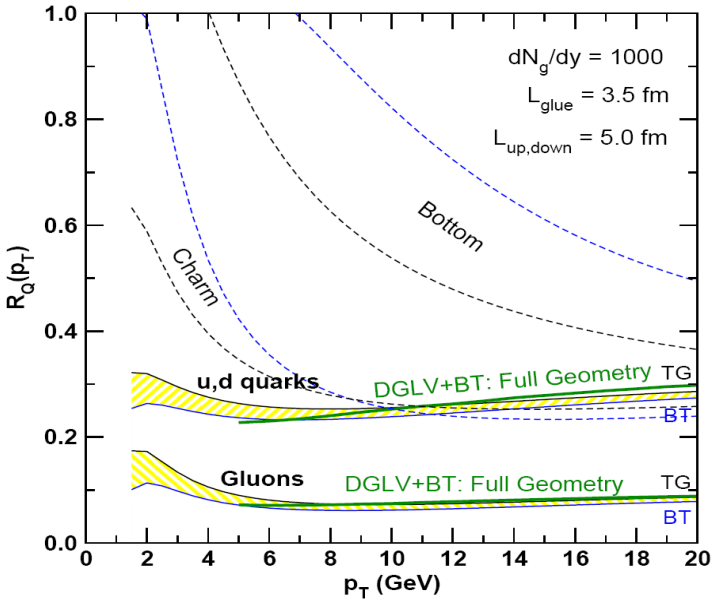
(2) ALICEオフライン環境でのシミュレーション

（ALICE環境での擬似データの解析。テーマを1つ決めて物理解析。）

(2-a) ALICE実験におけるジェット事象の再構成

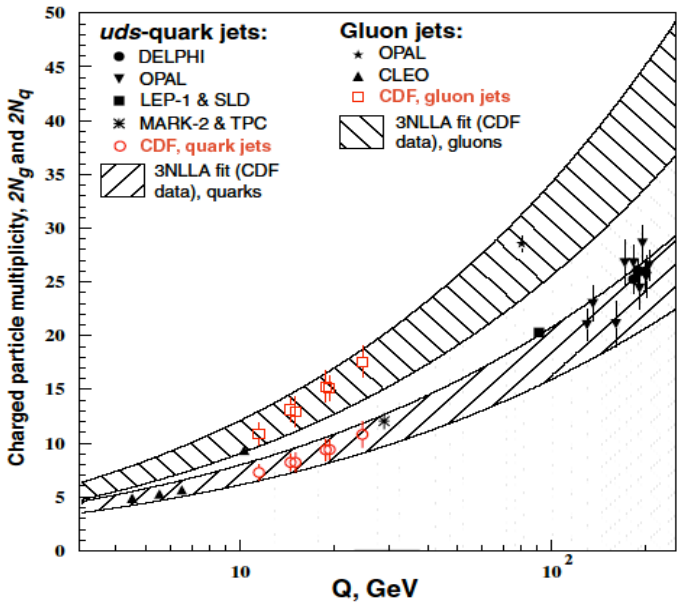
（担当：金野）

- Utilize initial hard parton scattering as a probe
  => High energy jets, photons, heavy flavors
- Measure jet structure & medium-induced modification
- Investigate energy loss mechanism with quark/gluon jets



エネルギー損失の大きさの予測
（クォーク、グルオン）

NPA 784, 426 (2007)



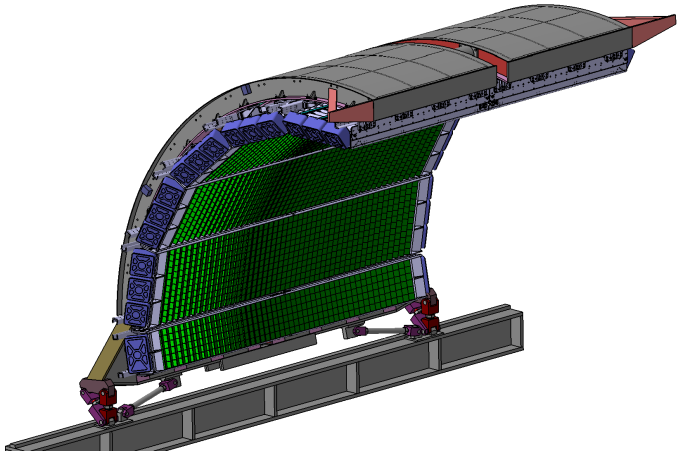
粒子多重度（クォークジェット、
グルオンジェット）

PRL 94, 171802 (2005)

- EMCal / HCal needed for triggering
  Approved fro funding: Jan. 2008
  Construct / Install: 2009-2011

⇒ Need to fix the detailed design!

← Detector simulation with Geant4

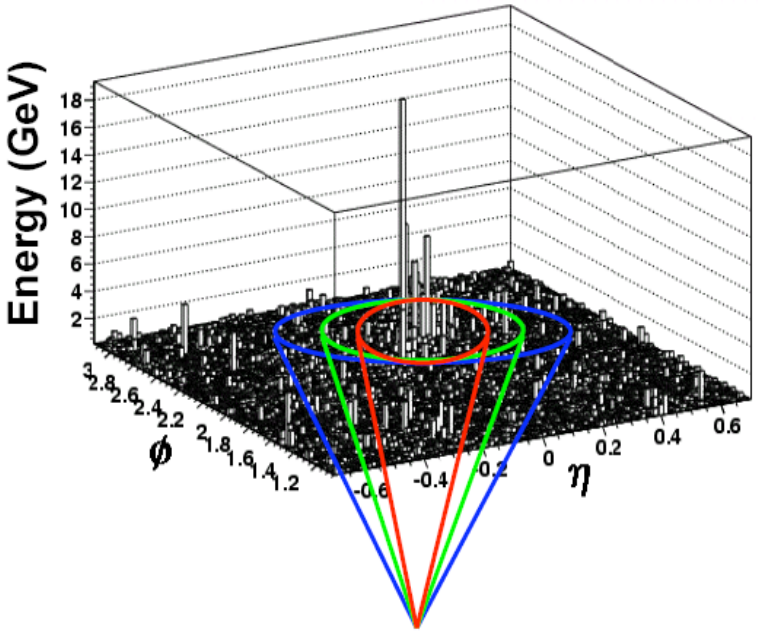


ALICE電磁カロリメータ

- Jet finding in heavy ion collisions
  the problem is soft particles background

=> How to subtract such background?
(p_T cut, jet cone size, etc.)

← Need to estimate the efficiency & S/N
(Pythia simulation)



100 GeV jet in central Pb+Pb

(2-b) p+p 衝突におけるQGP的性質

（担当：金野）

- Heavy Ion Physics with p+p at LHC?
  Particle density $dN_{ch}/d\eta$ ~ 50 – 100 can be reached in p+p
  > central S+S @ SPS, mid-central Cu+Cu @ RHIC

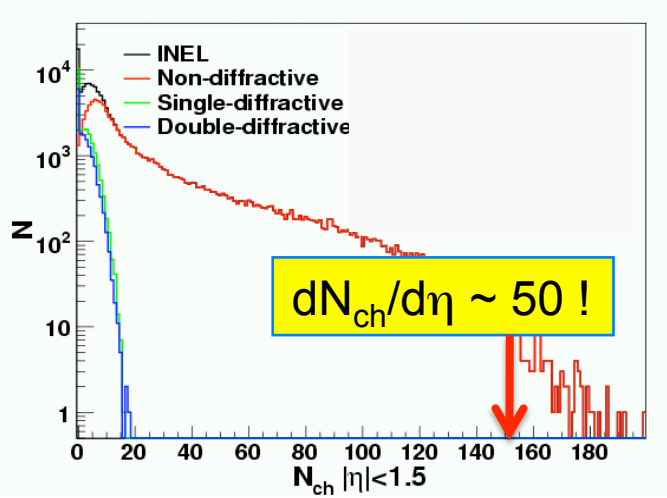
- Hadronic FS interactions
- Multiple partonic interactions
  => Collective flow, Thermal behavior
  => small QGP?

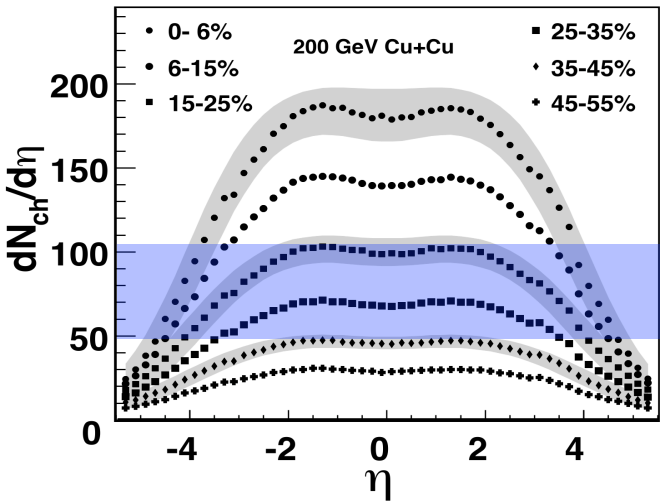
- Comparison between p+p and A+A at similar dN/dη
  => Volume/density/lifetime effect?

v2 や HBT 測定を試す。

Shukraft, Alice08

Multiplicity distributions in p+p at LHC





PHOBOS
nucl-ex 0709.4008

- High multiplicity p+p events = Jets
  => Can one separate the ‘soft’ from the ‘hard’?
  => Try veto on jets

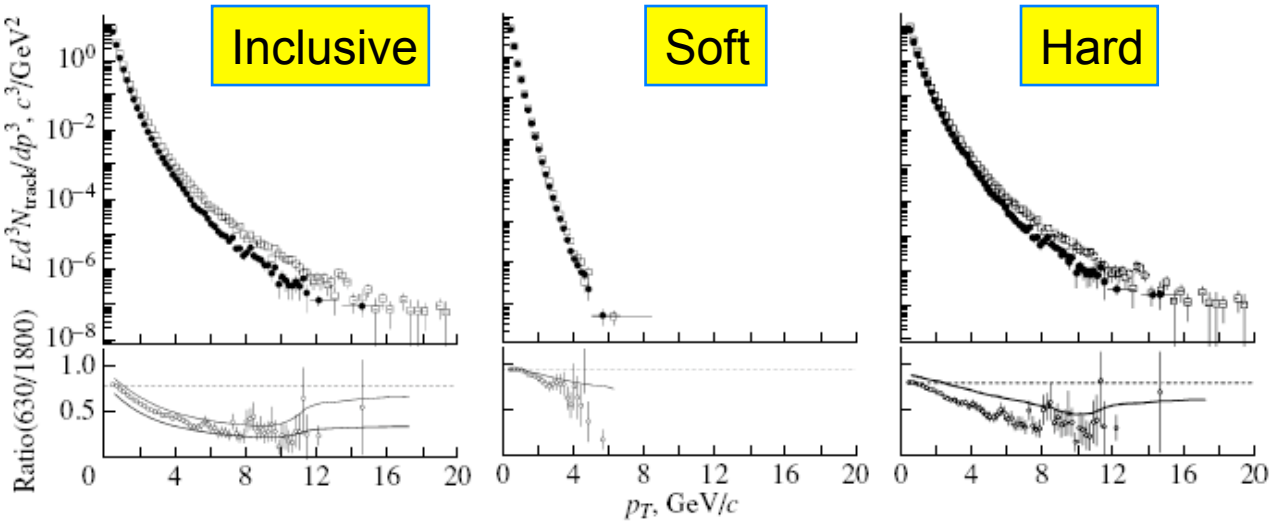


Fig. 2. Transverse momentum distributions at (□) 1800 and (•) 630 GeV ($|\eta| \leq 1.0$) for (*a*) the full MB samples, (*b*) the soft samples, and (*c*) the hard samples. In the bottom panel, the ratio of the two distributions is shown. The two curves delimit the band of all systematic uncertainties [see Section 2; for (*b*) and (*c*), the lower limit overlaps the data points]. N_{track} refers to the number of charged tracks in a unit η interval.

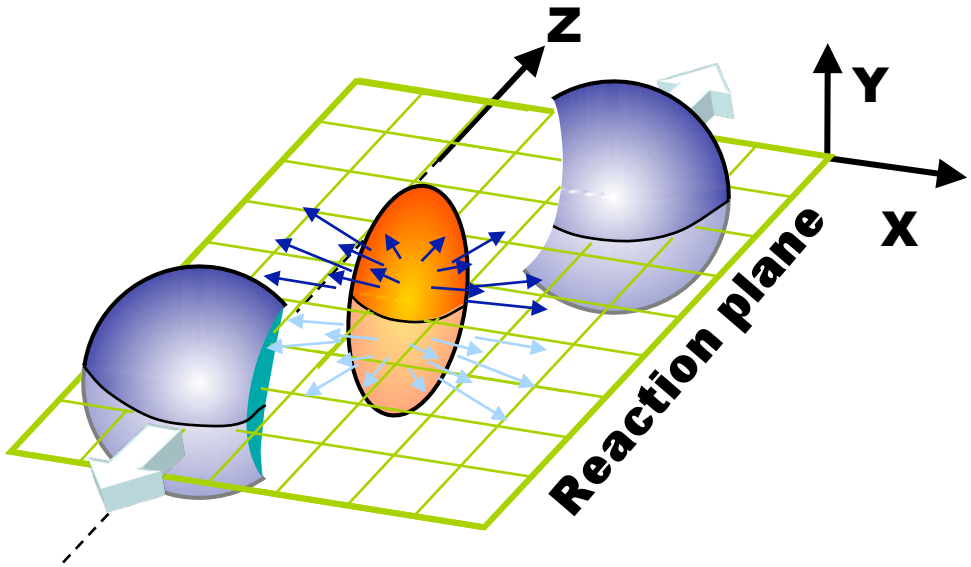
CDF (PRD 65:072005, 2002)

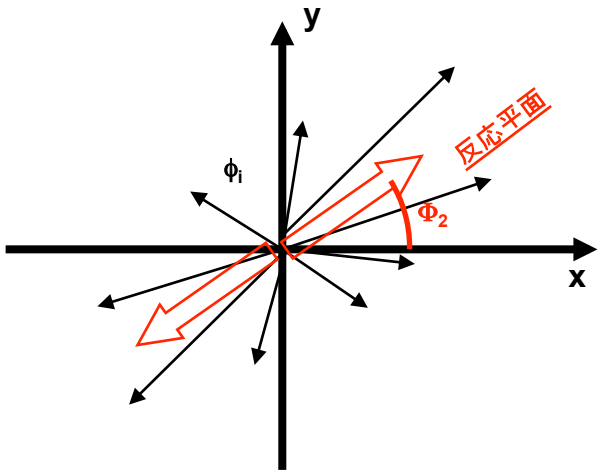
- How do high multiplicity events look like
  in various event generators (Pythia, Herwig, etc.)?

- Veto on jets in the ALICE environment a la CDF/STAR
  => p_T sum Σp_T, p_T balance (event shape)

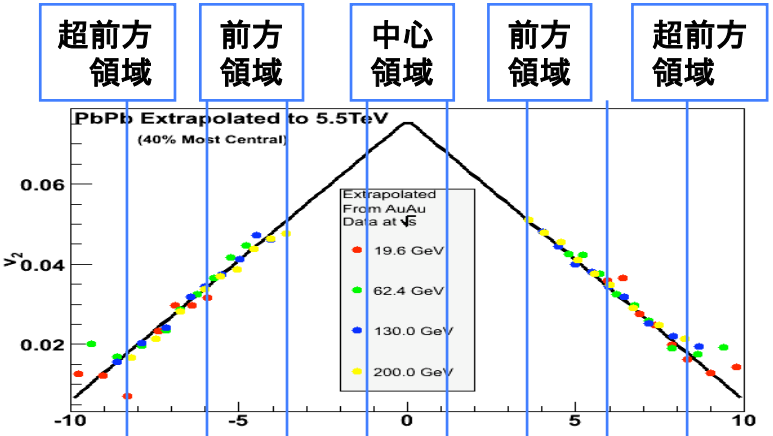
ALICE実験環境
での手法のテスト。

(2-c) ALICE実験における反応平面の可能性 （担当：江角）





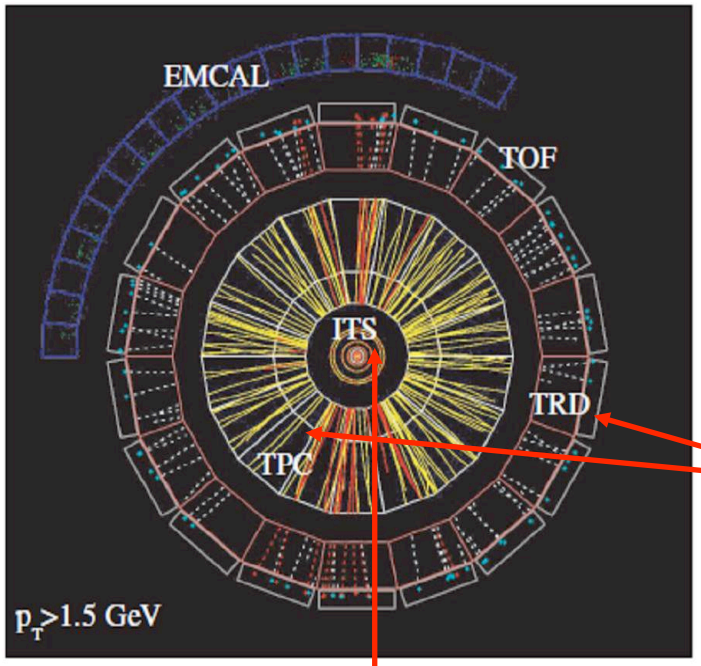
$$\tan(n\Phi_n) = \frac{\Sigma\, w_i * \sin(n\phi_i)}{\Sigma\, w_i * \cos(n\phi_i)}$$

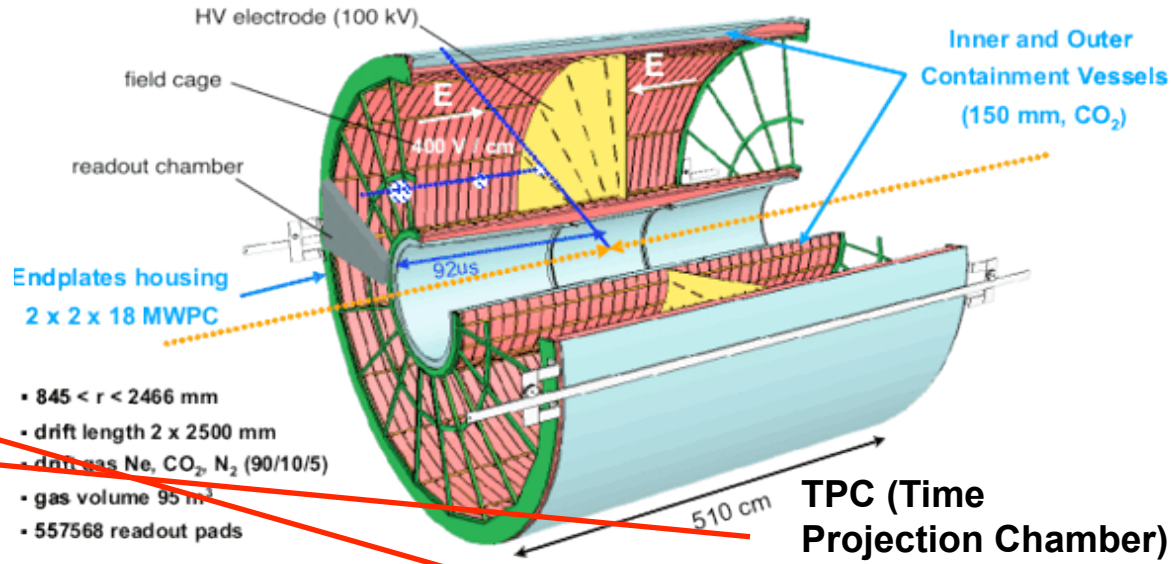


v_2(楕円的粒子放出)の原因：
- **異方性を持った圧力勾配**
- **QGP形状とジェット吸収**

PYTHIA (p+p)
HIJING (p+p の重ね合わせ、ジェット消滅)
AMPT (パートンカスケード)
HYDRO+JET (流体+ジェットモデル)

＋ ALICE検出器

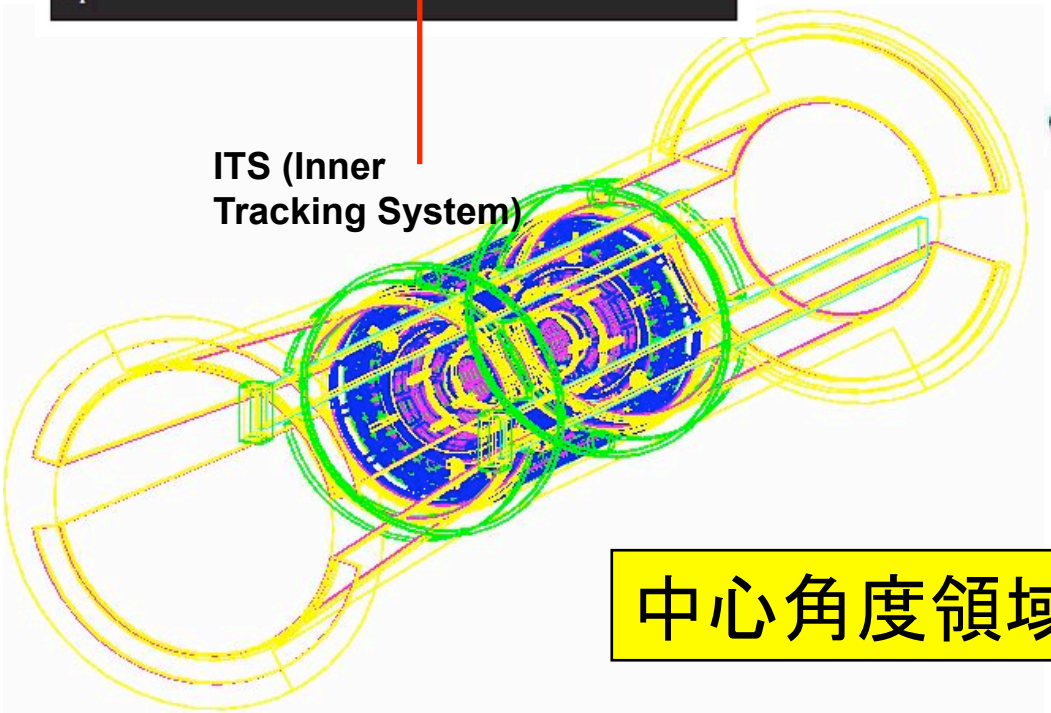


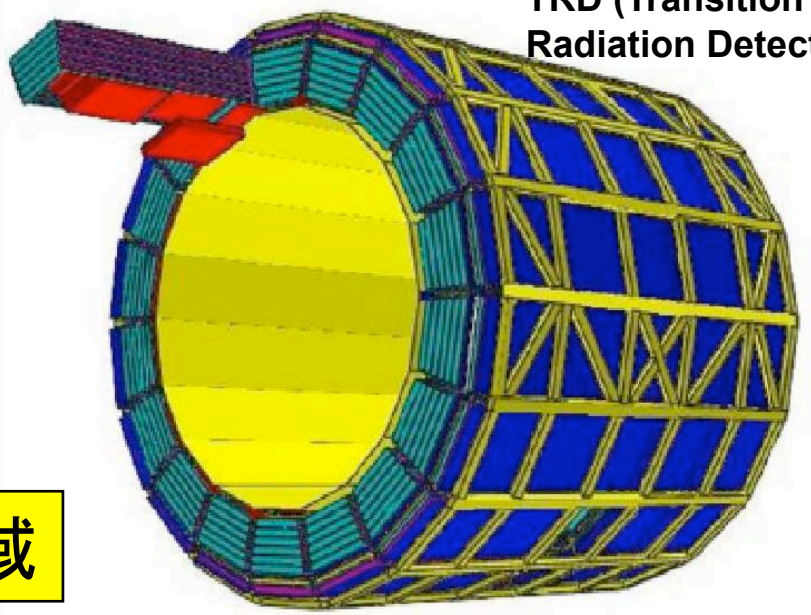


TPC (Time Projection Chamber)

TRD (Transition Radiation Detector)

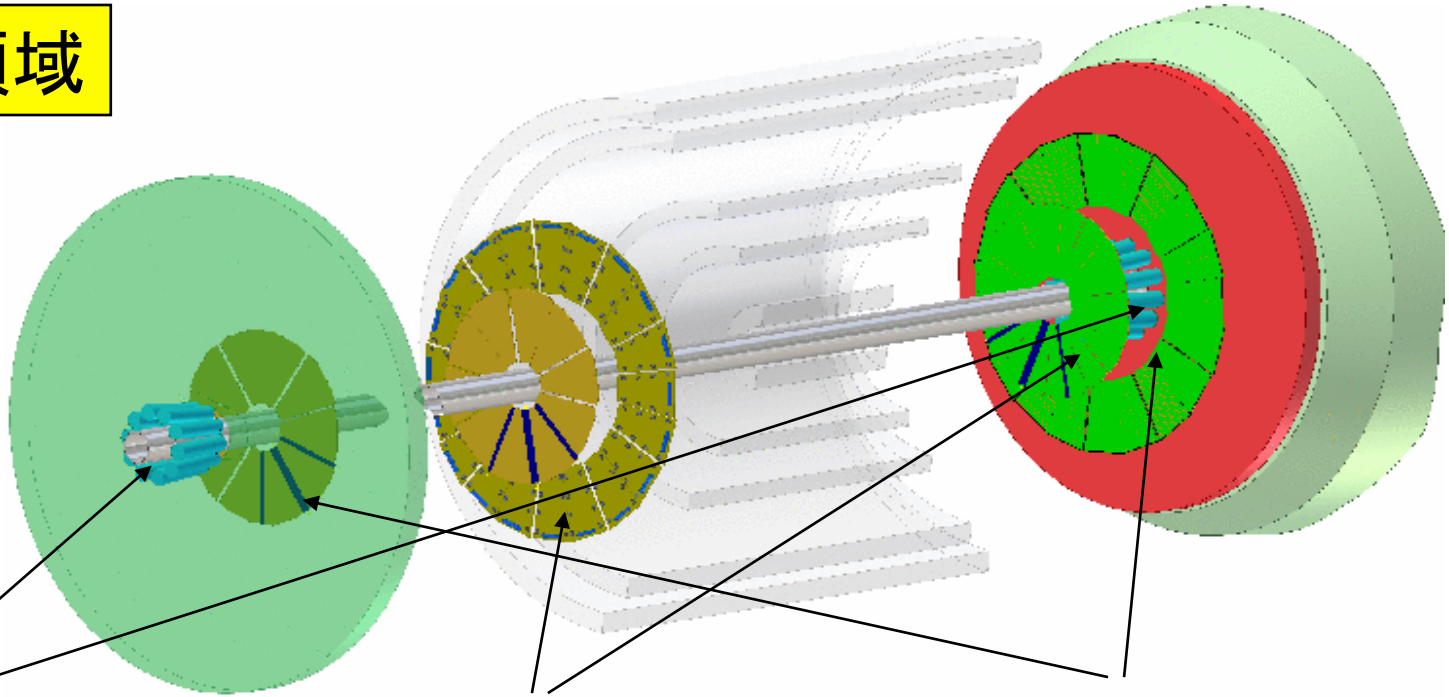
ITS (Inner Tracking System)

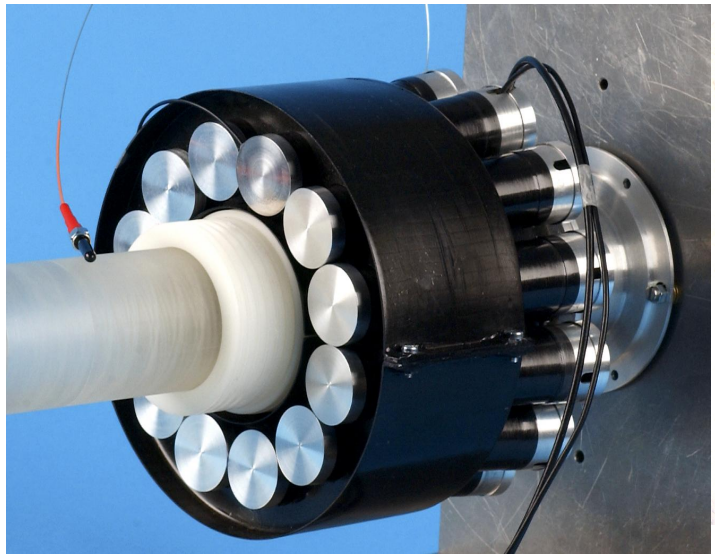


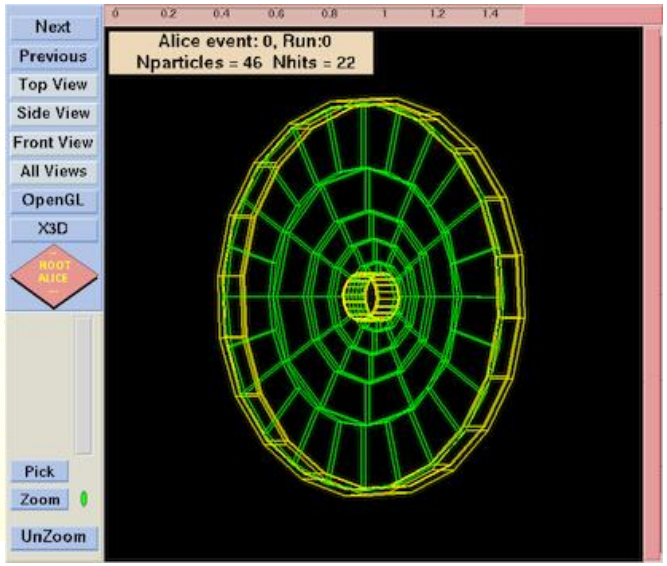


中心角度領域

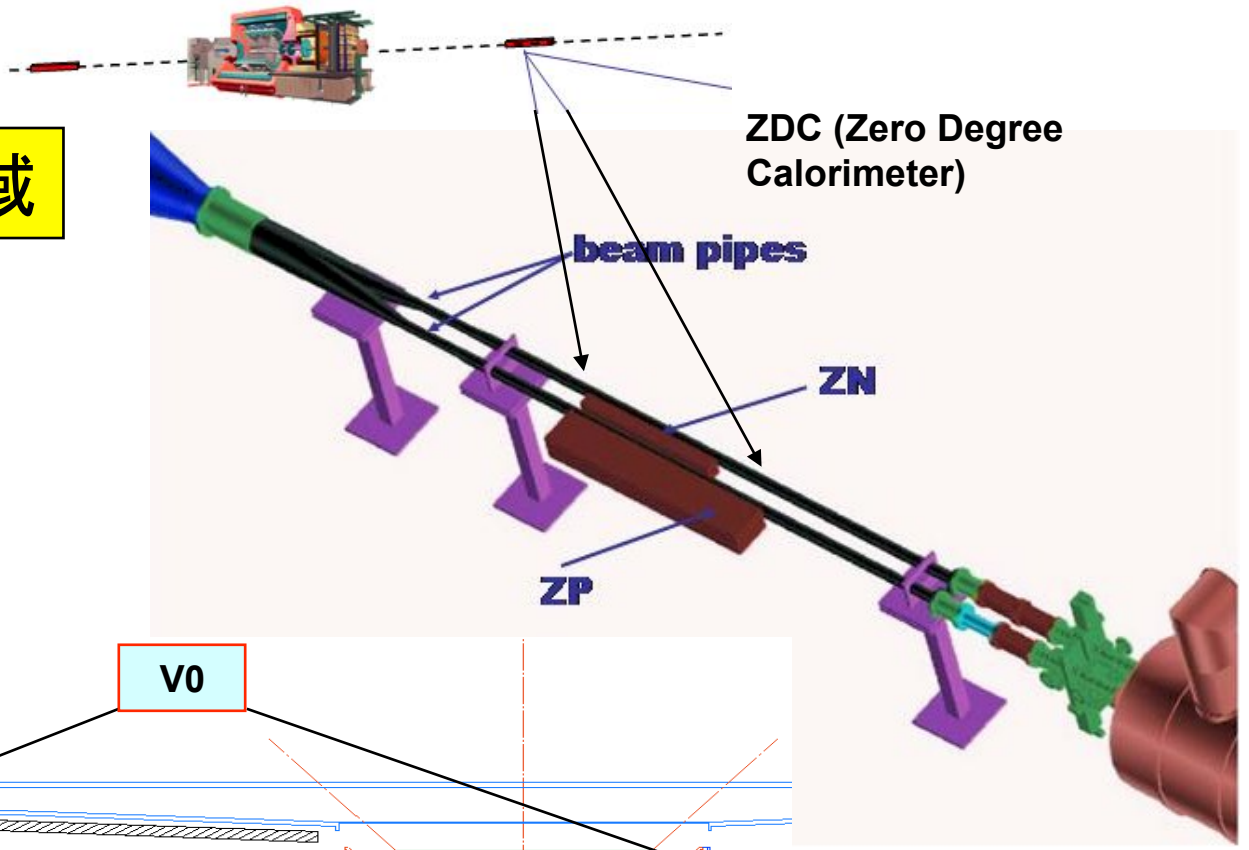
前方角度領域

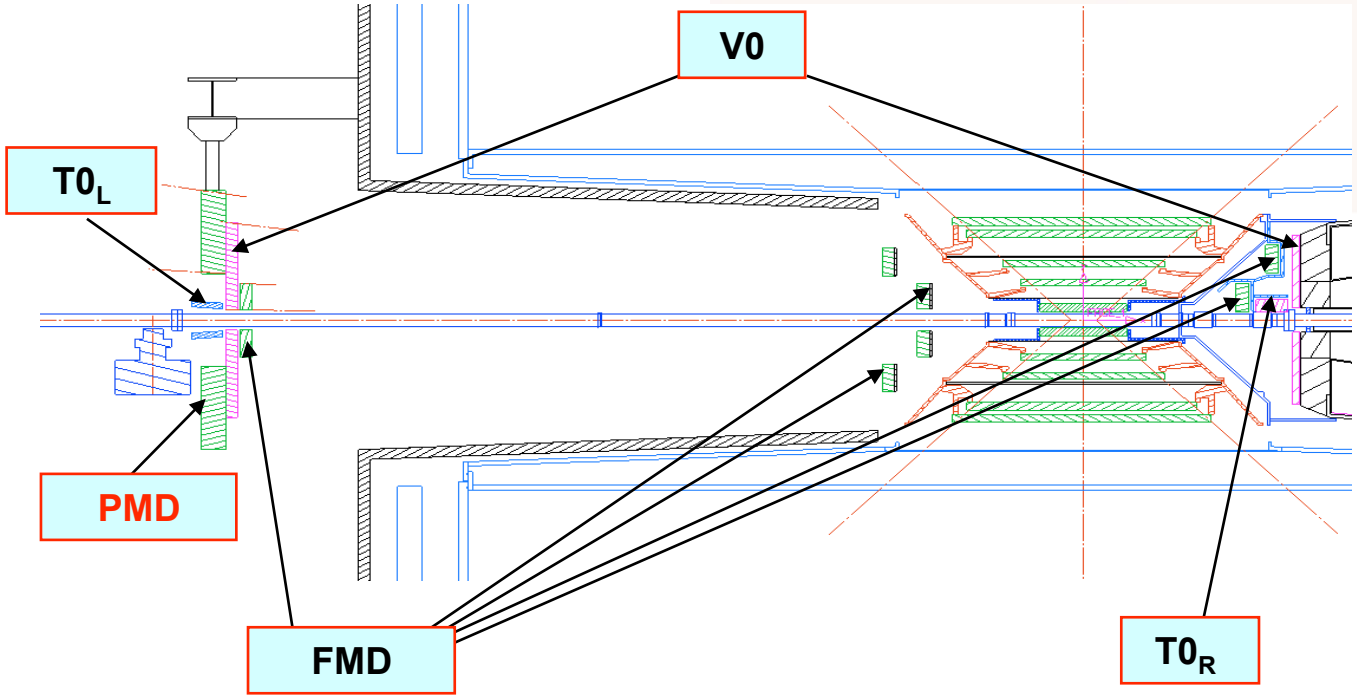

T0
FMD (Forward
Multiplicity Detector)
V0




Next
Previous
Top View
Side View
Front View
All Views
OpenGL
X3D
ROOT
ALICE
Pick
Zoom
UnZoom
Alice event: 0, Run:0
Nparticles = 46 Nhits = 22

(超)前方角度領域


ZDC (Zero Degree Calorimeter)
beam pipes
ZN
ZP

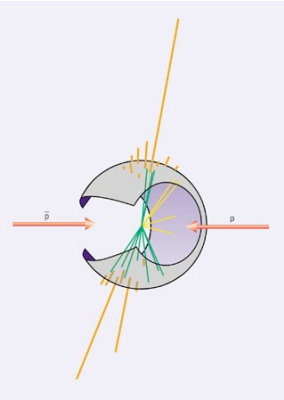

V0
T0L
PMD
FMD
T0R

(2-d) Three-particle correlations （担当：中條）

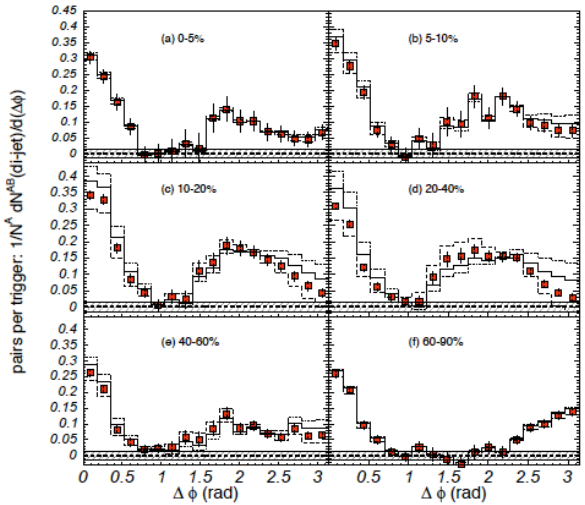
Three-particle correlations in Pb+Pb and p+p collisions at LHC-ALICE

- (possibly) producing a Mach-cone shock wave at LHC, when a energetic parton is traveling though a hot and dense medium (QGP).
- Measure the Mach-cone angle, speed of sound in QGP!

Jet modification at RHIC



A UA2 two-jet event, ca 1982



Phys. Rev. Lett. **97** (2006) 052301 (PHENIX)

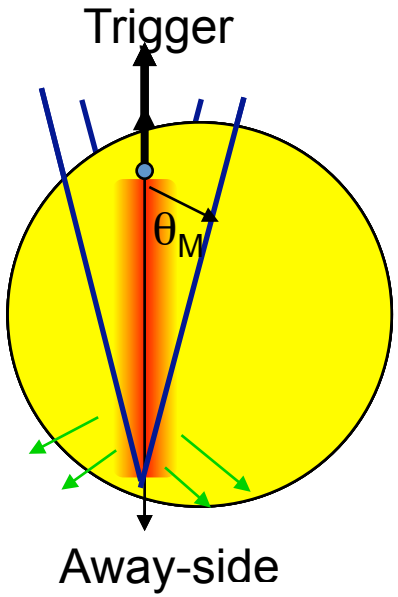
- From two particle correlations of charged hadrons, away side jet modification is observed at RHIC.
- Possible mechanism is due to the Mach-cone shock wave generated by large energy deposition in the hydrodynamic medium.

- Three particle correlation provides a powerful tool to identify the underlying physics process.
- If it is Mach-cone shock wave:
  - Speed of sound (c_s) in the strongly interacting QGP
  - EOS of the matter.

Mach-Cone

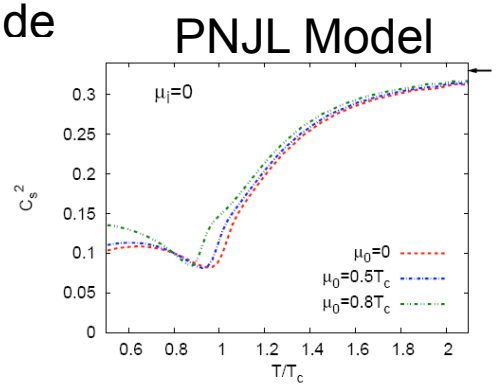
$$\frac{c_s}{v_{parton}} = \cos(\theta_M)$$

$$c_s^{\,2} = \frac{\partial p}{\partial \varepsilon};\ v_{parton} \approx c$$

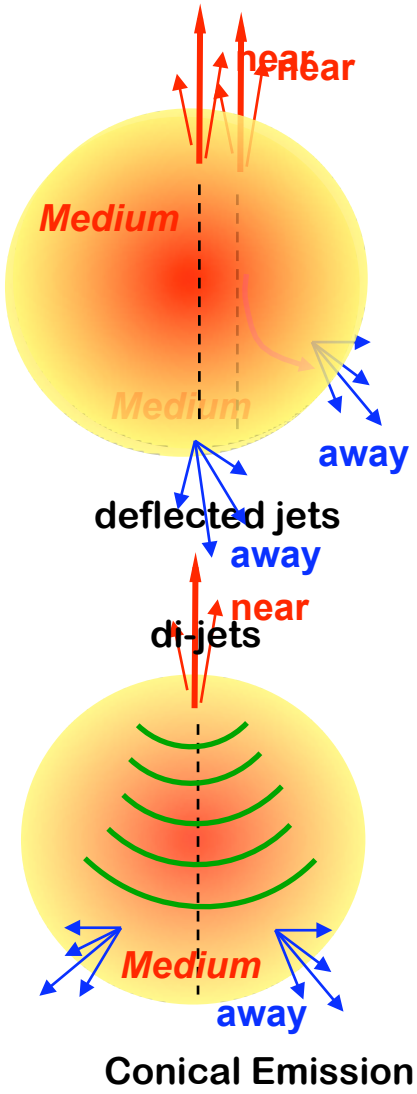


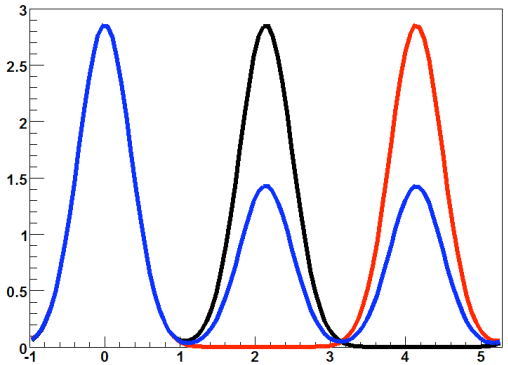
- Mach angle depends on speed of sound in medium
  - T dependent
- Angle independent of associated p_T.

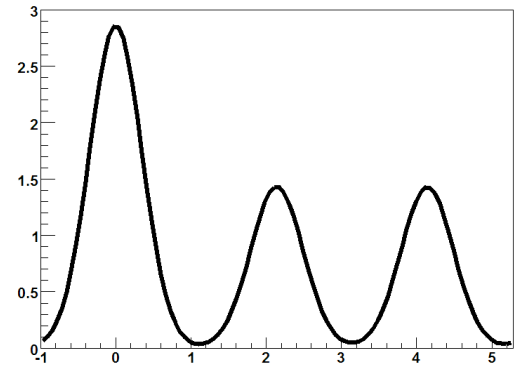
Mikherjee, Mustafa, Ray
Phys. Rev. D75 (2007) 094015

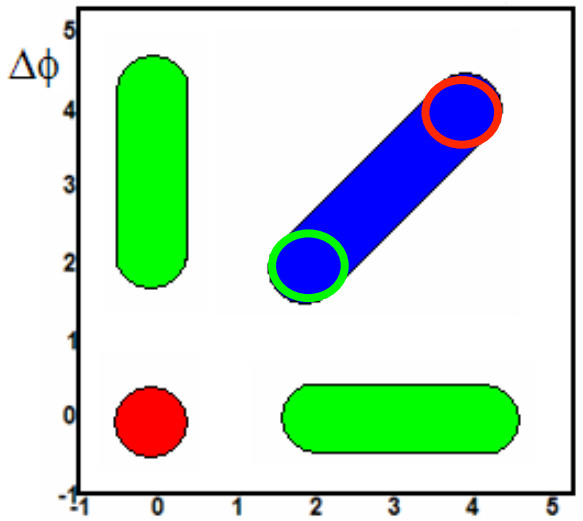


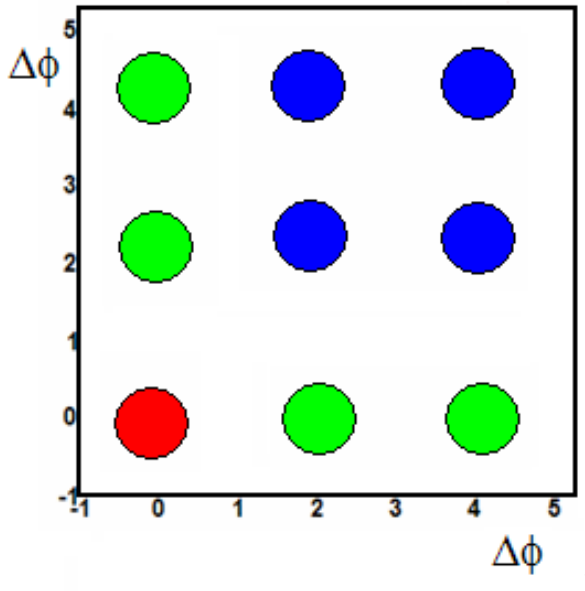
Azimuthal 3-Particle Correlations





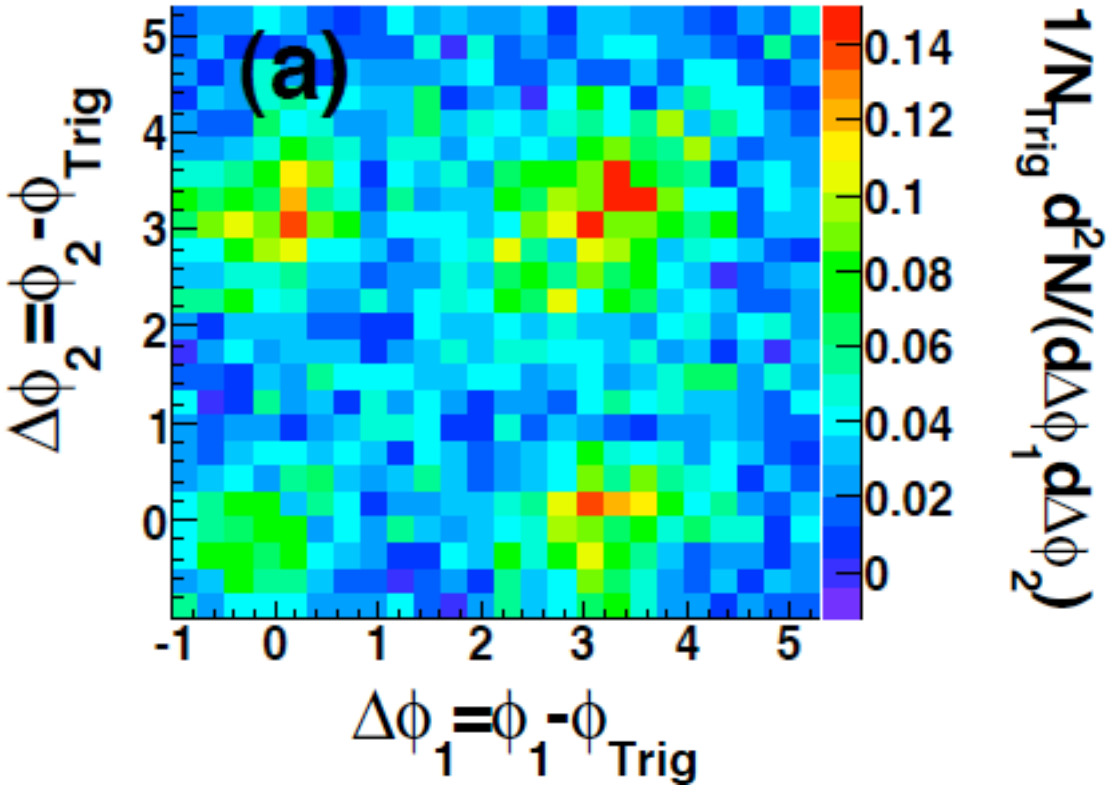






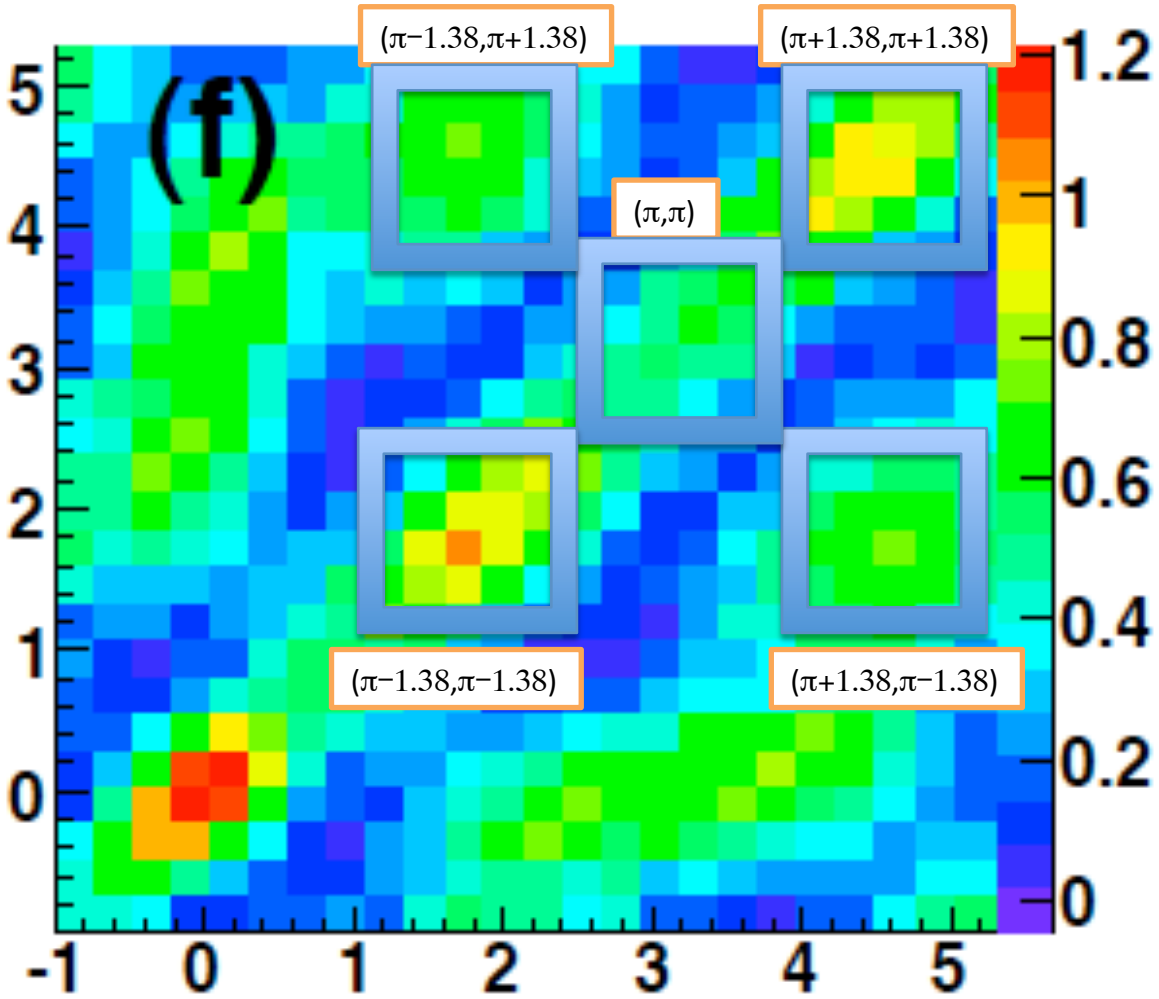
p+p 200 GeV (RHIC)

Background subtracted 3-particle correlations Y_3-hat



Au+Au 200 GeV (RHIC, STAR)

Background subtracted 3-particle correlations Y_3-hat



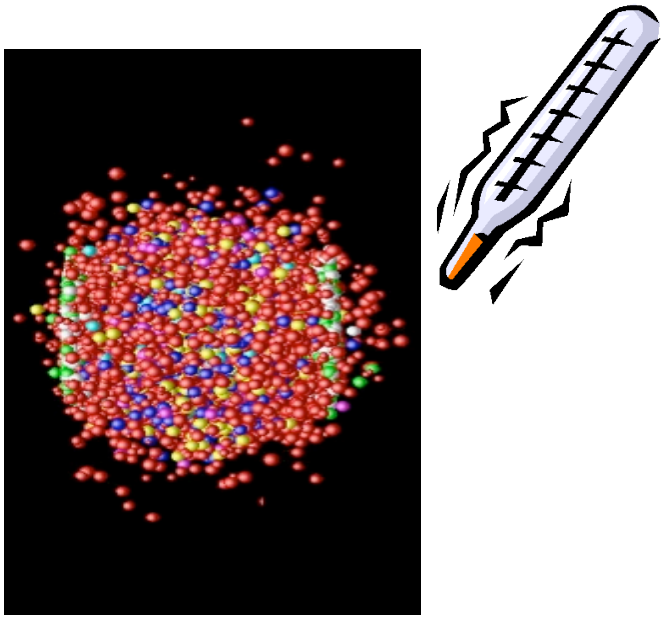
Outline for subject

- Tools:
  - AliRoot, simulation files (ESD, AOD) for p+p and Pb+Pb.
- Detectors: TPC, ITS…
- Measured charged hadron correlations, one trigger particle and two associated particle (lower p_T).
    - $\Delta\phi_1$, $\Delta\phi_2$, η, for foreground and background.
    - Start from the simplest case, p+p, 2 particle correlations.
- **Timeline:**
  - week-1: Get familiar with AliRoot, ALICE offline frame work, use CAF and batch job system.
  - week-2: Reconstruct two particle correlations in p+p. Study on the BG.
  - week-3: BG subtraction in p+p, three particle correlations in p+p.
  - week-4: Study on Pb+Pb simulation data (AMPT available?), results. Preparation for the presentation.
  - week-5: Presentation (and analysis note if it's possible).
- **GOAL:** Establish and develop the three particle analysis tool, and check with the simulated p+p data, especially how to estimate the background distribution. If time permits, go to Pb+Pb simulated data (but it needs to study on v2, v4 subtractions).

(2-e) Initial temperature at LHC （担当：中條）

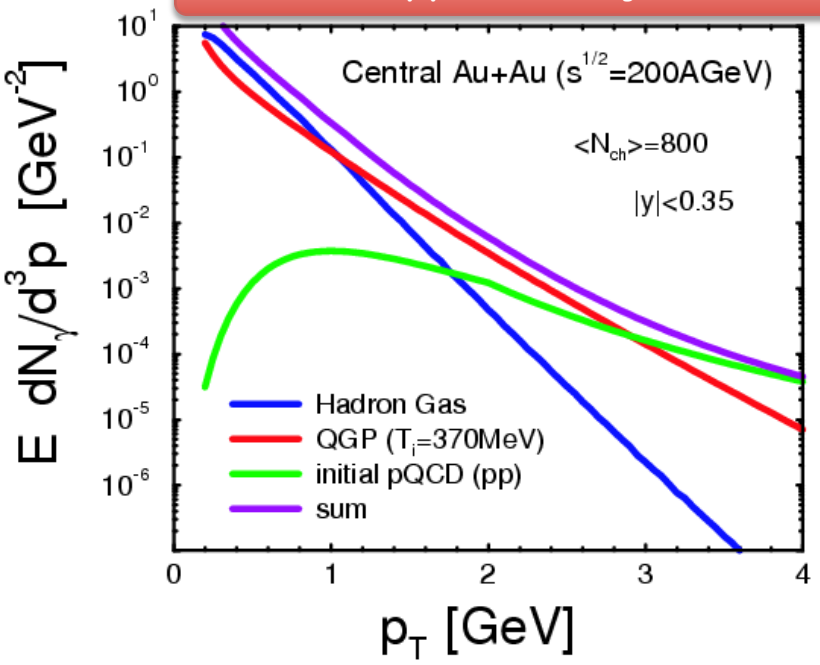
Measurement of direct photon spectra using the internal conversion method in Pb+Pb and p+p collisions at LHC-ALICE

- p_T spectra of direct photon by internal conversion method (e^+e^- pair).
- From p_T slope, one can extract the initial temperature of the matter.



What can we expect in Heavy Ion Collisions?

Turbide, Rapp, Gale, Phys. Rev. C 69 (014903), 2004



Direct photon:

- Produced by the initial hard scatterings.
- No strong interaction, thus a clean signal.
- Sensitive to the initial state of the matter.
- Thermal photon radiation.
- From p_T spectrum, initial temperature can be deduced.

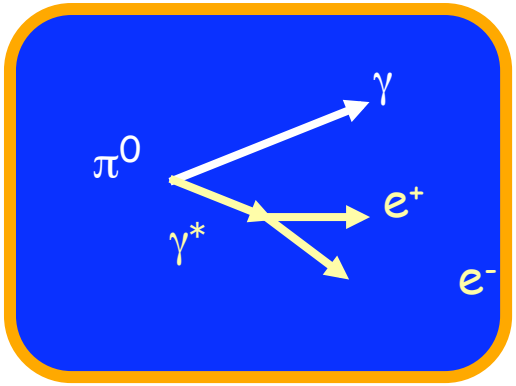
But…

- Huge back ground to measure thermal photons (only 10% of hadron BG).
- Window for thermal photons from QGP in this calculation (@ RHIC): **p_T = 1 - 3 GeV/c**

A new Idea of thermal photon measurement

Use lepton pairs to measure

virtual γ



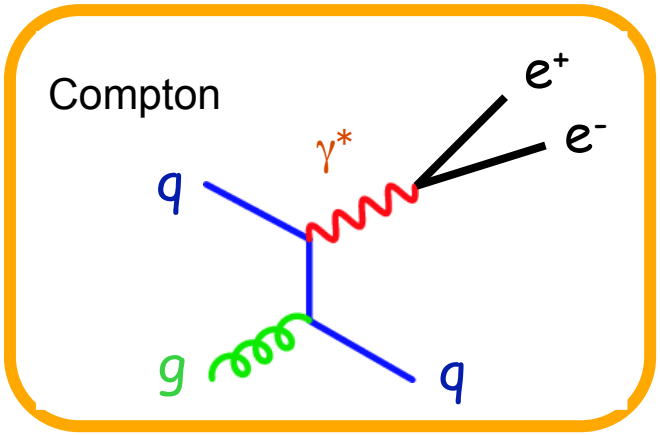
Daliz decay

Two sources of virtual γ with very low (invariant) mass:

1. **Background from Dalitz decay**
   - **Kroll-Wada formula**
2. **Hard photon (signal) = thermal photon candidate**

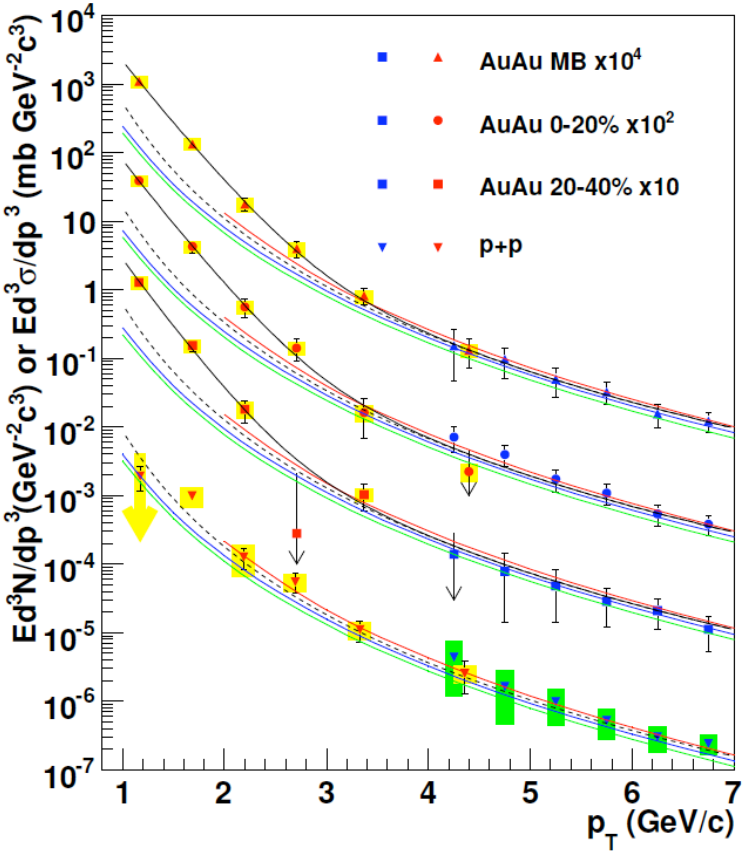
$$\frac{\gamma^*_{direct}}{\gamma^*_{incl.}} = \frac{\gamma_{direct}}{\gamma_{incl.}}$$

excess over known hadronic source



e^+e^- internal conversion pair from hard scattering

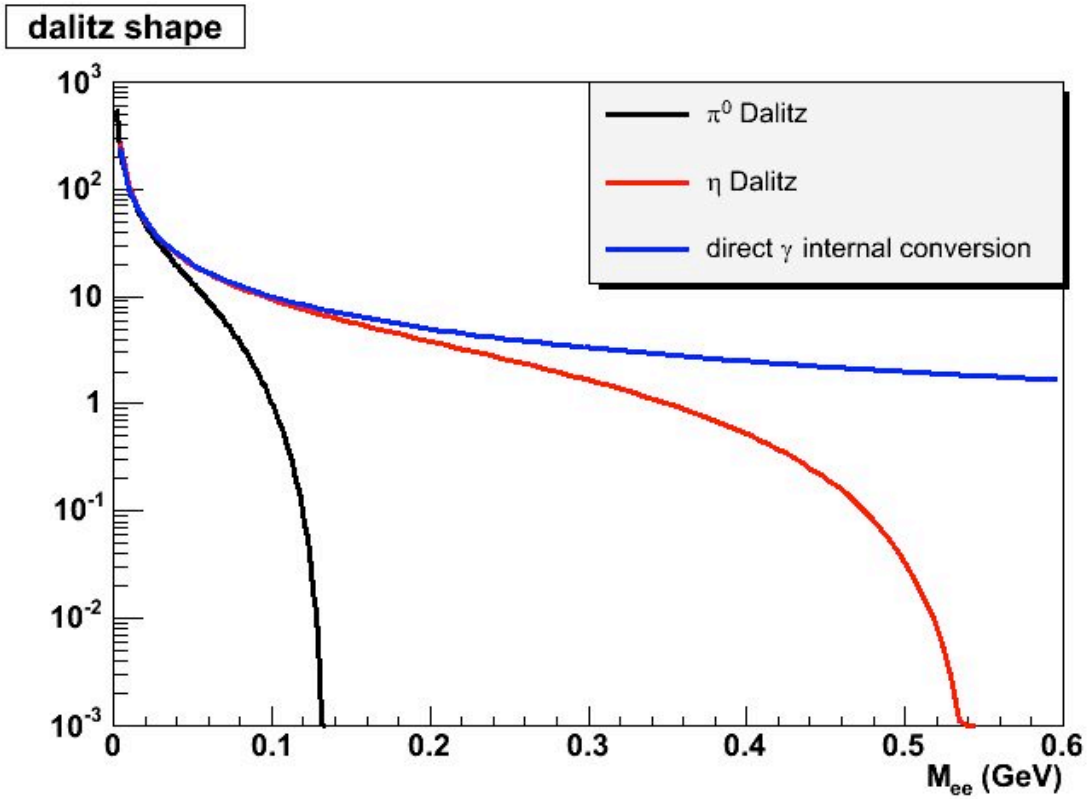
Initial Temperature at RHIC



T_0 = 370 MeV at RHIC?

Invariant Mass Distribution of Dalitz Pairs

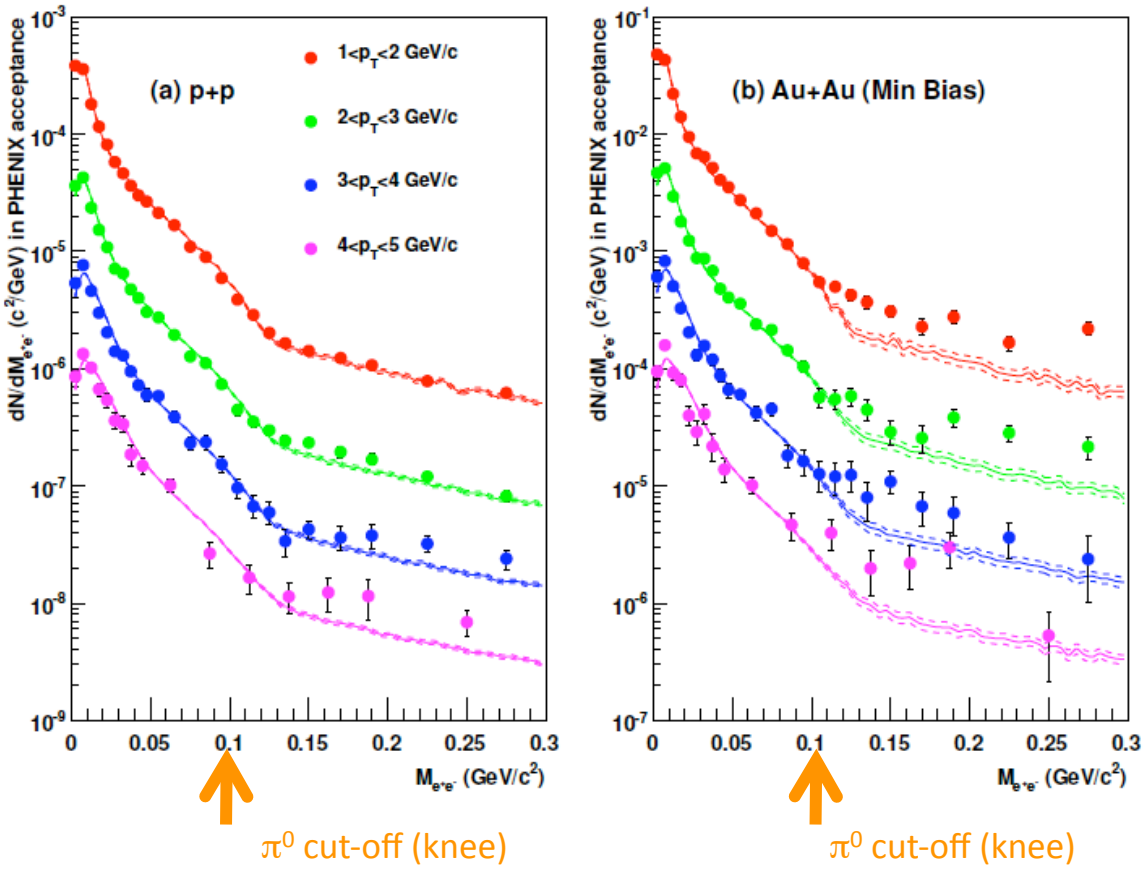
$$\frac{1}{N_\gamma}\frac{dN_{ee}}{dm_{ee}} = \frac{2\alpha}{3\pi}\sqrt{1-\frac{4m_e^2}{m_{ee}^2}}\left(1+\frac{2m_e^2}{m_{ee}^2}\right)\frac{1}{m_{ee}}\left|F(m_{ee}^2)\right|^2\left(1-\frac{m_{ee}^2}{M^2}\right)^3$$



Kroll-Wada formula
(mass distribution of Dalitz decay for pseudo-scalar meson, π^0, η, η')

(1) Pure QED part
(2) Form factor: F
(3) Phase space factor

e^+e^- invariant mass distributions (RHIC-PHENIX)



π^0 cut-off (knee)

π^0 cut-off (knee)

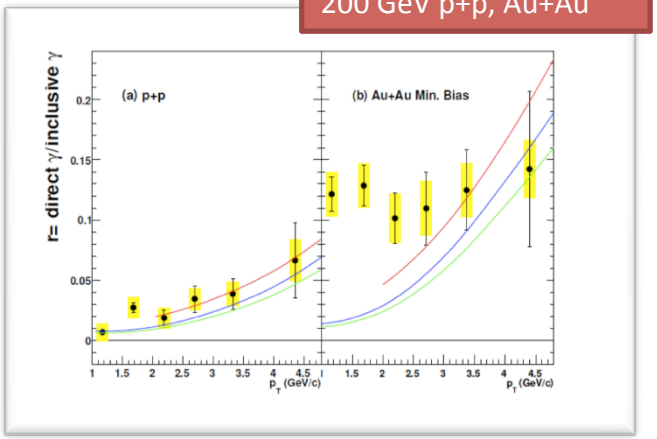
- Hadronic BG above cut-off is reduced by 80%.
- p+p: consistent with BG at low pT, but an (little) excess at high pT.
- Au+Au: excess for all pT.

Possible source of excess is internal conversion of direct photons.

Outline for subject

- (Maybe) only p+p data can be used due to the complexity of this analysis (and not yet measured baseline spectra in Pb+Pb at LHC).
- **Timeline**
  - Week-1: Get familiar with AliRoot, simulation files (p+p), ALICE offline framework.
  - Week-2: Electron Identification study.
    - S/B, efficiency, by using TRD, TPC.
  - Week-3: Make an invariant mass distribution of e+e- pairs.
    - Check the known resonance peaks (ϕ, ω, J/ψ,...).
    - Study on the conversion in the detector material, and how to remove them.
    - Combinatorial BG.
  - Week-4: Extract direct photon.
    - Make a inclusive photon spectra.
    - Make a ratio of direct photon and inclusive photon.
    - Comparison with NLO pQCD.
    - Prepare for the presentation.
  - Week-5: Presentation (and Analysis Note writing)
- **GOAL: Test of NLO pQCD in p+p.**

RHIC-PHENIX
200 GeV p+p, Au+Au

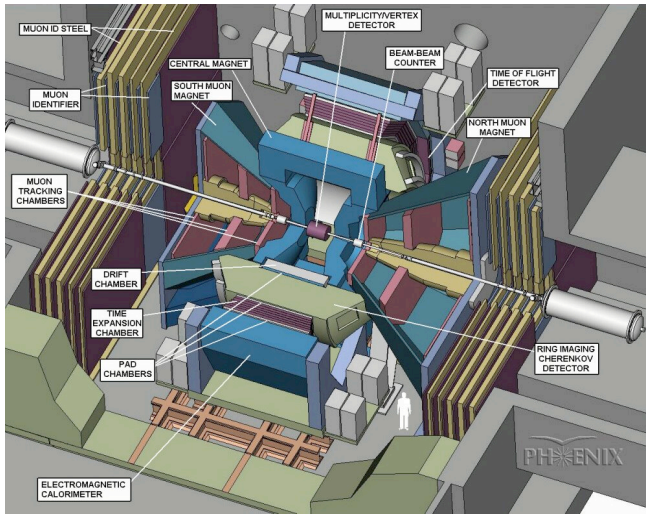


(3) PHENIX重イオン衝突データの解析

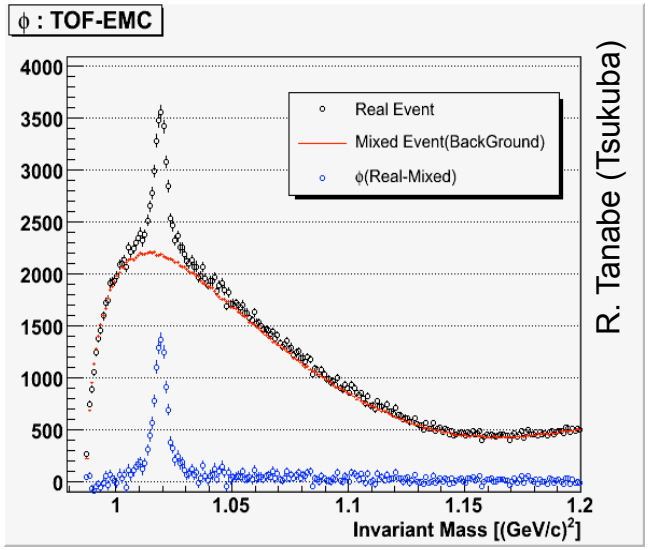
（RCFのコンピュータアカウントが必要）

(3-a) Run-7 データを用いたΦ･Λの測定　（担当：江角）

- Root Tree 形式のSummary Data (DST)を使う
- 衝突事象、粒子軌跡、粒子種の選別
- 不変質量の計算による崩壊粒子の再構成
- イベントミキシングによるランダムなBGの見積もり
- 粒子横運動量分布、方位角異方性の計算
- モンテカルロシミュレーションによる効率等の補正
- 反応平面分解能の見積もり、補正

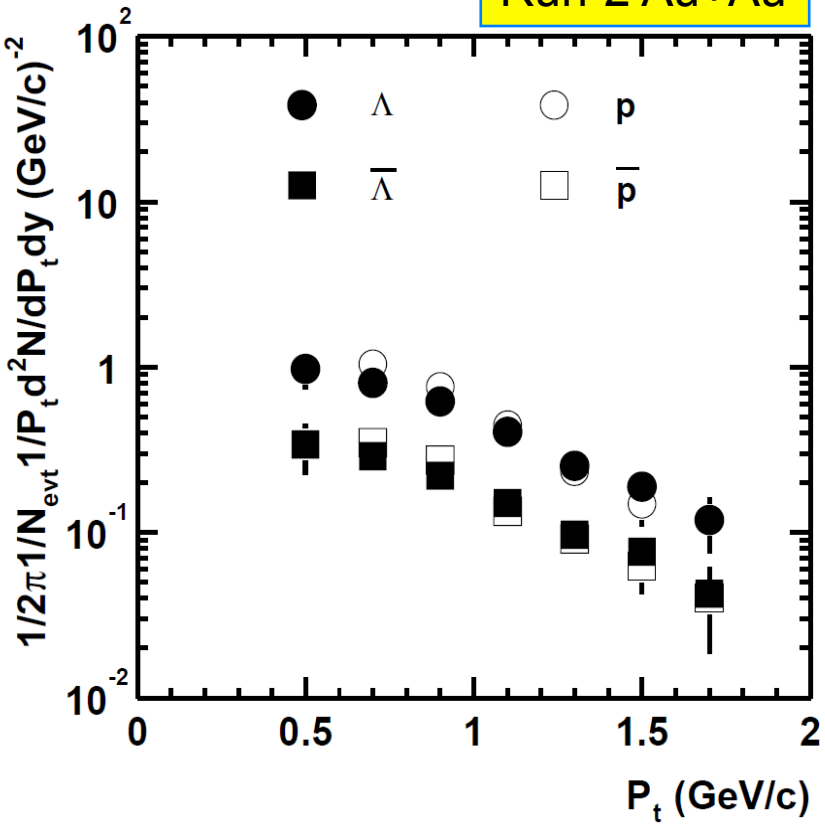


PHENIX検出器



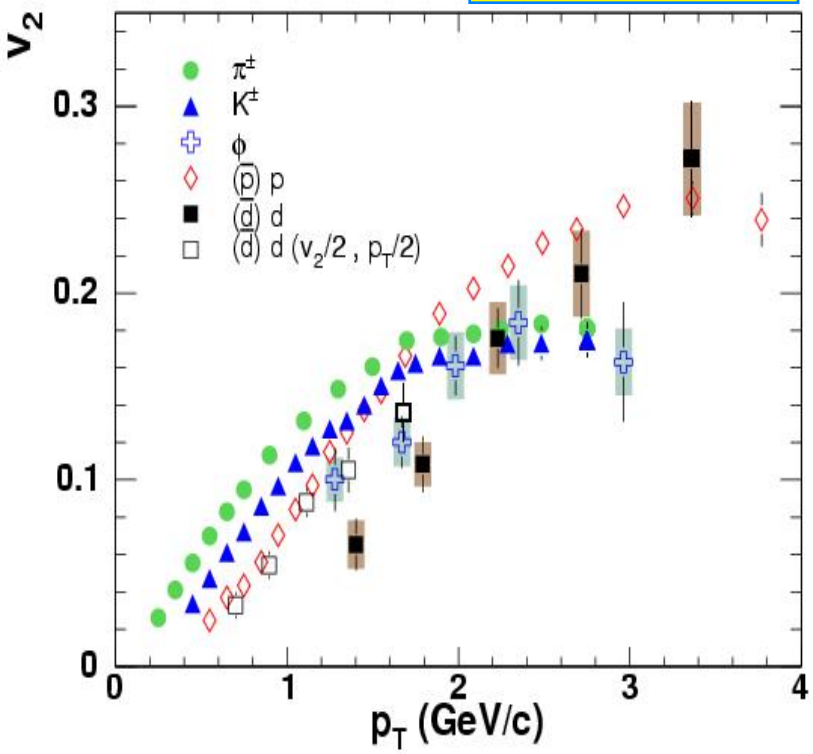
不変質量分布(Φ->KK)

Run-2 Au+Au



Λの横運動量分布

Run-4 Au+Au



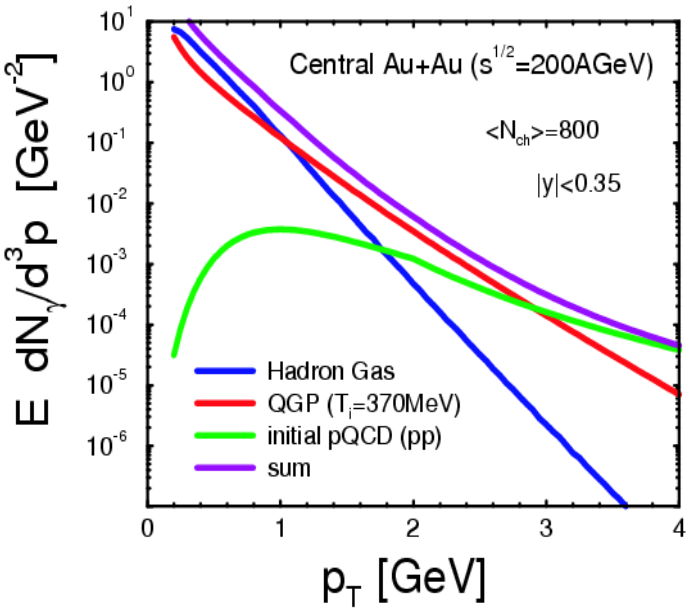
Φの方位角異方性(v2)

Merits: - High statistics Run-7 Au+Au data (x3 Run-4 Au+Au)
- New detectors for particle identification
- Reaction plane resolution improved with a new detector

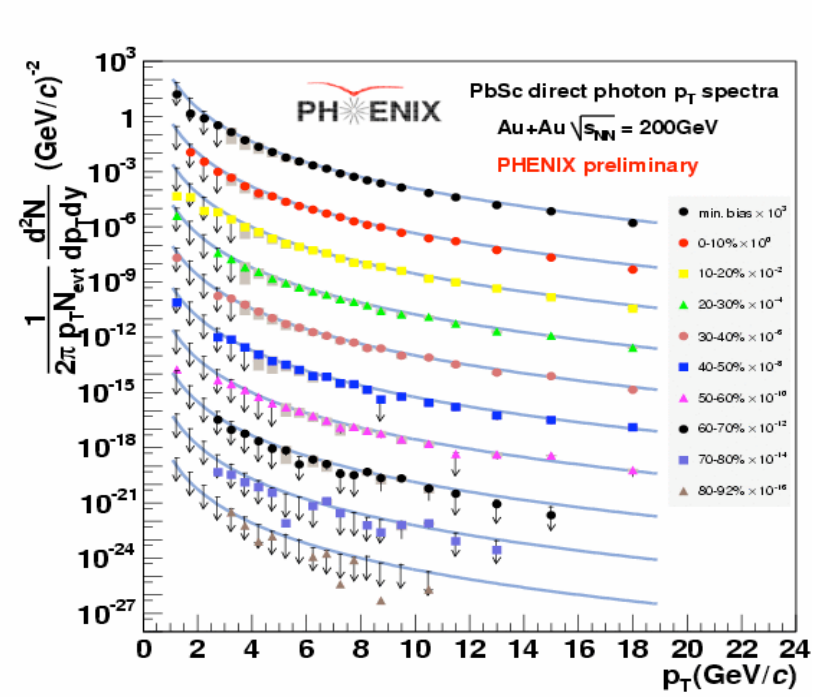
(3-b) Run-7 データを用いたパイゼロ・光子の測定 （担当：金野）

- Direct photo is a penetrating probe
  for the initial hot and dense matter created in heavy ion collisions.

- There are several photon sources in heavy ion collisions (see left).

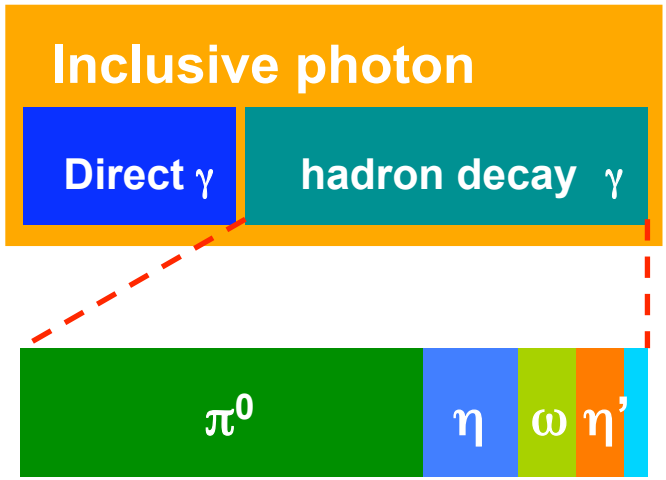


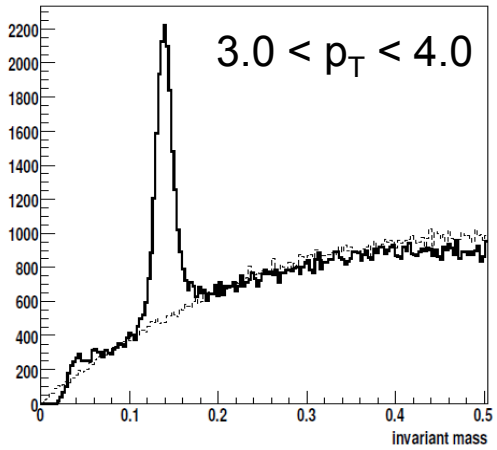
Phys. Rev., C69:014903(2004)

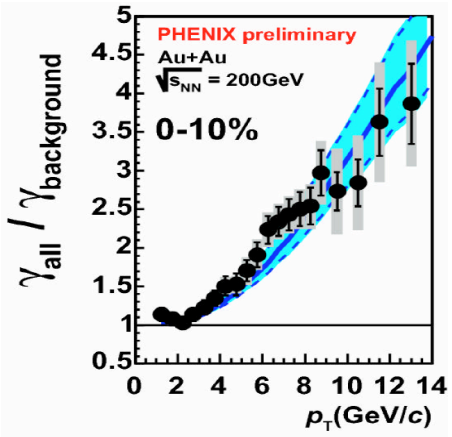


- Reconstruct neutral pion via two-gamma decay
- Calculate p_T spectra, v_2 for neutral pion, inclusive photon
- Subtracting hadron decay photon from inclusive photon
  => Calculate p_T spectra, v_2 for direct photon

典型的な解析手法。



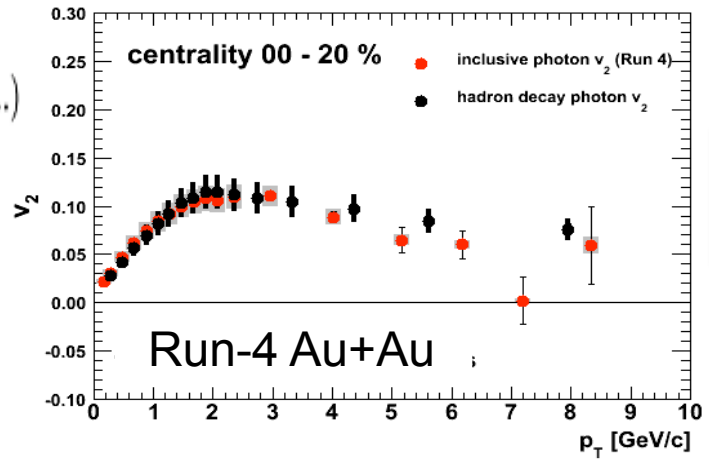




Merits: - High statistics Run-7 Au+Au data (x3 Run-4 Au+Au)
- Reaction plane resolution improved with a new detector

$$\frac{dN}{d(\phi-\Psi)} = N_0(1+2v_1\cos(\phi-\Psi)+2v_2\cos(2(\phi-\Psi))+.....)$$

Elliptic flow



さらに高いp_Tでの直接光子測定。

Miki, QM08