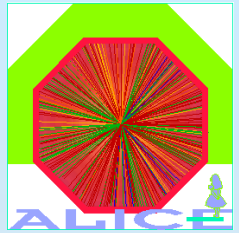
Quark Physics Laboratory
Hiroshima University, Japan

Korean Heavy Ion Meeting 2007-10 on
Physics with PHENIX and ALICE



Photon Physics in ALICE

Jeju in Korea

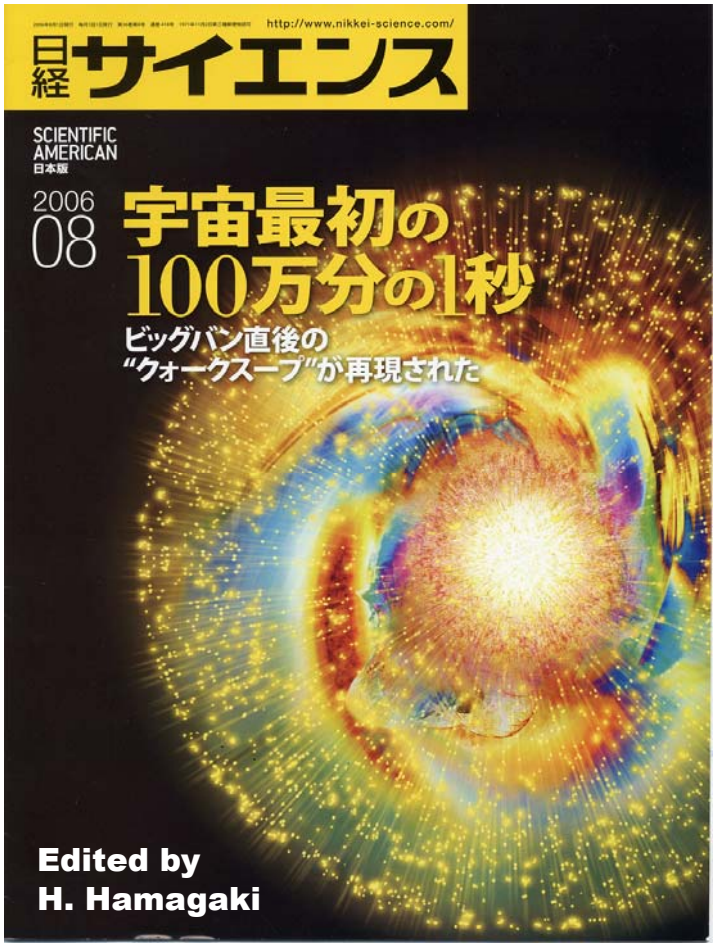
Oct. 19 - 20, 2007

Toru Sugitate / 杉立　徹
Hiroshima University / 広島大学大学院理学研究科
sugitate@hiroshima-u.ac.jp

What learned at RHIC

E802/859/866 @AGS-BNL	p=14.6 GeV/A, $\sqrt{s_{NN}}$=5.4 GeV
NA44/WA98 @SPS-CERN	p=160 GeV/A, $\sqrt{s_{NN}}$=17 GeV
PHENIX @RHIC-BNL	p=100+100 GeV/A, $\sqrt{s_{NN}}$=200 GeV

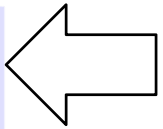
- hot: thermally radiative (!?)
  - thermal photons (!?), T~500MeV
- dense: energy loss of (even heavy) quarks, ε>15GeV/fm^3, dN_g/dy>1100
  - jet quenching (high p_t suppression)
  - jet modification
- partonic: quarks' degrees of freedom, screening
  - quark number scaling of collective motion
  - J/Ψ suppression
- strongly coupled: perfect fluidity
  - hydro-dynamic behavior of collective motion

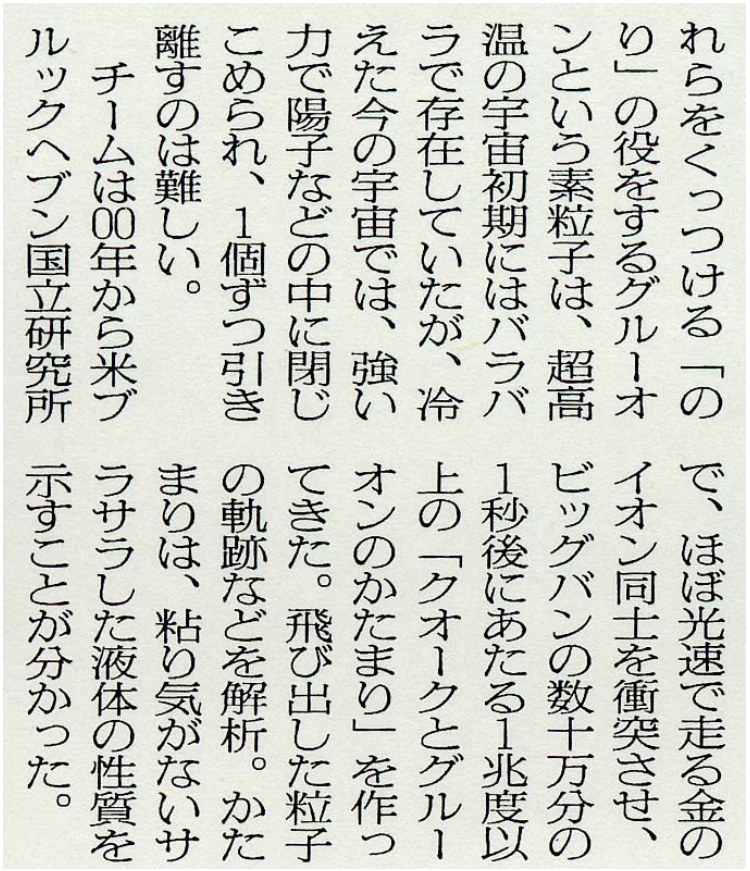


How it impacts to people?

Asahi newspaper on April 17, 2005

Liquid drop at the birth of Universe ?





宇宙の誕生 しずくから?

「クオークは液体状態」解明

日米など国際チーム

宇宙誕生の大爆発「ビッグバン」直後に相当する超高温・高密度の状態を再現する実験をしてきた日米などの国際チームは18日、物質を形づくる究極の基本粒子クオークは超高温でバラバラになるが、気体のように自由に跳び回るのでなく、しずくのような液体状態にあったと考えられる、と発表した。理論的に予想外の発見で、宇宙や物質のなりたちを説明するシナリオに影響を与える可能性がある。

基本粒子クオークとそれらをくっつける「のり」の役をするグルーオンという素粒子は、超高温の宇宙初期にはバラバラで存在していたが、冷えた今の宇宙では、強い力で陽子などの中に閉じこめられ、1個ずつ引き離すのは難しい。

チームは00年から米ブルックヘブン国立研究所で、ほぼ光速で走る金のイオン同士を衝突させ、ビッグバンの数十万分の1秒後にあたる1兆度以上の「クオークとグルーオンのかたまり」を作ってきた。飛び出した粒子の軌跡などを解析。かたまりは、粘り気がないサラサラした液体の性質を示すことが分かった。

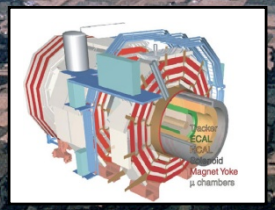
Heavy Ion Collisions at LHC

$\sqrt{s}$ = 14 TeV for proton + proton

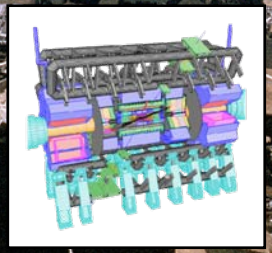
$\sqrt{s_{NN}}$ = 5.5 TeV for Pb + Pb

$\sqrt{s_{NN}}$ at LHC = 28 x RHIC =320 x SPS = 1000 x AGS

CMS実験



LHC-b実験



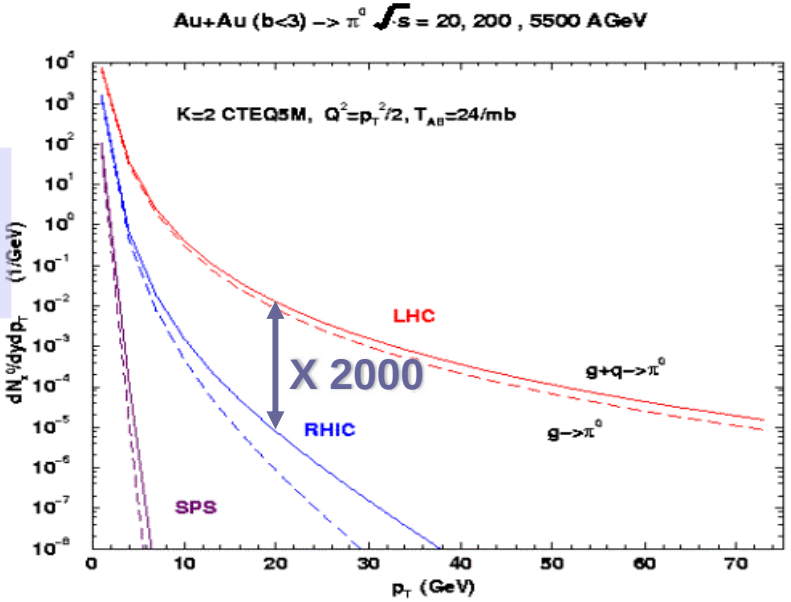
ATLAS実験

ALICE実験

New features at LHC

- QGP formation
  - X 2 T^{RHIC}
  - X 10-20 ε^{RHIC}
  - X 3-5 V_{FO}^{RHIC}
  - X 3-5 τ_{QGP}^{RHIC}

Thermo-dynamic feature p~T~GeV



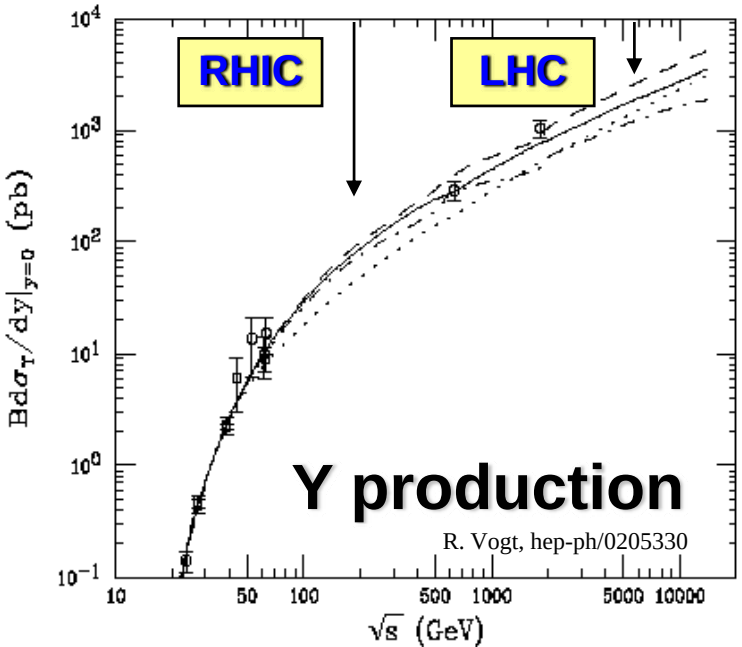
- dominant hard process

$$\sigma^{hard} / \sigma^{tot}$$

~2% at SPS
~50% at RHIC
~98% at LHC

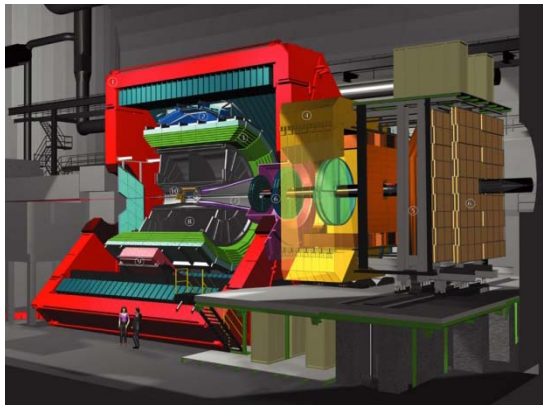
- heavy quark production

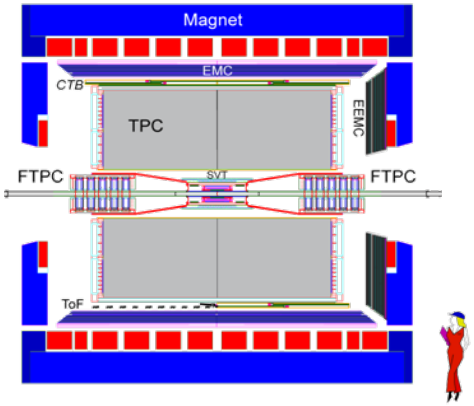
$$\sigma_{\Upsilon}^{LHC} \approx 20 \times \sigma_{\Upsilon}^{RHIC}$$

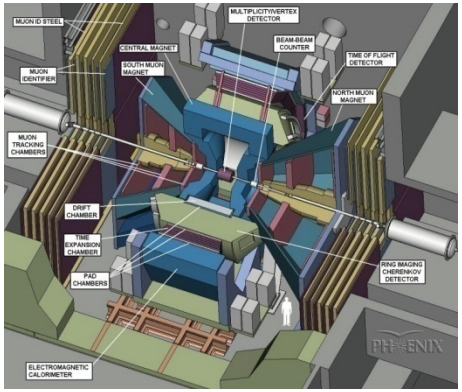


One dedicated exp. for HI Physics

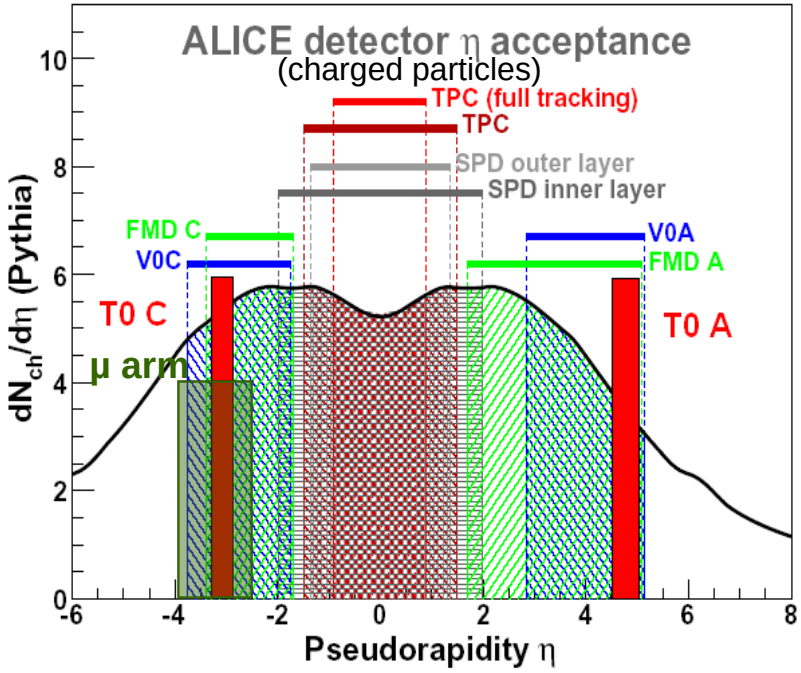
ALICE = STAR + PHENIX + ・ ・



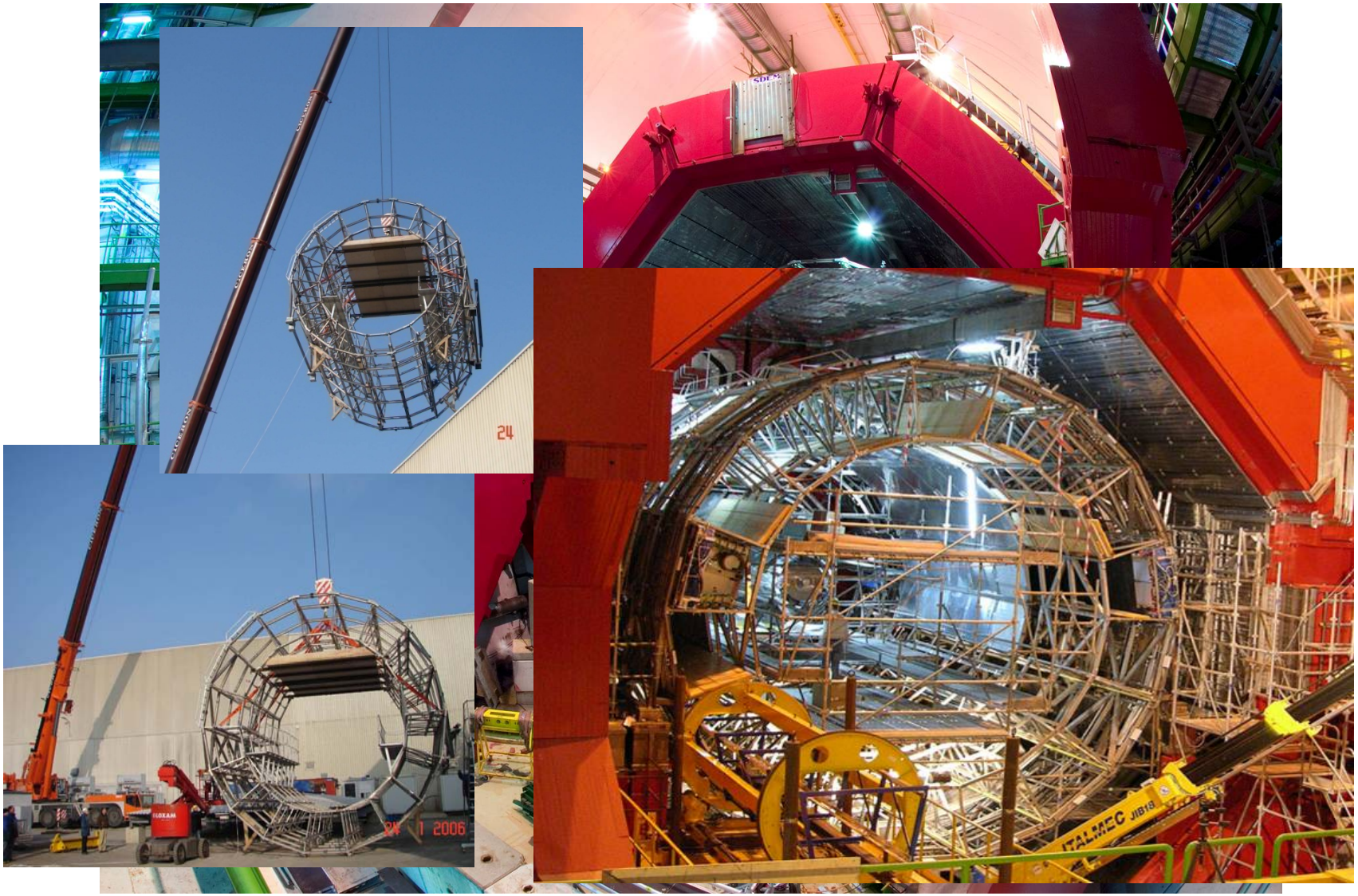




- central barrel: -0.9 < η < 0.9
  - tracking and particle identification in full azimuth
  - partial coverage of HMPID, PHOS, EMCal
- forward μ arm: - 4 < η < -2.4
- multiplicity: - 3 < η < 5.4

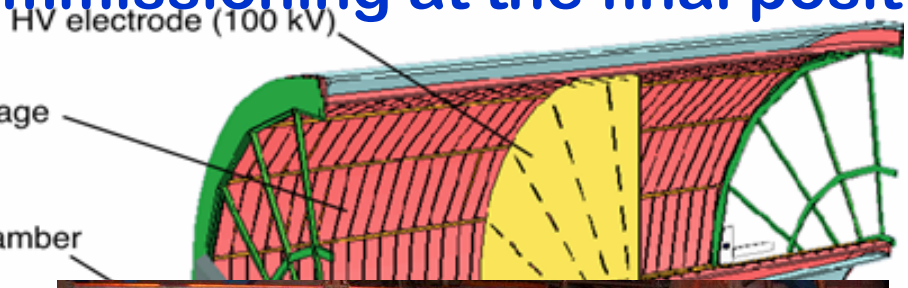


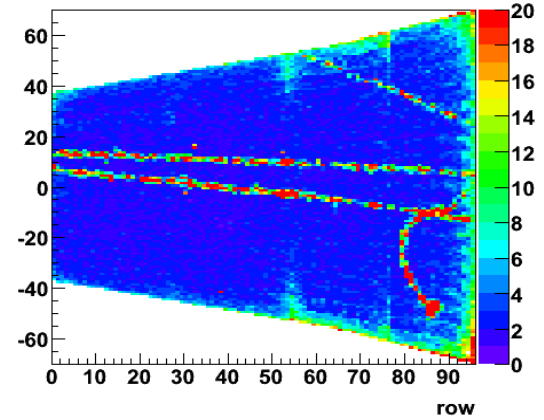
Central barrel support

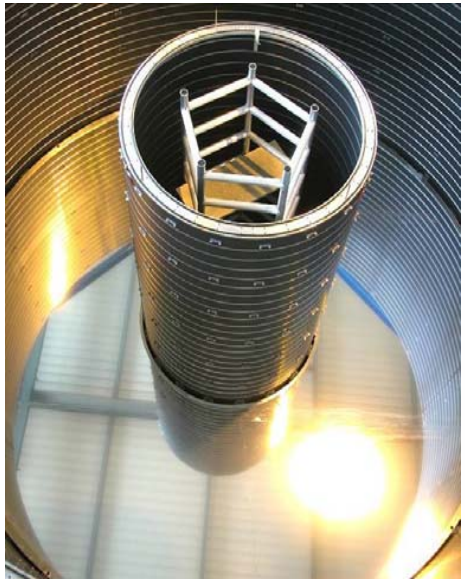


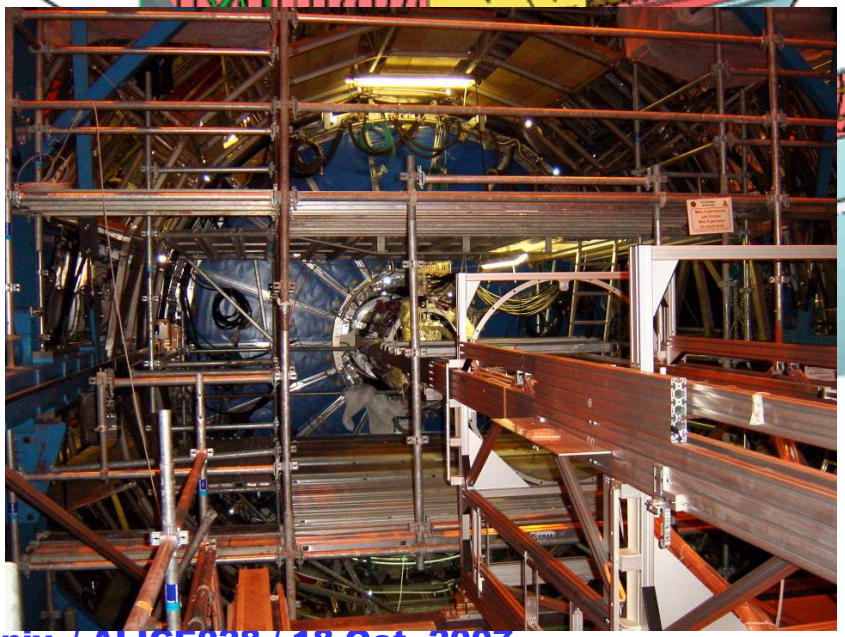
Time Projection Chamber

- largest ever
  - 88 m^3, 10 m long, 5.6 m diameter, 570 k channels
  - $X/X_0(\%)=3.5(Ne)-4.6(Ar)$
- under commissioning at the final posit



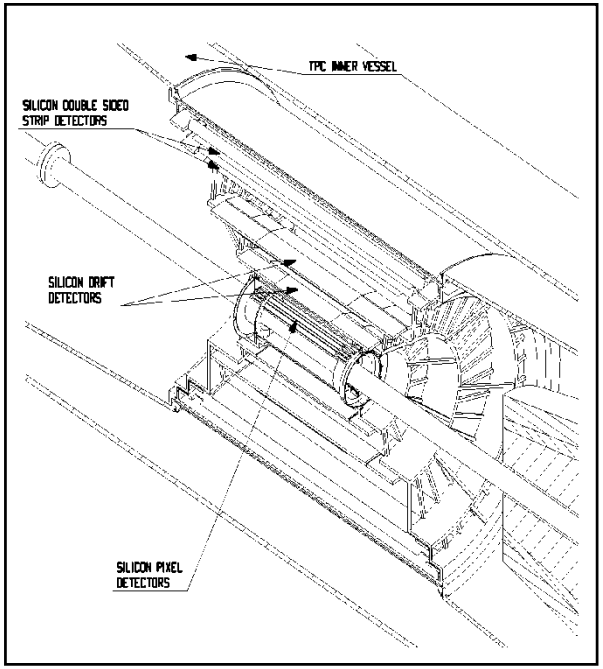


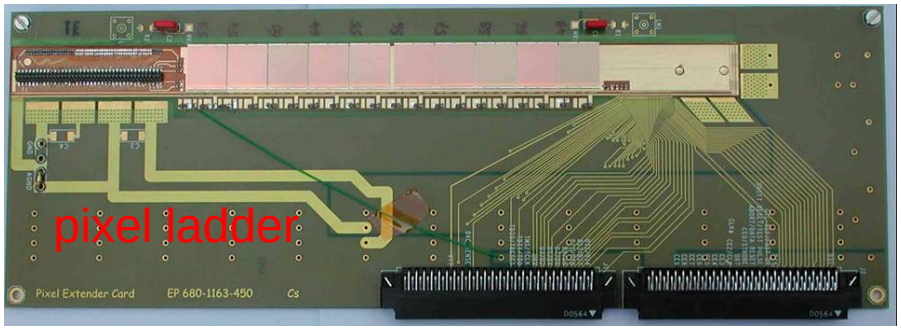


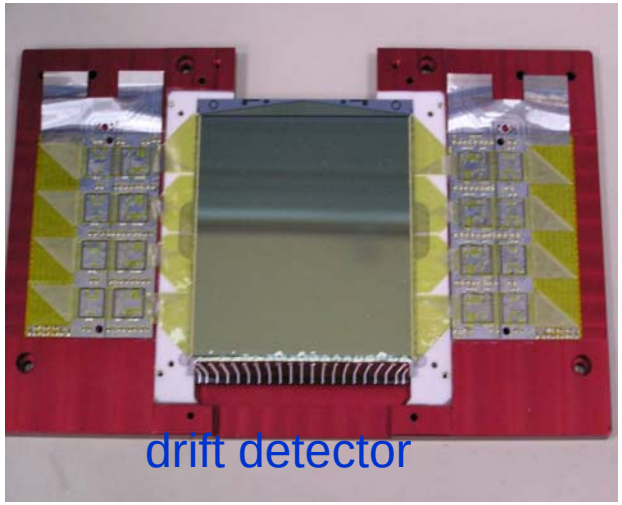


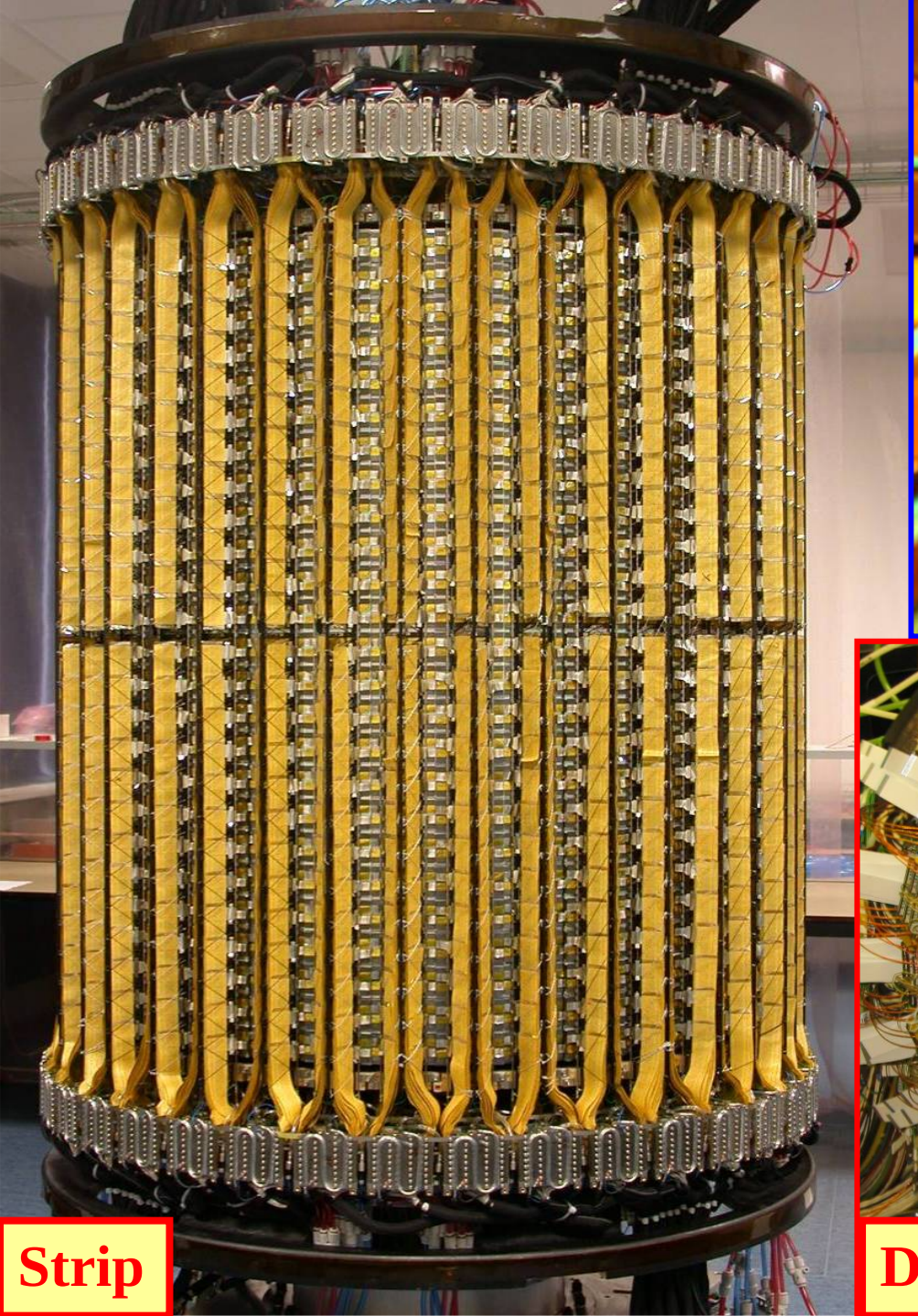
Inner Tracking System

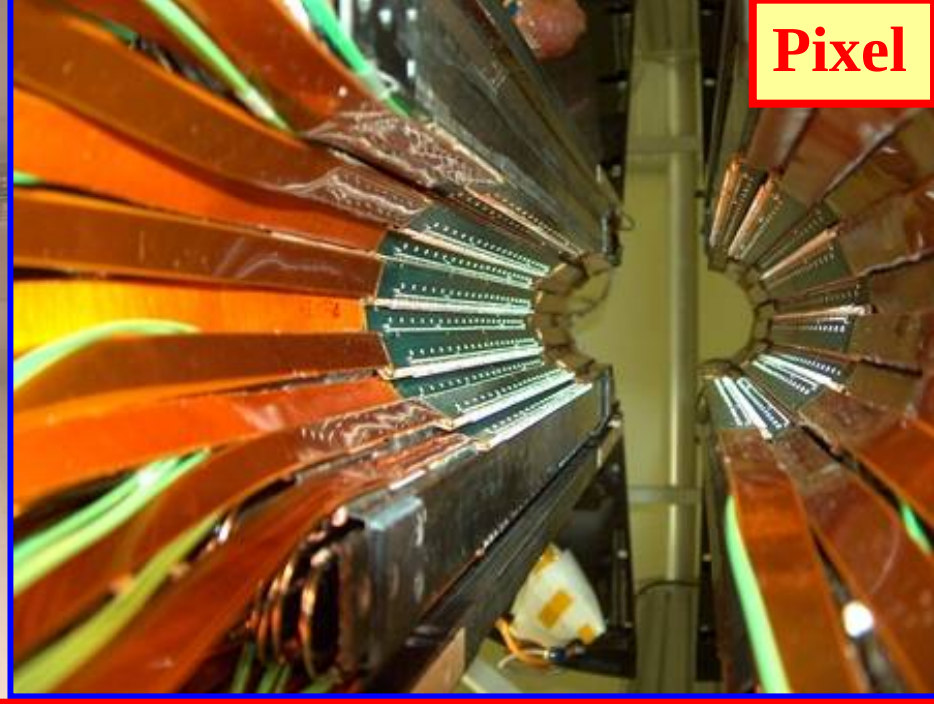
- tracking ($|\eta|< 1$) + multiplicity ($|\eta|< 2$)
- Si pixel/drift/strip
- $X/X_0(\%)$="4.4"

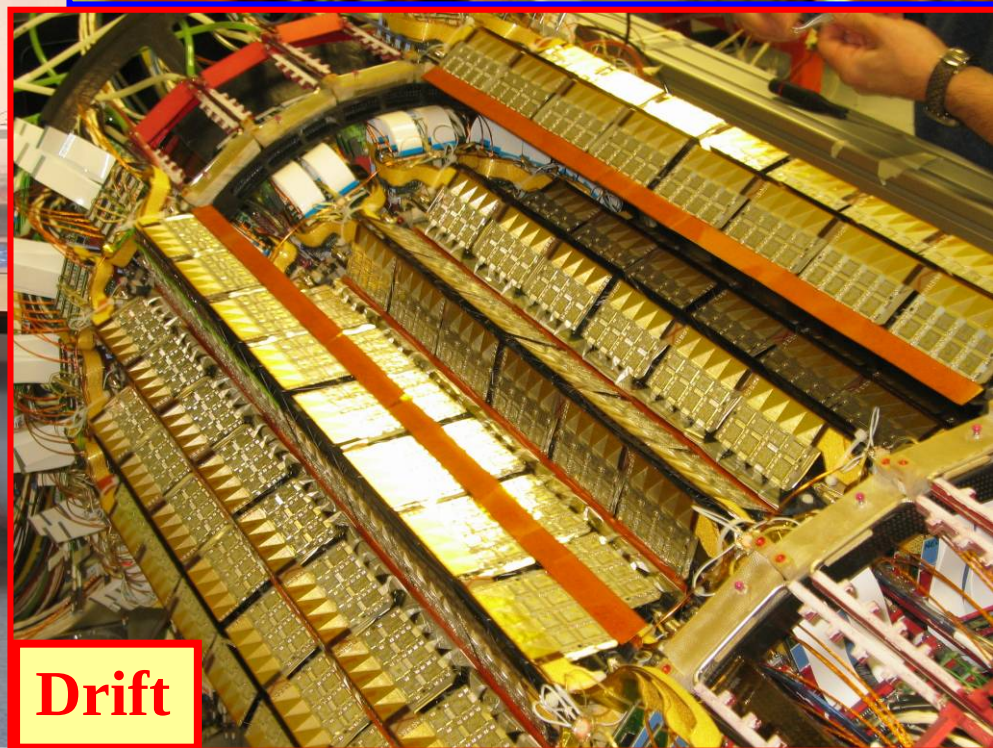




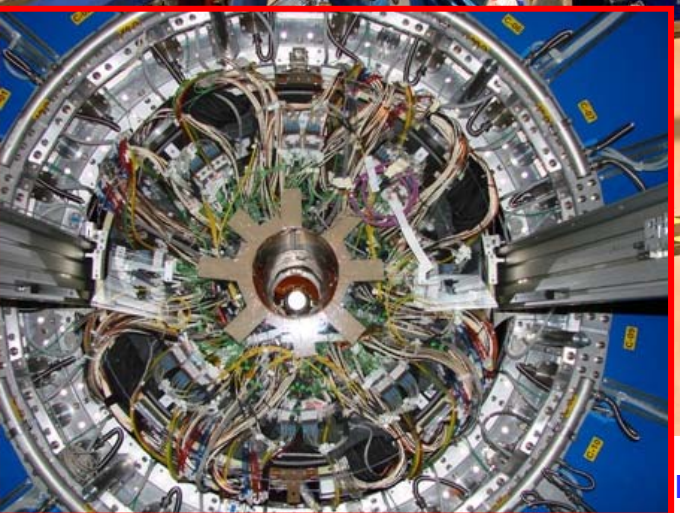



Strip


Pixel


Drift

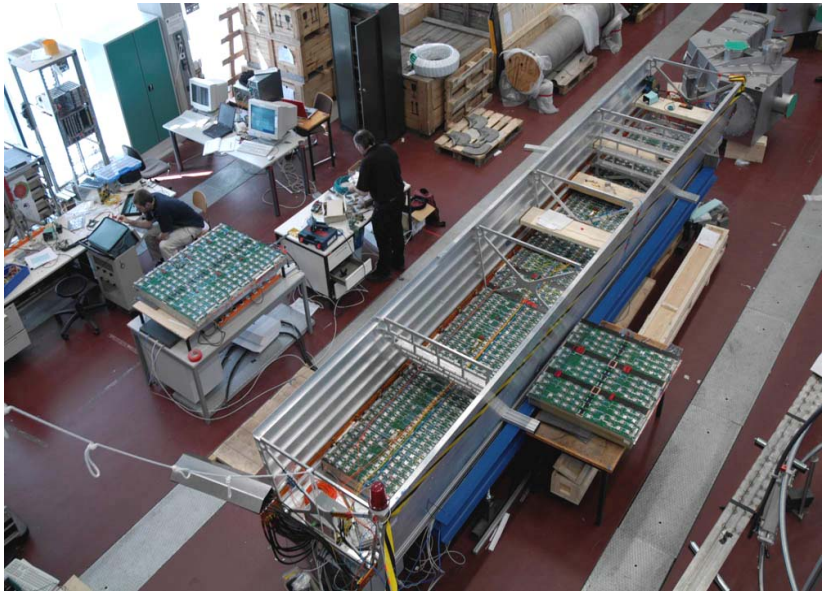
ITS Installation 15.3.07



E028 / 18 Oct. 2007

Transition Radiation Detector

- tracking and particle identification
  - 400 – 600 μm resolution in rφ, 23 mm in z
  - e/π separation > 100 at p_t > 3 GeV/*c*
- |η| < 0.9, full azimuth
  - X/X_0(%)= “14.3”

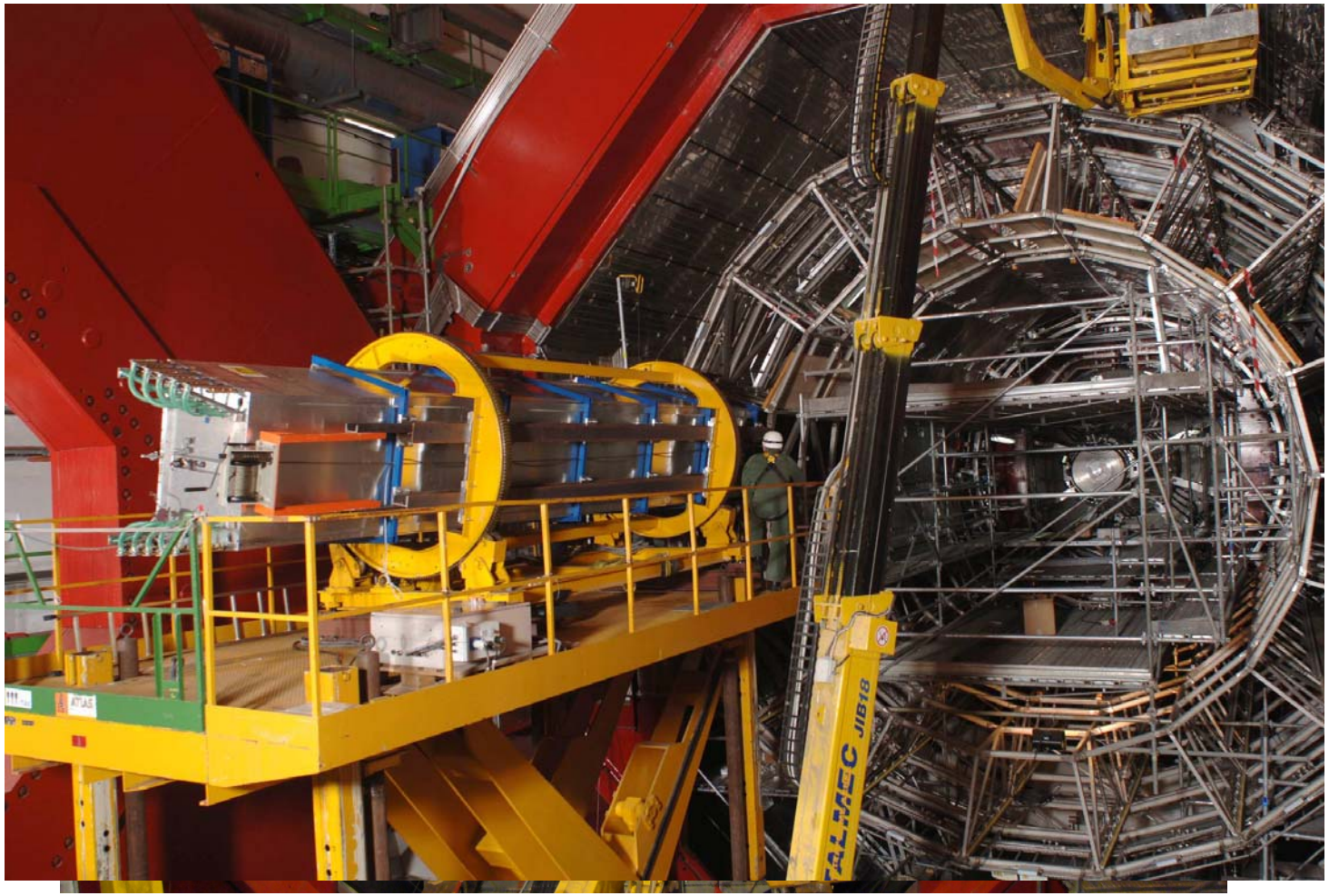


Time of Flight Detector

- multi-gap resistive plate chamber (MRPC)
  - time resolution < 100 ps
  - $X/X_0(\%)$="20"
- $|\eta| < 0.9$, full azimuth; 3.7 m from beam axis

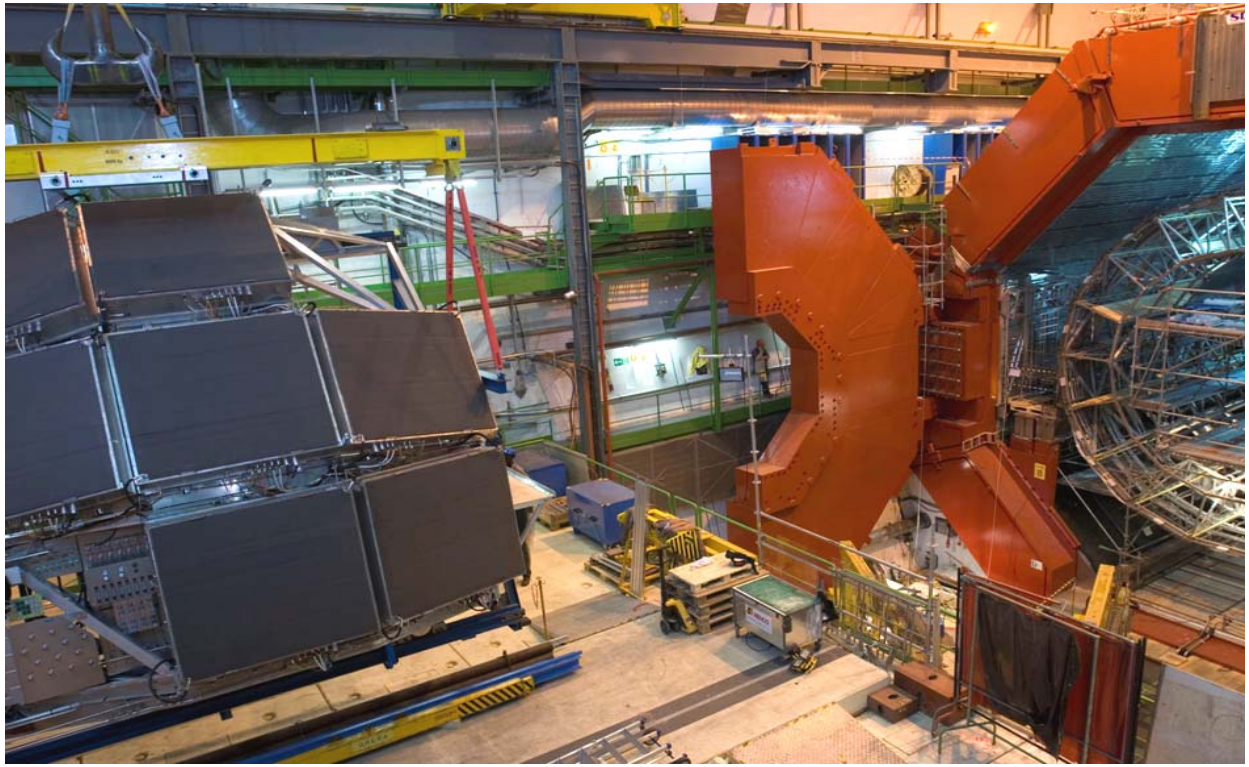
Installation of TRD&TOF

◆ 2-3/18 TRD and 9/18 TOF for 2007



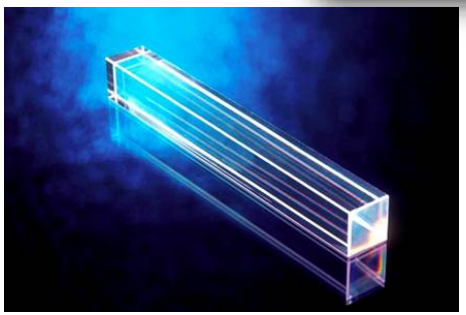
High Momentum PID

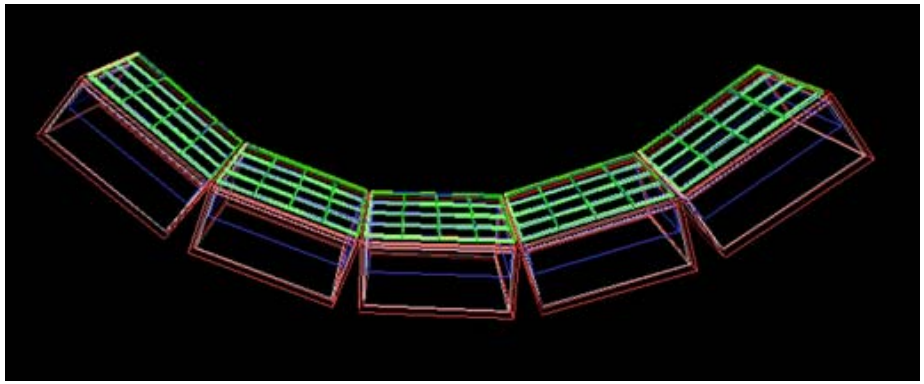
- ring imaging Cherenkov with CsI photo-cathodes
- $|\eta| < 0.5$, $\Delta\phi = 60$ degrees
- built and installed (not yet in this picture)



Photon Spectrometer (PHOS)

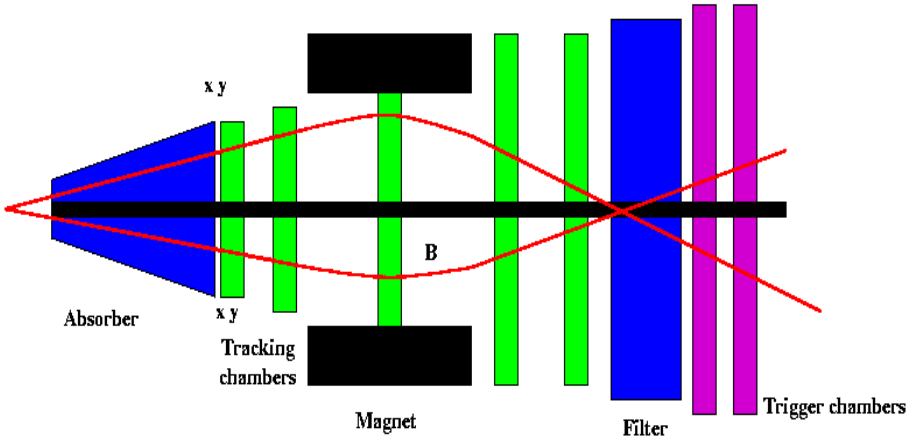
- high-granularity, high-resolution EM calorimeter
  - 64x56x5 $PbWO_4$ crystals readout with ***APD/CSP***
  - for photons and neutral mesons measurements, and for γ-jet tagging
  - providing level-0 and level-1 trigger.

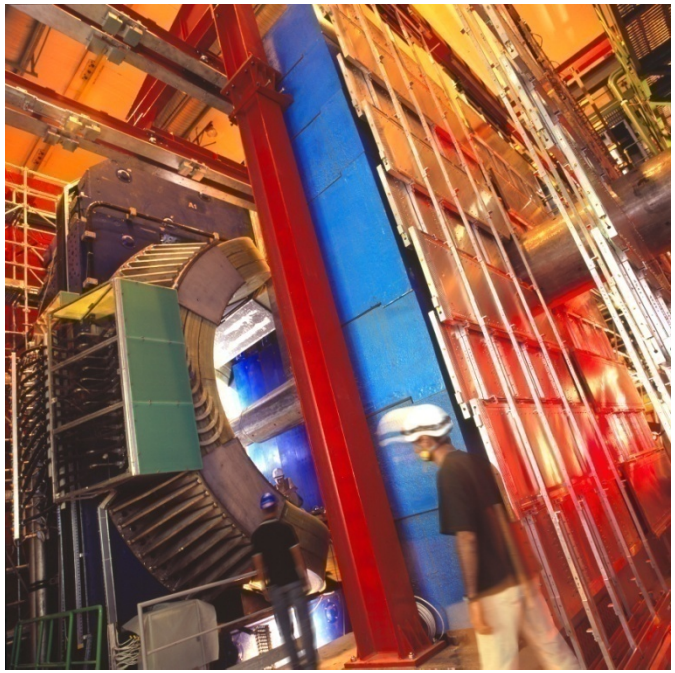


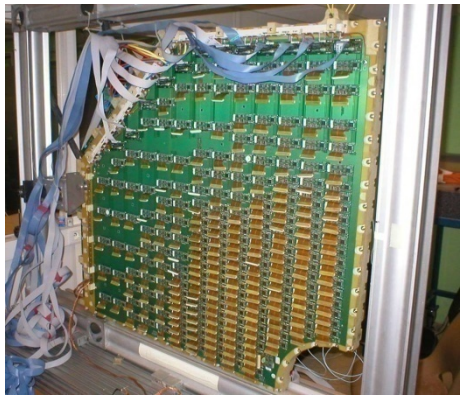


Forward (Di-)Muon Spectrometer

- a 3Tm dipole magnet; largest warm ever.
- p>5GeV, 2.4 < η < 4.0
- mass resolution: < 70 MeV at J/Ψ, < 100 MeV at Υ



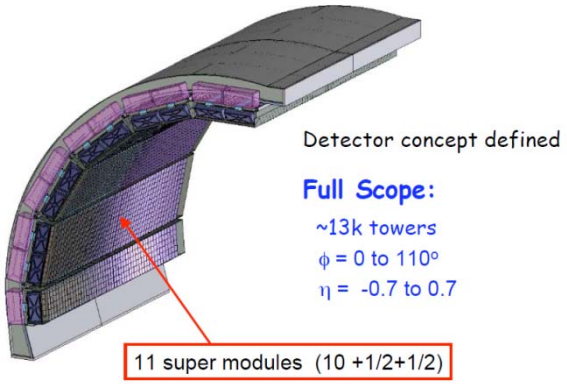


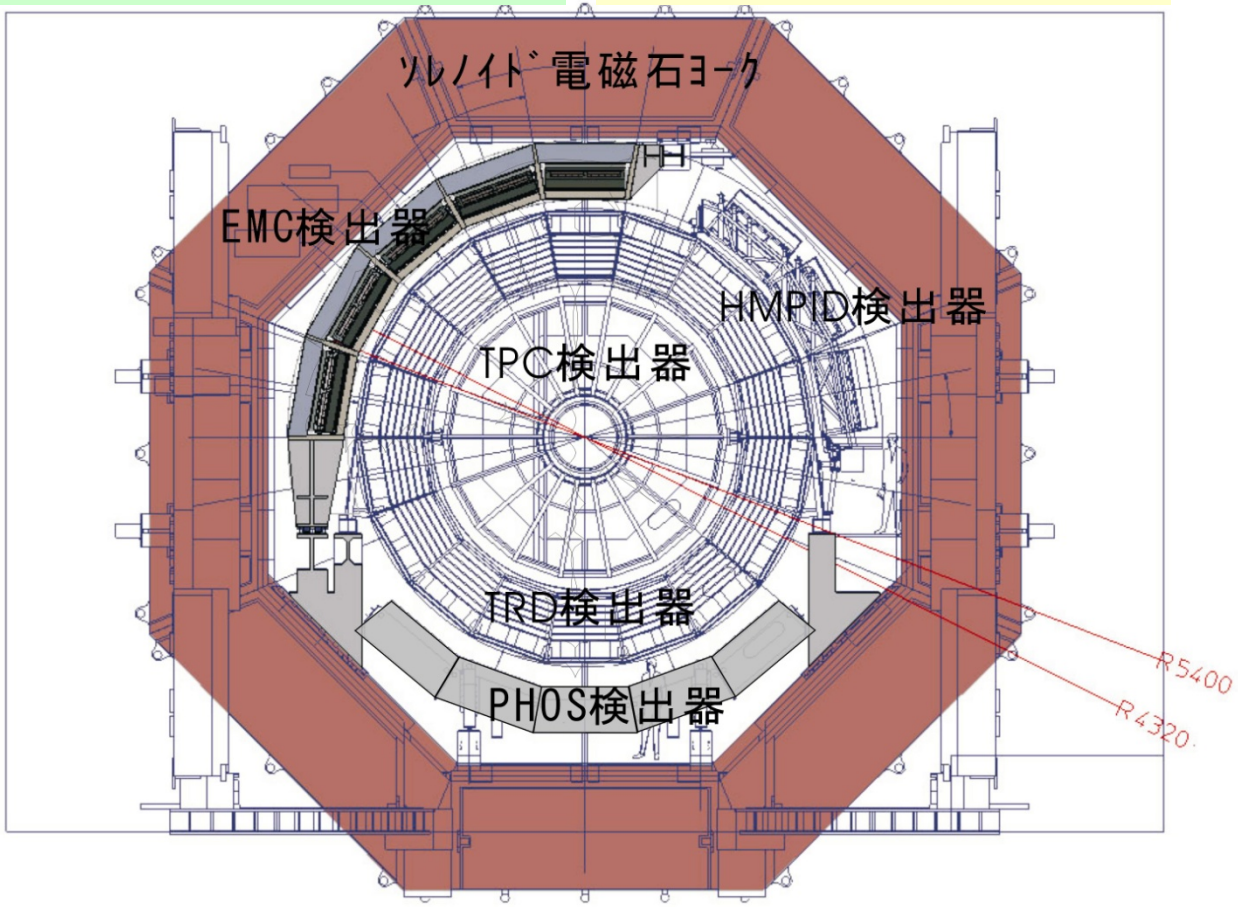


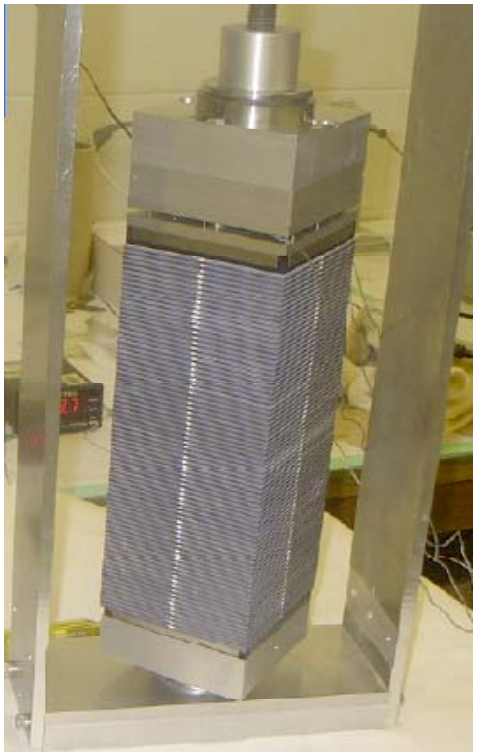
A large acceptance EMCal.

EMCal（Pb/Sci+APD）
Jet physics
Element dim: 6x6x25cm
$-0.7 < \eta < +0.7$ & $\Delta\phi=110°$
$\Delta E/E=8\%/\sqrt{E\,(GeV)} \oplus 1\%$

PHOS（PWO+APD）
Photon physics
Element dim: 2.2x2.2x18cm
$-0.12 < \eta < +0.12$ & $\Delta\phi=100°$
$\Delta E/E=3\%/\sqrt{E\,(GeV)}$





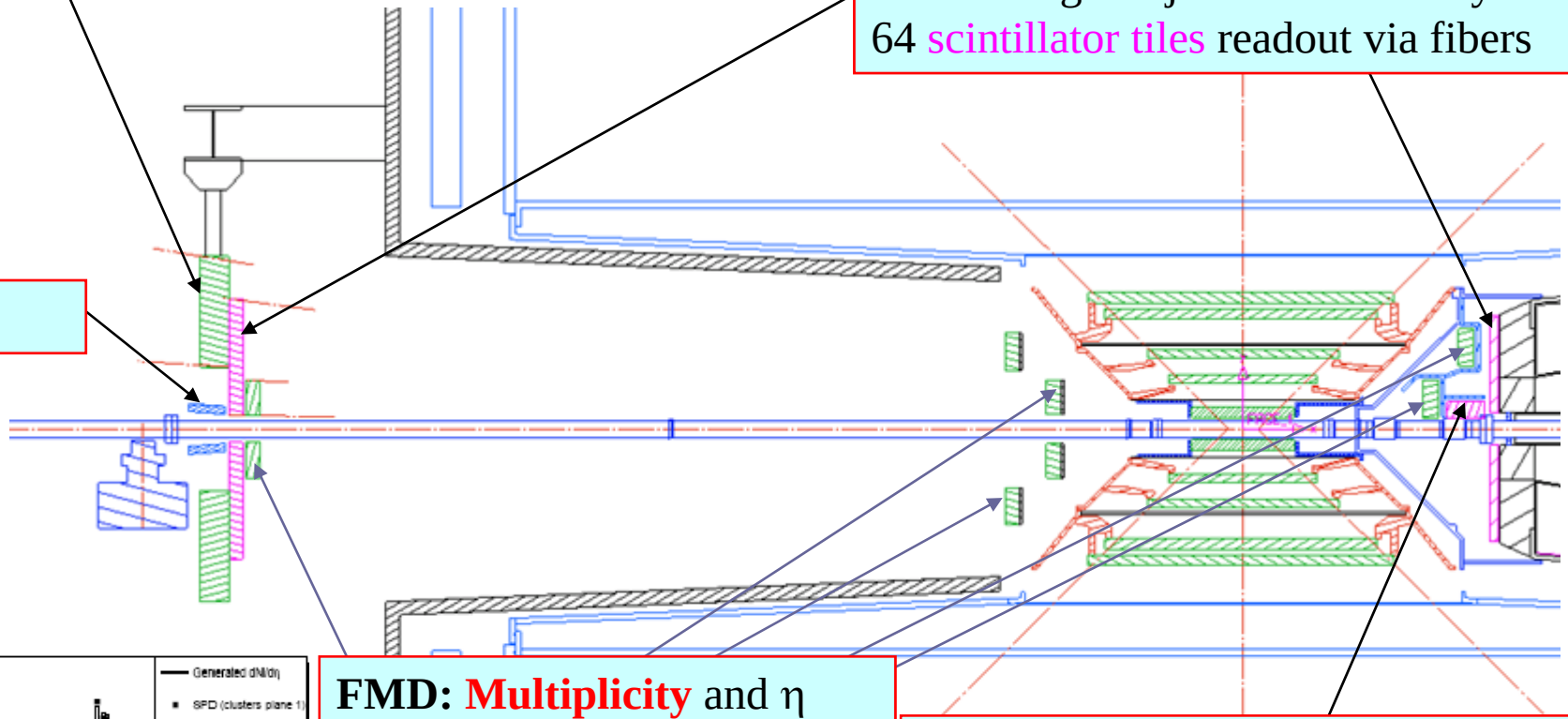


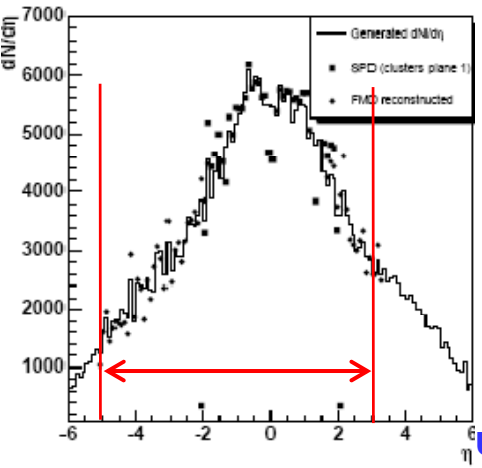
Forward Detectors

PMD Pre-shower detector $2.3 < \eta < 3.5$, $N_{charged}$ and $N_{photons}$ (DCC's)

V0 $1.6 < |\eta| < 3.9$ **Interaction** trigger (beam-gas rejection), centrality trigger and beam-gas rejection. Two arrays of 64 scintillator tiles readout via fibers

$T0_L$



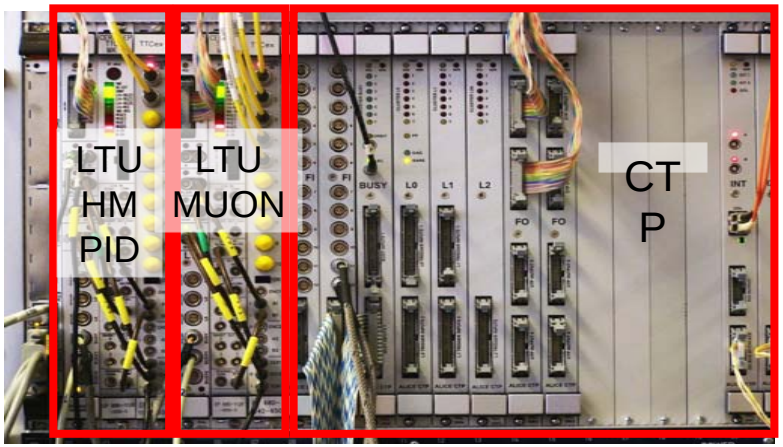


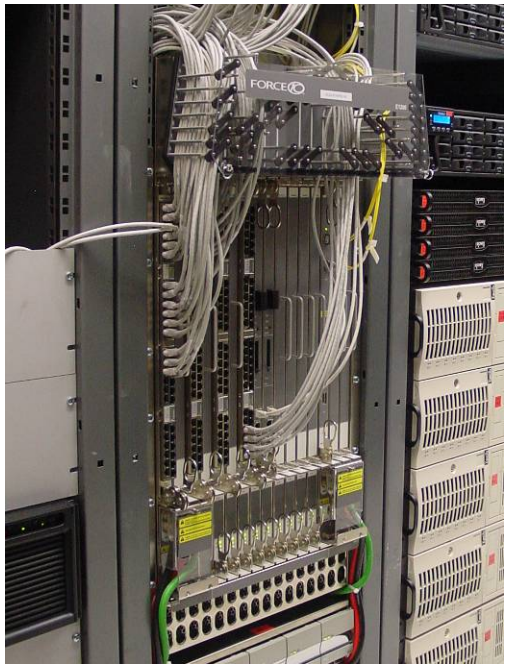
FMD: Multiplicity and η dist. $1.6 < \eta < 3$, $-5.4 < \eta < -1.6$ Silicon strip disks ,12k analog channels

$T0_R$: $2.6 < |\eta| < 3.3$ **Time** (T_0) for the TOF (~ 50 ps time res.) Two arrays of 12 quartz counters. Also backup to V0

ZDC: Centrality, 2 sets of Zero Degree Calorimeters, > 100m inside LHC tunnel

Data Acquisition System and HLT





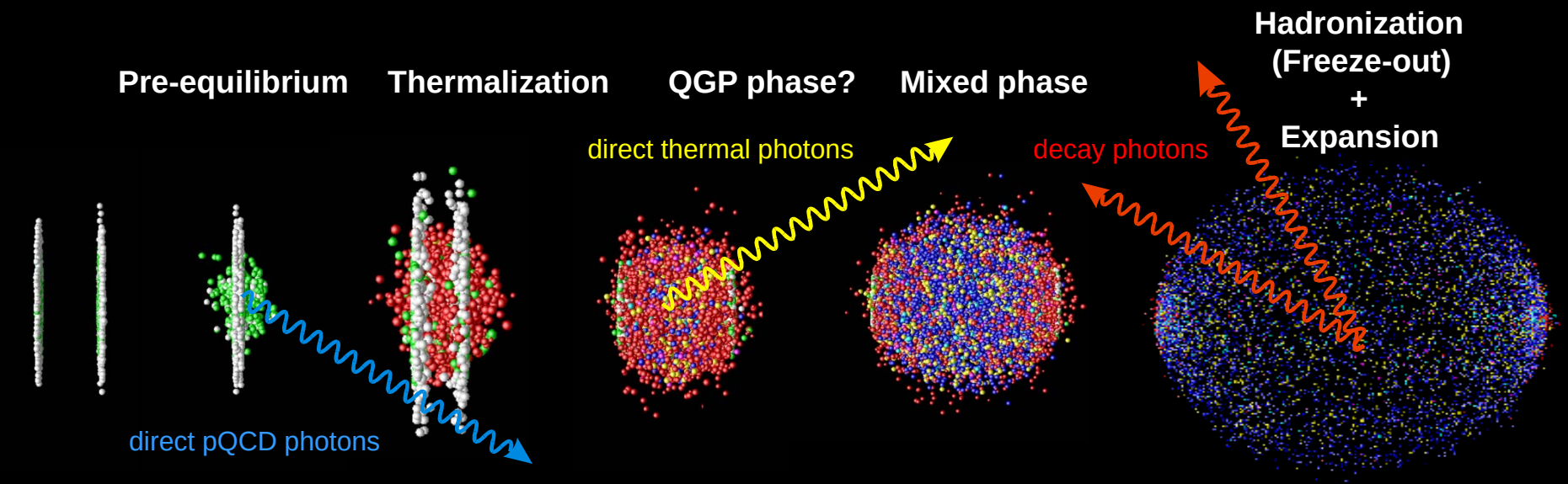
DAQ: be fast and scalable

- up to 3 Gbyte/s (in&out)
- commodity PC's and
- fast network switches

HLT: be fast and flexible

- event selection
- data compression
- selective R/O
- up to 20 GB/s data input
- 200Hz Pb-Pb

Relativistic Heavy Ion Collision and photons



Experimental advantages of Photon Measurement

- Global observables: Multiplicities, p_T distributions
  - photons and neutral mesons measured in same detector
  - particle identification to very high transverse momentum
- Degrees of freedom as a function of T: hadron ratios and spectra, dilepton continuum, direct thermal photons
- Early state manifestation of collective effects: elliptic flow
- Energy loss of partons in quark gluon plasma: jet quenching, high p_T spectra, open charm and open beauty

More interesting physics outcome at LHC

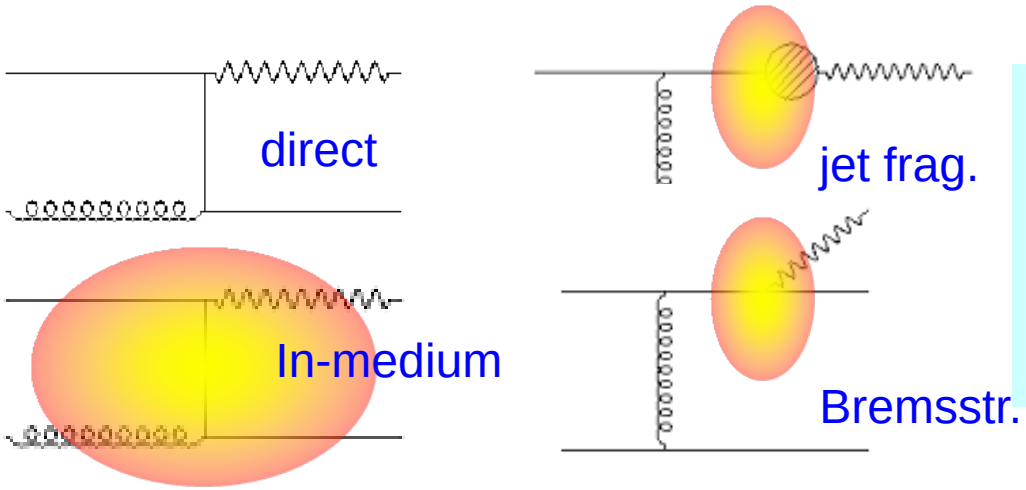
- Deconfinement: charmonium and bottonium spectroscopy
- Chiral symmetry restoration: neutral to charged ratios, res. decays
- Fluctuation phenomena - critical behavior: event-by-event particle comp. and spectra
- Geometry of the emitting source: HBT, impact parameter via zero-degree energy flow

Quite important physics outcome on DAY 1

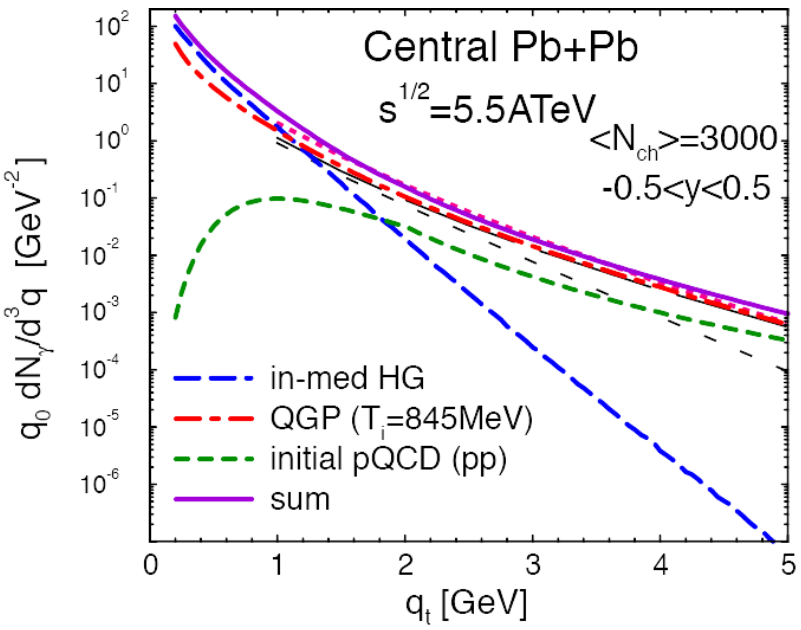
pp collisions in a new energy domain

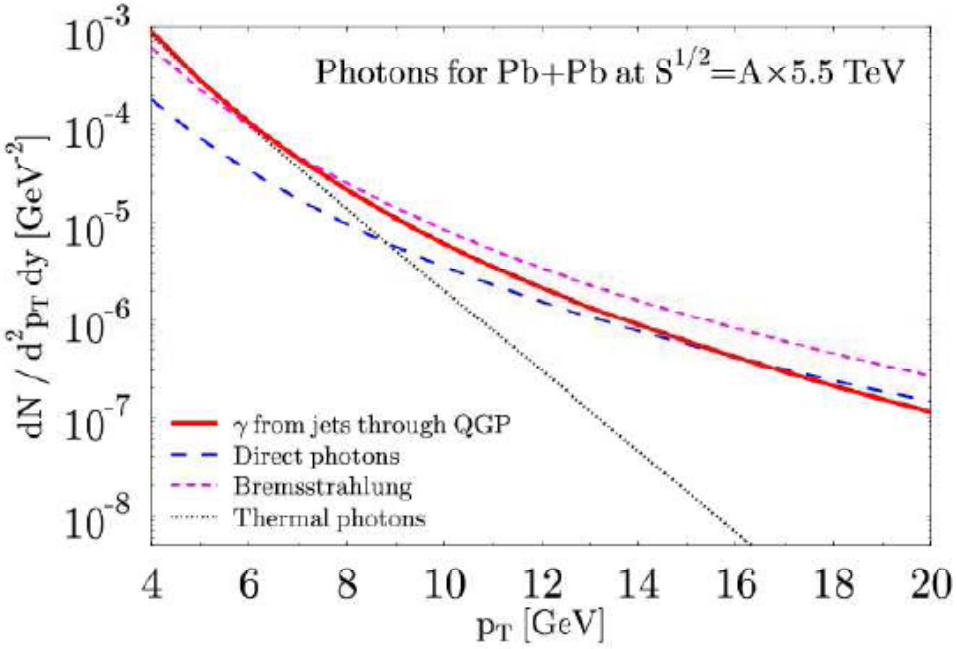
Suppression of hadrons with large transverse momentum in central Au+Au collisions at s(NN)**(1/2) = 130-GeV.
By PHENIX Collaboration (K. Adcox et al.). Sep 2001. 6pp.
Published in Phys.Rev.Lett.88:022301,2002 / e-Print Archive: nucl-ex/0109003

Photon Physics at LHC



In high multiplicity environment, a photon detector should satisfy;
- sensitive to GeV photons,
- high granularity and
- good energy resolution.

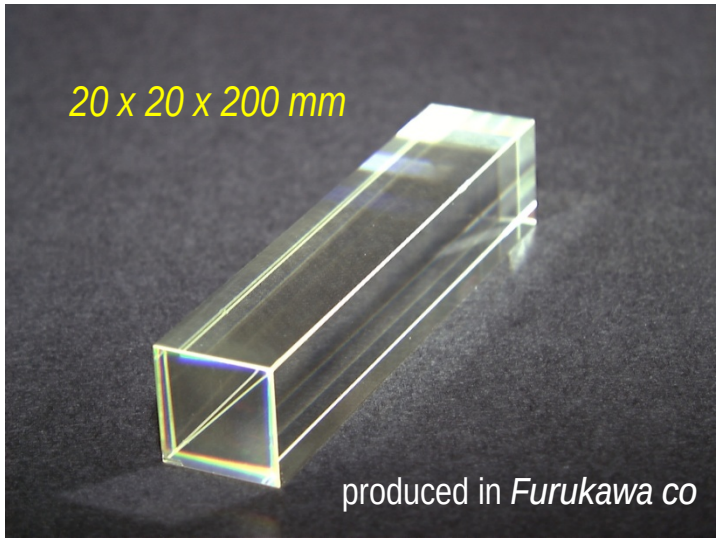


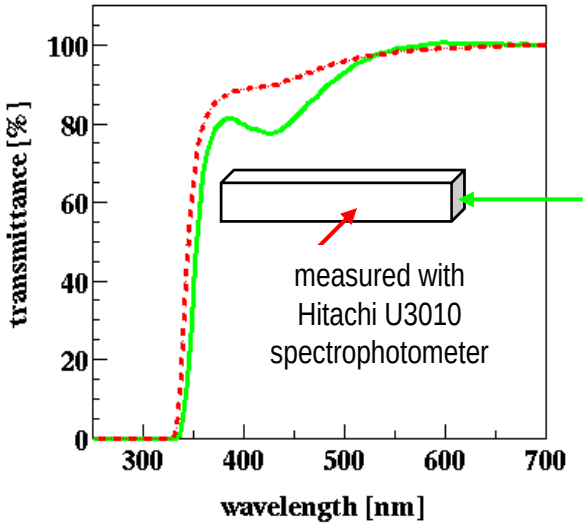


R&D studies in Hiroshima

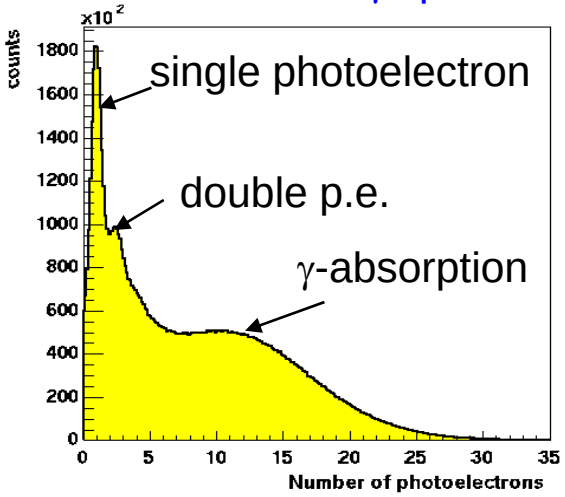
Y-doped $PbWO_4$

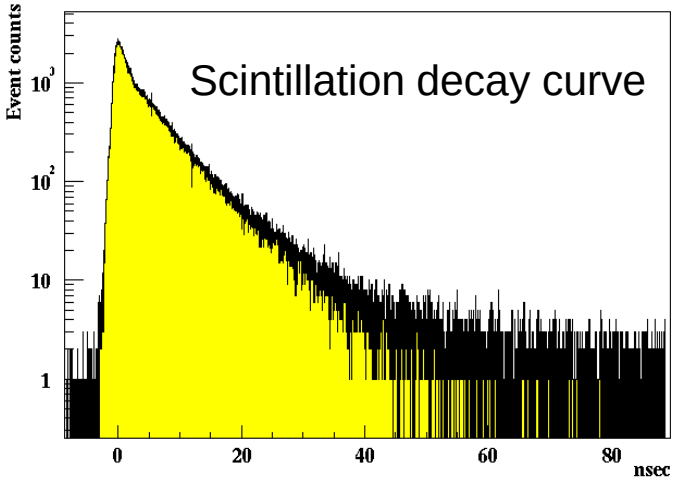
Density 8.28 [g/cm^3]
Radiation length 0.89 [cm]
Moliere radius 2.2 [cm]
Peak emission 420~440 [ns]
Refractive index 2.3





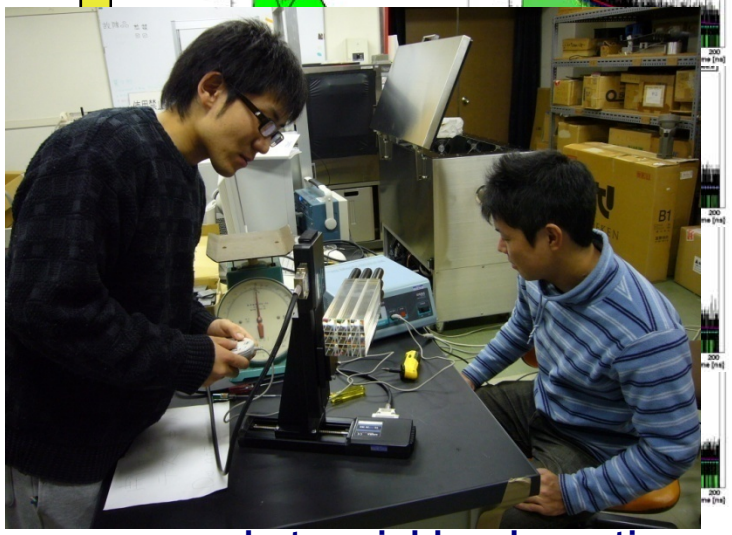
^{60}Co γ spectrum w/ Hamamatsu R7056 @1900V





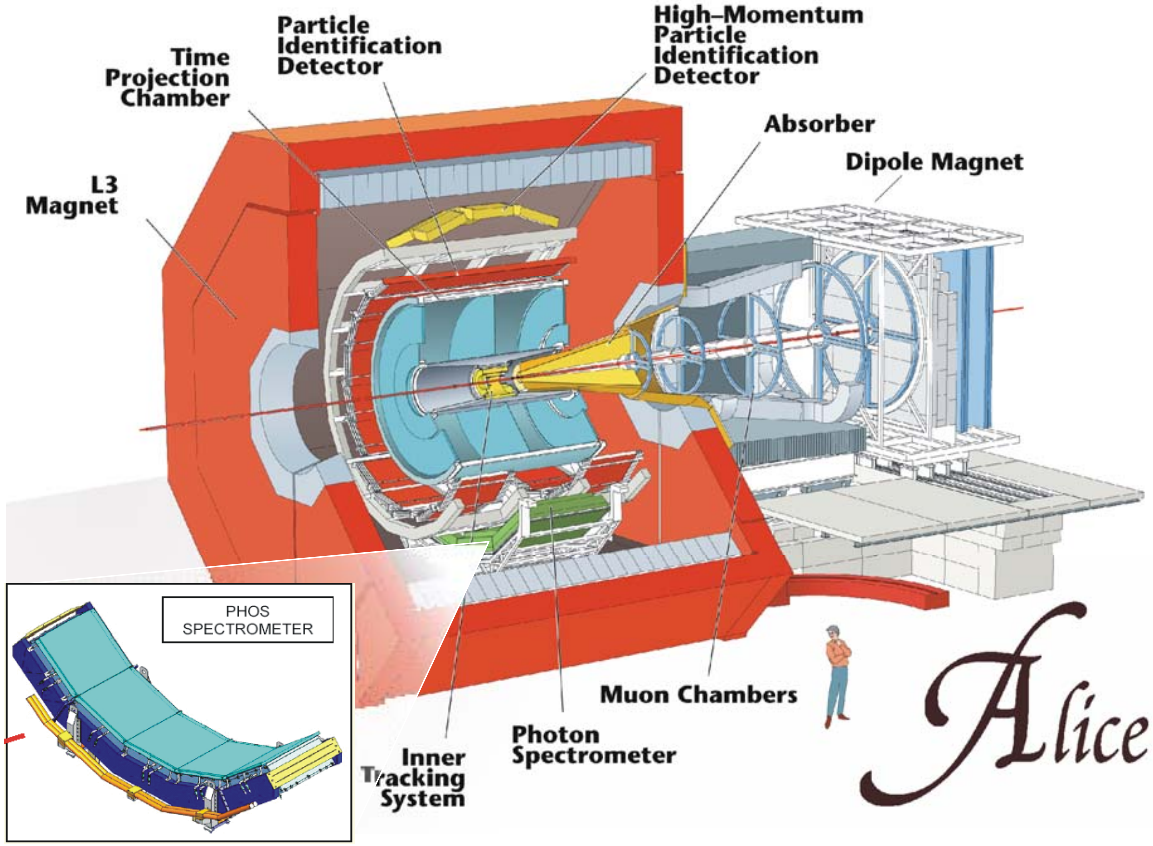
Expertise on $PbWO_4$ and APD

- calorimeter oriented property studies since 2000
  - temperature dependence down to -35 ˚C
    - $PbWO_4$: photon yield, decay constants
    - APD: gain, breakdown voltage, noise
  - crystals from different manufactures
  - newly developed large aperture APD



photon yield decay time

PHOS parameters

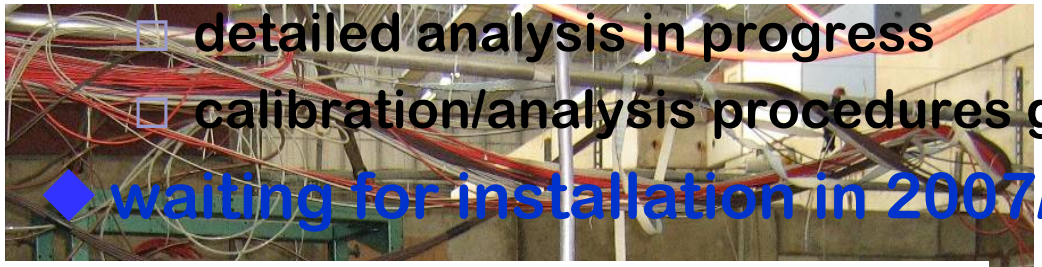


density	8.28 g/cm^3
radiation length	0.89 cm
Moliere radius	2.2 cm
peak emission	420-440 nm
refractive index	2.3

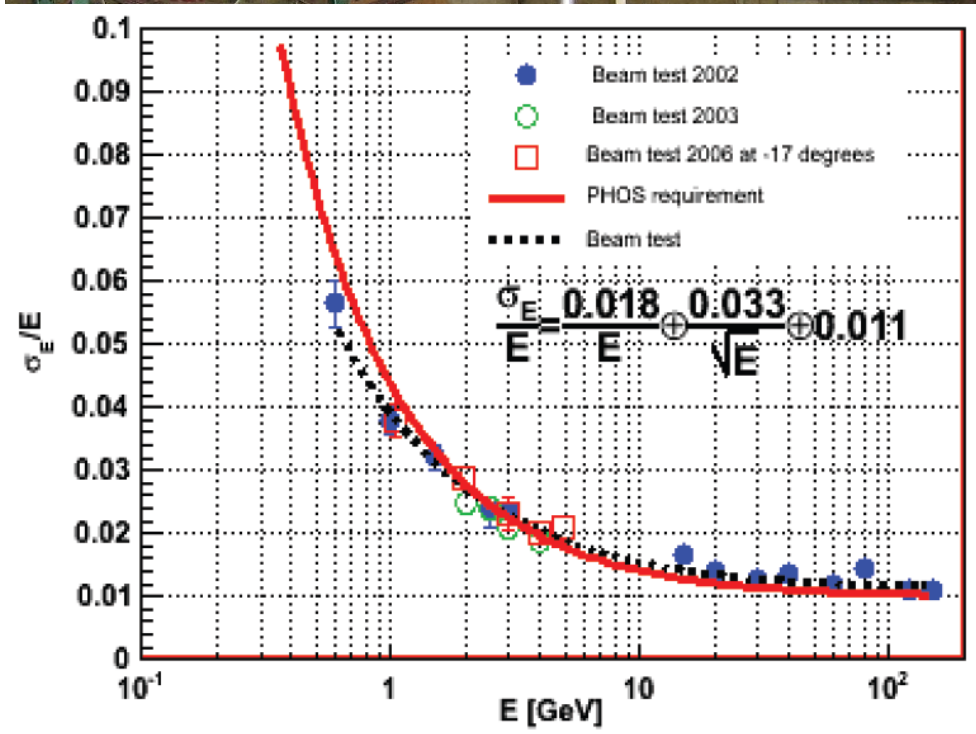
element	Lead tungstate crystal coupled with APD
number of elements	17,920 (3,584/module)
crystal dimensions	22×22×180 mm
distance from IP	4400 mm
η coverage	$-0.12<\eta<+0.12$
ϕ coverage	100° (20°/module)
η granularity	$\Delta\eta$=0.005
ϕ granularity	$\Delta\phi$=0.005 rad
area covers	8.67 m^2
energy range	5 MeV ~ 80 GeV
energy resolution	3.6% / $\sqrt{E(GeV)}$
π^0 identification	0.2 < p < 60 GeV
weight	12.9 t (721g/ea)
operation temp.	-25℃

First PHOS Module

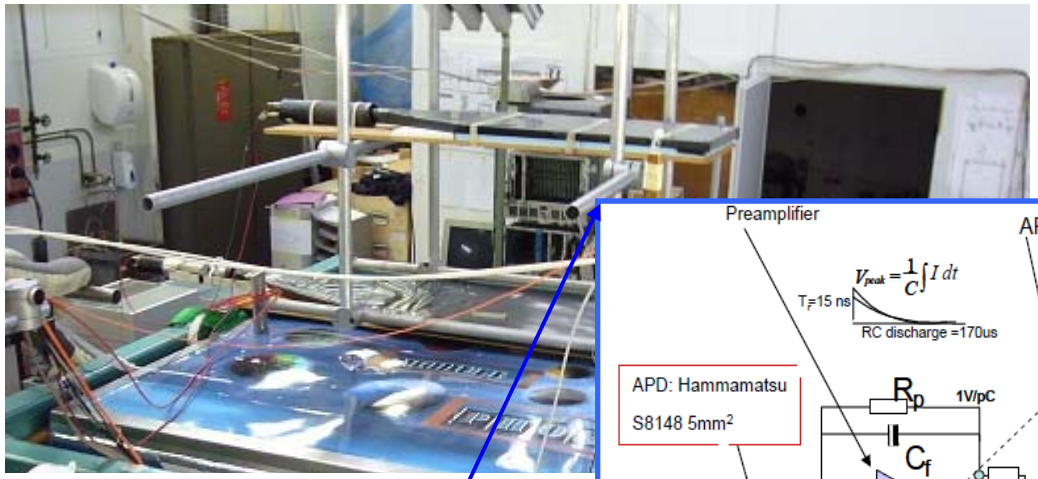
- completed and tested at CERN PS/SPS in 2006
  - successfully read out with ALICE readout/DAQ system
  - detailed analysis in progress
  - calibration/analysis procedures getting established
- waiting for installation in 2007/06/22 ⇛ 2007/11/12-14



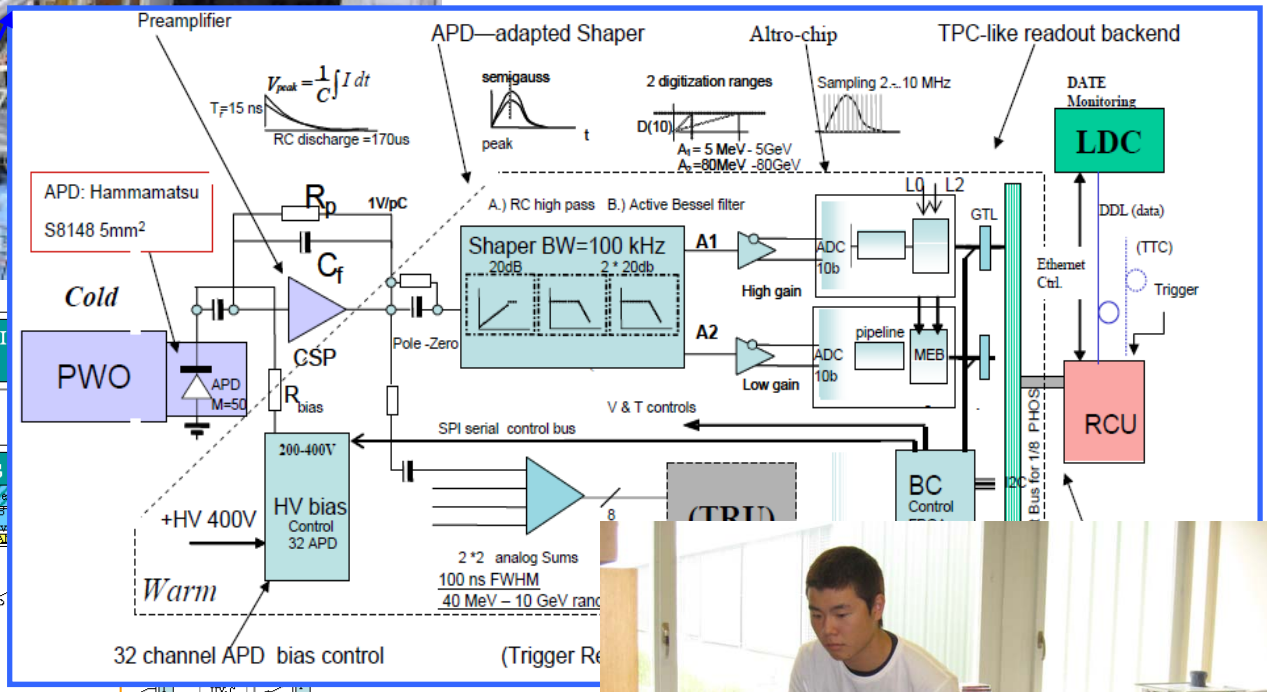
H.Torii

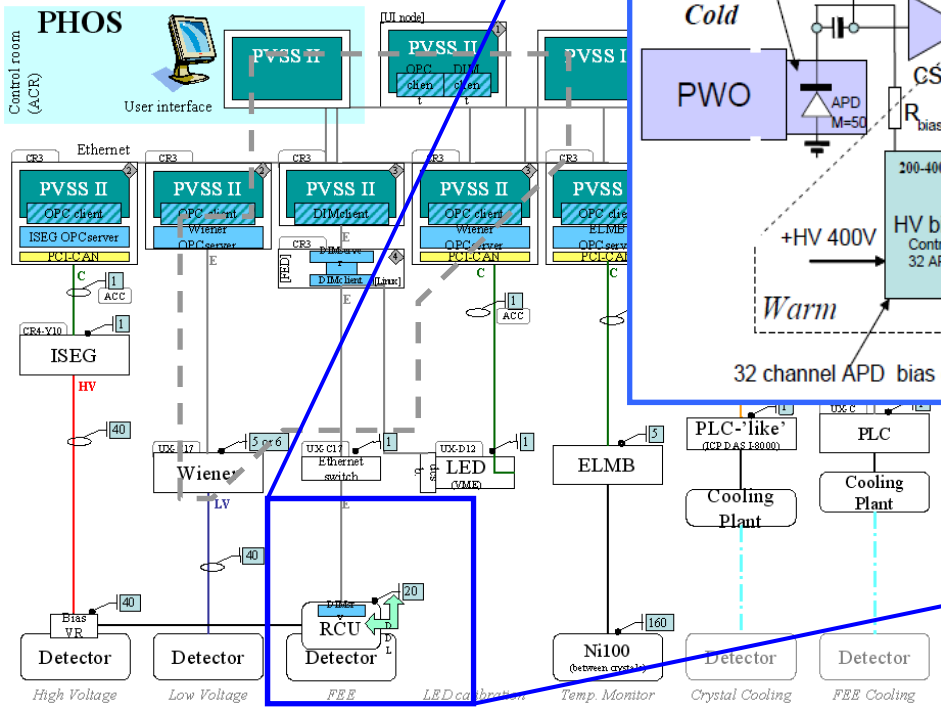


1st PHOS module waiting in lab.

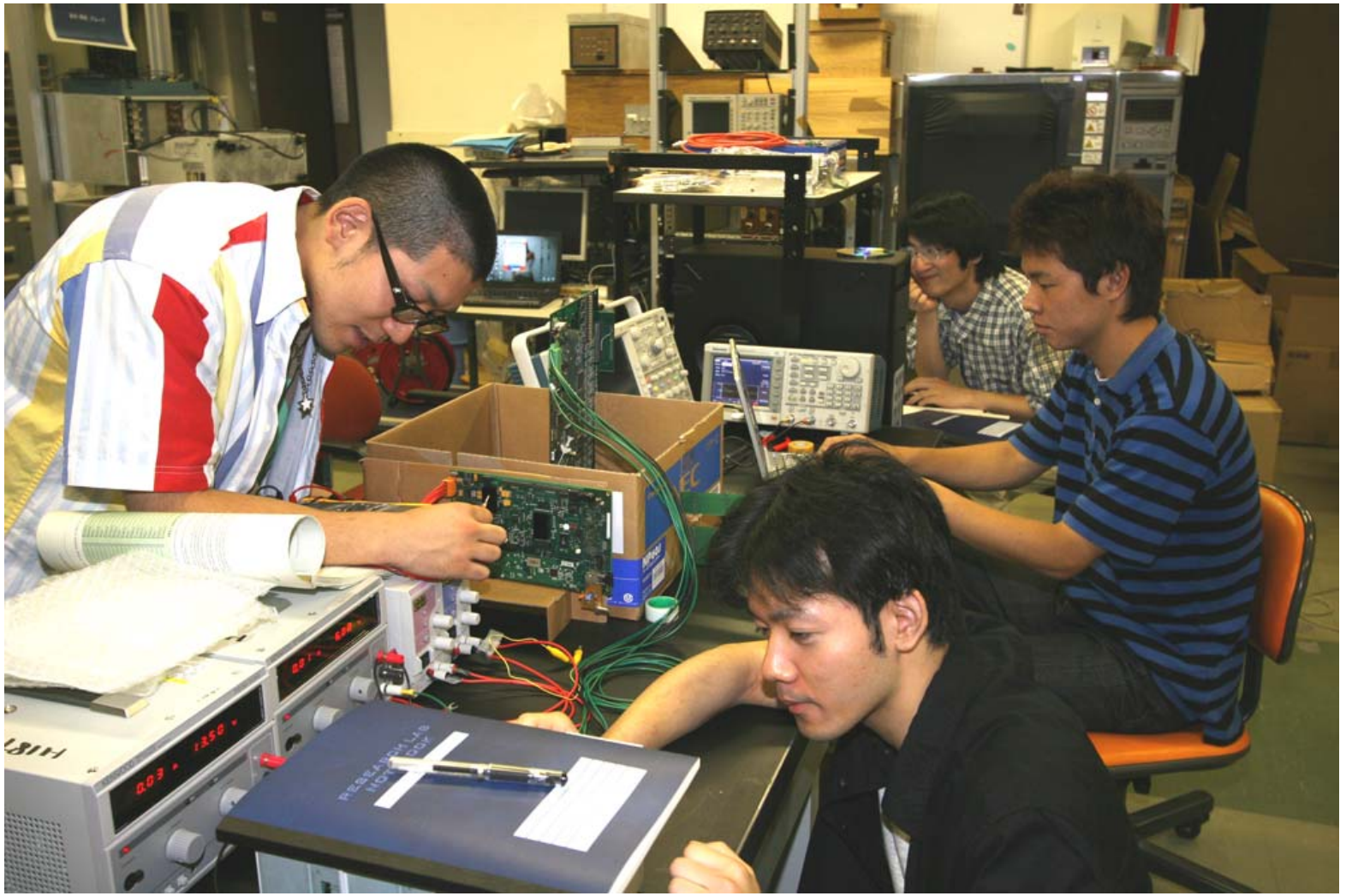


Taking cosmic-ray data implementing DCS functions, and Testing TRU functions for LVL-0



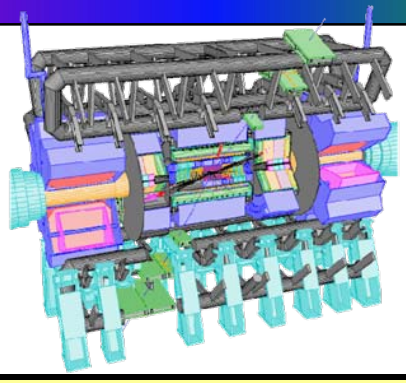


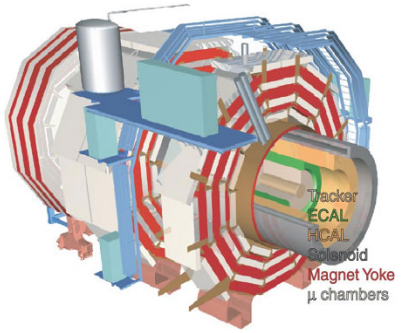
PHOS Full-chain test-bench

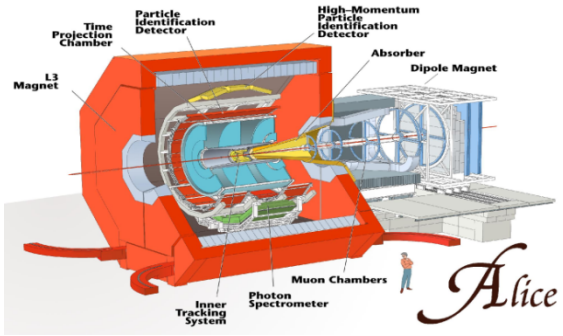


PHOS Lab at Hiroshima

Photon Detectors at LHC







Exp.	ATLAS		CMS		ALICE	
Name	LAr Barrel	LAr Endcap	ECAL(EB)	ECAL(EE)	PHOS	EMCal
Structure	Liquid Ar		PWO + APD		PWO + APD	Pb + APD
Coverage	$0<\|\eta\|<1.4$, 2π	$1.4<\|\eta\|<3.2$, 2π	$0<\|\eta\|<1.5$, 2π	$1.5<\|\eta\|<3.0$, 2π	$0<\|\eta\|<0.12$, 0.6π	$0<\|\eta\|<0.7$, 0.6π
Granularity $\Delta\eta\times\Delta\varphi$	0.003x0.100 0.025x0.025 0.025x0.050	0.025x0.100 0.025x0.025 0.025x0.050	0.0174x0.0174	0.0174x0.0174 to 0.05x0.05	0.004x0.004	0.0143x0.0143
Res.	$10\%/\sqrt{E}$ $\oplus 0.5\%$	$10\%/\sqrt{E}$ $\oplus 0.5\%$	$2.7\%/\sqrt{E}$ $\oplus 0.55\%$	$5.7\%/\sqrt{E}$ $\oplus 0.55\%$	$3.3\%/\sqrt{E}$ $\oplus$ 1.1%	$7\%/\sqrt{E}$ $\oplus 1.5\%$

Photon Physics in ALICE

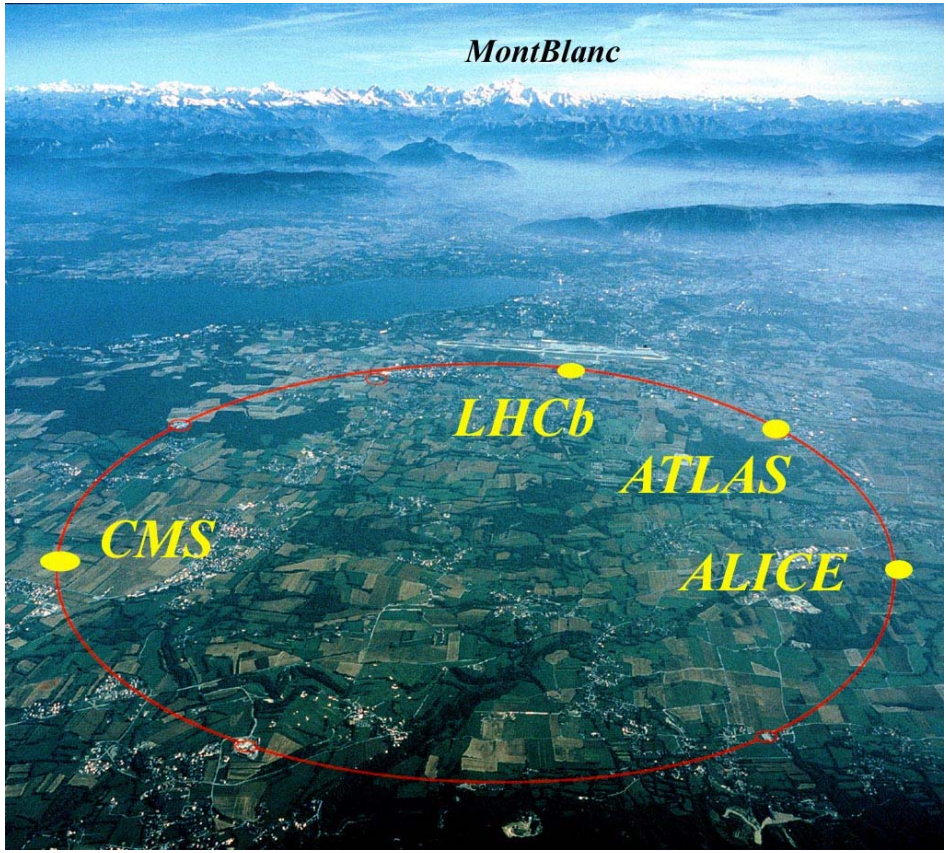
Physics issues

- thermal γ
- π^0 and η at high accuracy
- γ, π^0 and η at high p_T up to ~80GeV
- non-photonic electrons
- jet fragmentation in medium
- direct γ-jet correlations
- γ–γ correlations
- and more...

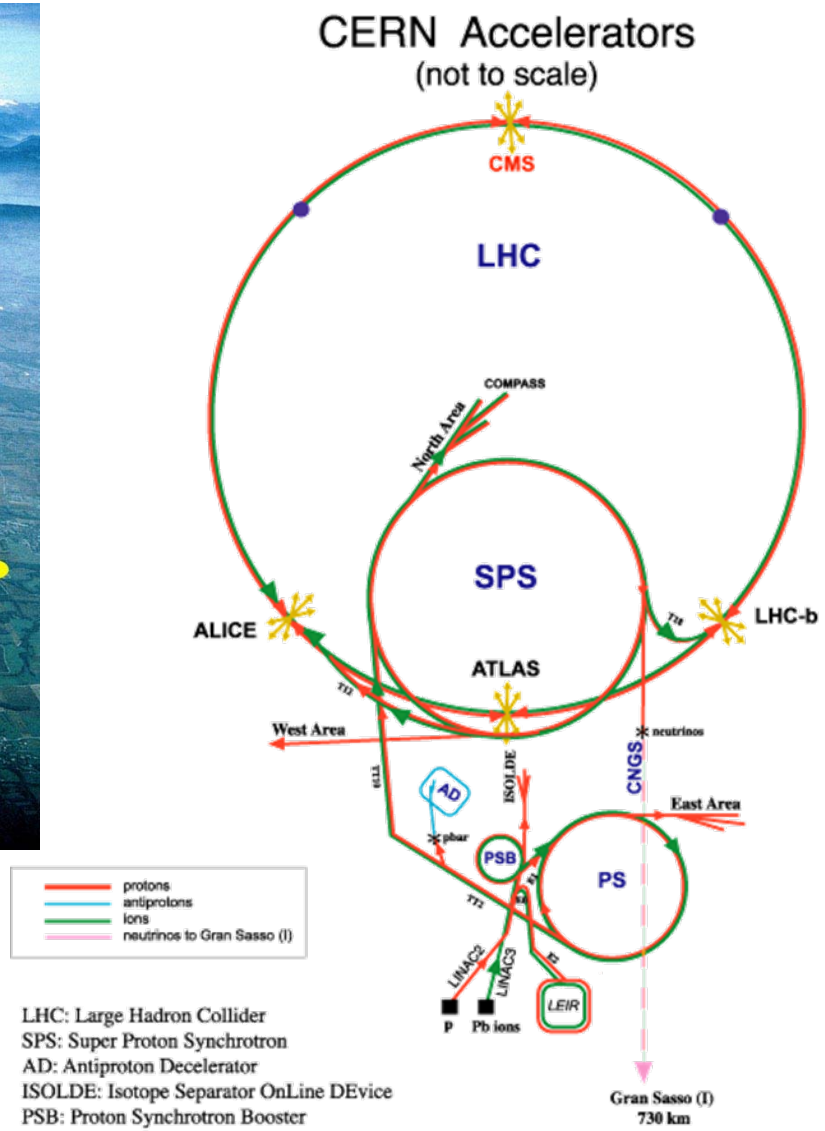
Key words in recent PWG4 (photons and high p_T)

- jet fragmentation
- jet correlations
- γ-hadron correlations
- prompt γ correlations
- high p_T particles
- π^0 and γ correlation
- isolation cuts
- jet reconstruction
- jet resolution
- π^0 reconstruction
- and more...

LHC Accelerator

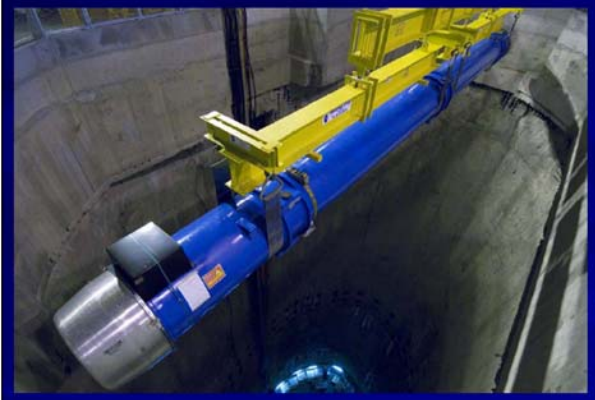


トンネル周長　27km

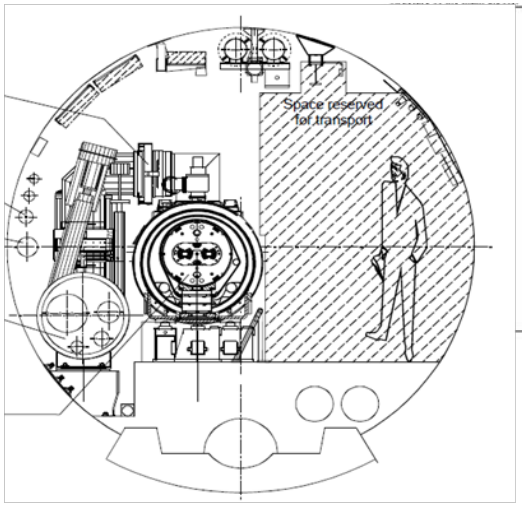


LHC dipoles

Descent of the last magnet, 26 April 2007



30'000 km underground at 2 km/h!



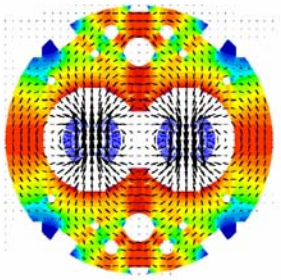


Figure 7.5: Dipole magnetic flux plot

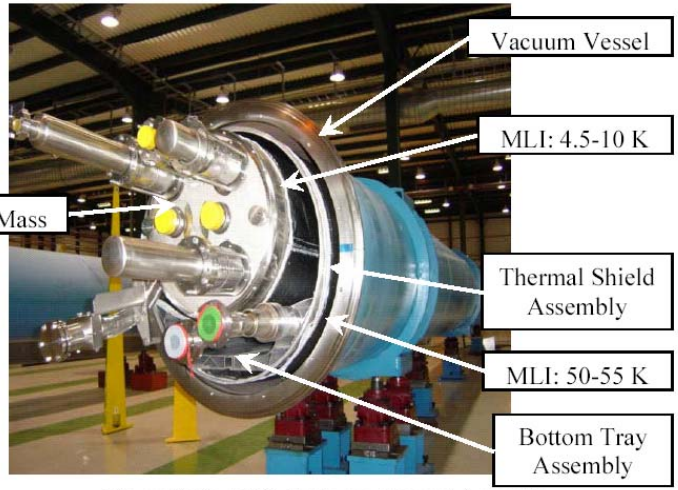


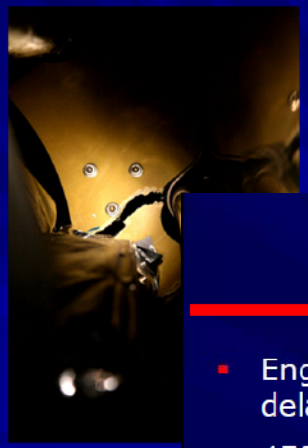
Figure 7.12: LHC dipole cryomagnet Assembly

Dipole-dipole interconnect: electrical splices

29

LHC update as of Jun.07

Inner Triplet Problem (March 2007)
Q1 supports at IP 5L



Dr. Robert Aymar (DG) の声明 (2007年6月27日)

- 財政等の危機から、CERN研究計画の見直し
- 2007年末のLHC始動@900GeVは省略
- 2008年に陽子＋陽子衝突実験の本格開始
- 重イオン実験についてはコメント無し

General schedule

- Engineering run originally foreseen at end 2007 now precluded by delays in installation and equipment commissioning.
- 450 GeV operation now part of normal setting up procedure for beam commissioning to high-energy
- General schedule being reassessed, accounting for inner triplet repairs and their impact on sector commissioning
  - All technical systems commissioned to 7 TeV operation, and machine closed April 2008
  - Beam commissioning starts May 2008
  - First collisions at 14 TeV c.m. July 2008
  - Pilot run pushed to 156 bunches for reaching 10^{32} $cm^{-2}.s^{-1}$ by end 2008
- No provision in success-oriented schedule for major mishaps, e.g. additional warm-up/cooldown of sector

9

日本チームの戦略

- 検出器建設責任部分は当初研究計画の記載年次で進行させ、その結果、
- より多くの人材と活力を2008年の陽子＋陽子衝突実験、引き続く、
- 鉛＋鉛原子核衝突実験に投入し、
- 世界をリードする研究成果を挙げる。

LHC Baseline program

- expect ~ 10 year 'baseline' program 2008 – 2017
  - **pp:** after few years diminishing return in terms of running time versus statistics
  - **HI**: **3 D phase** space to cover: statistics – beam type – beam energy

- first 5 years (~ RHIC)
  - initial Pb-Pb run in 2008 (**1/20th design L**, i.e. ~ 5 x 10^{25})
  - 2 Pb-Pb runs (medium -> design Luminosity L ~ 10^{27}), **integrate > 1nb^{-1}**
  - 1 p A run (measure cold **nuclear** matter **effects**, e.g. shadowing)
  - 1 low mass ion run (**energy density & volume** dependence)
  - **continuous pp running** √s = 14 TeV (comparison data, some genuine pp physics)

- following ~ 5 years
  - program and priorities to be decided based on results
    - lower energies (energy dependence, thresholds, RHIC, pp at 5.5 TeV)
    - additional AA & pA combinations
    - increased statistics
  - expect modest detector modifications & upgrades
    - discussion has started, R&D to follow after 2007, decisions ~ 2009

by Jurgen Schukraft in Sept.2007

Analysis CPU farm

◆Online: storing up to 1.2 Gbyte/s

⇔~ 10 x RHIC !

□ raw data >2 PByte/year

⇔ 20 days @100%DF

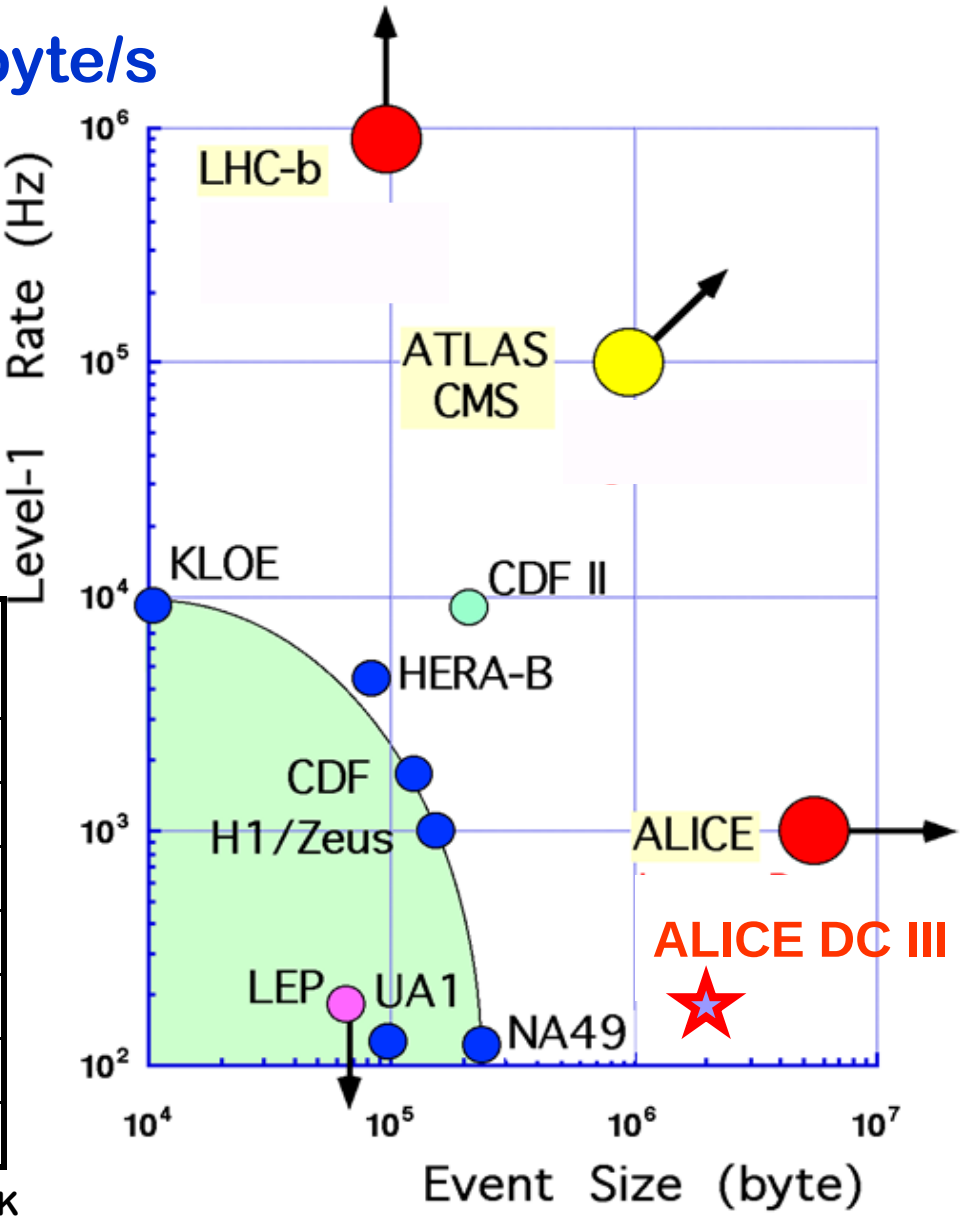
◆Offline: need 35M SpecInt2000

⇔10k high-spec PC's.

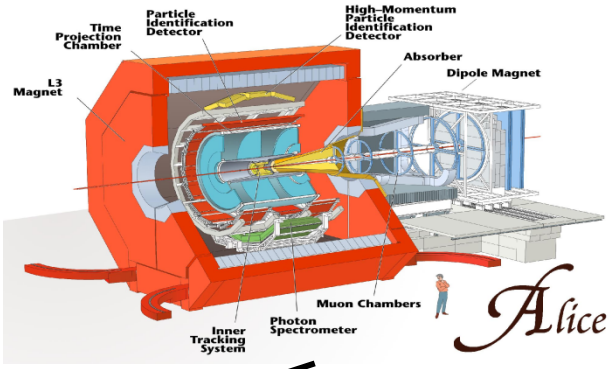
>10 x RHIC !! ⇒ ***WLCG***

		2008		2010	
		T1	T2	T1	T2
CPU	req.(MSI2K)	10.2	10.2	22.9	19.0
	missing(%)	▲32	▲13	▲34	▲30
Disk	req.(PB)	4.2	1.6	9.8	5.3
	missing(%)	▲32	43	▲31	▲5
MS	req.(PB)	7.0	-	20.9	-
	missing(%)	▲42	-	▲53	-

c.f. PE1950(Xeon5160 x 2cpu)=3.1kSI2K



Worldwide LHC Computing Grid



T*: Tier-*
CAF: CERN Analysis Facility
ESD: Event Summary data
AOD: Analysis Object Data

User Analysis

First Reco

Offline Analysis

2-3 Reco

On line Analysis

DAQ

T0

ESD

T1

ESD

AOD

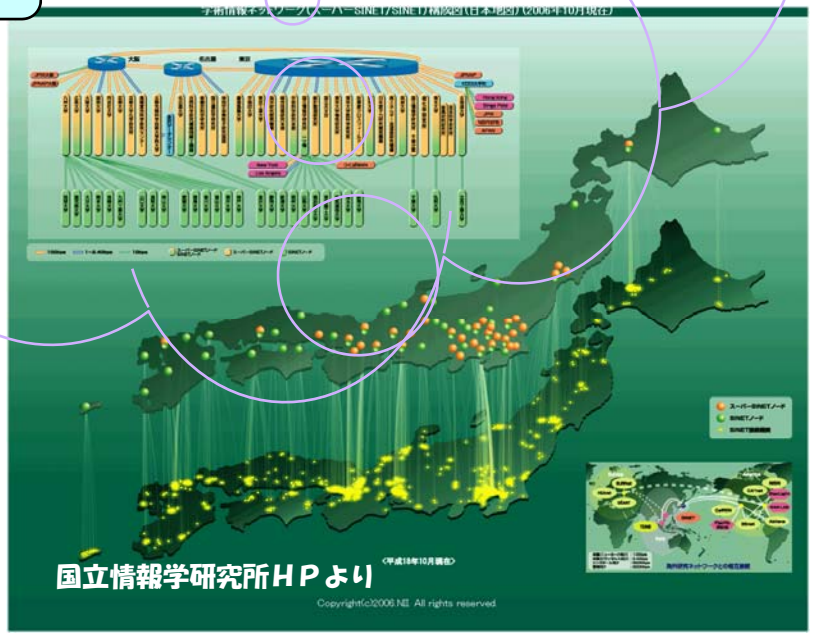
T2

T2

Buffer

CAF

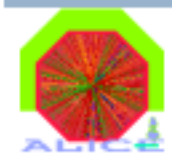
CASTOR @ T0



Grid Projects Collaborating in LHC Computing Grid

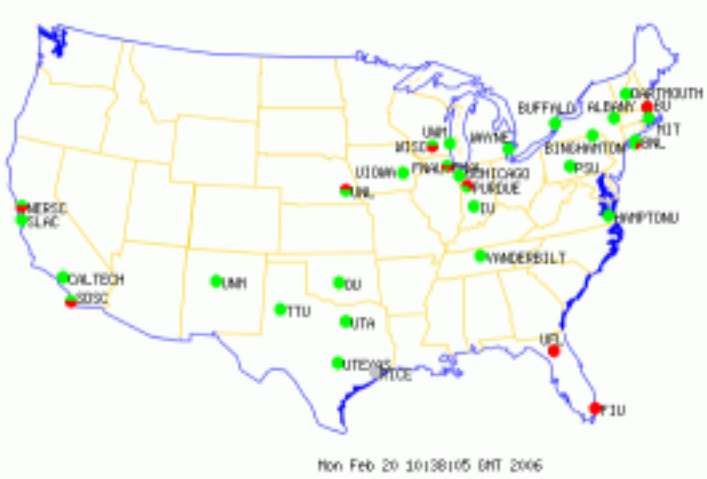
World-wide LHC Computing Grid

Open Science Grid



EGEE Operations Information

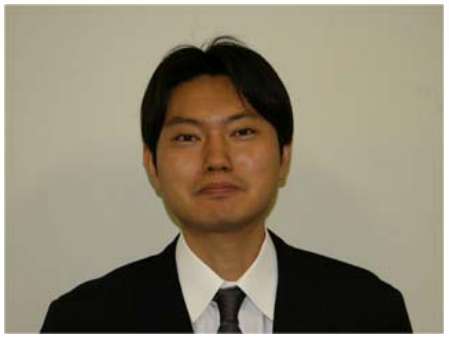
Active Sites	177
Available CPU	32183
Available Storage (TB)	3212214



LastBuild:Fri Mar 16 03:16:01 GMT 2007 GstatQuery:2006-12-15

WLCG-ALICE Tier-2 at Hiroshima

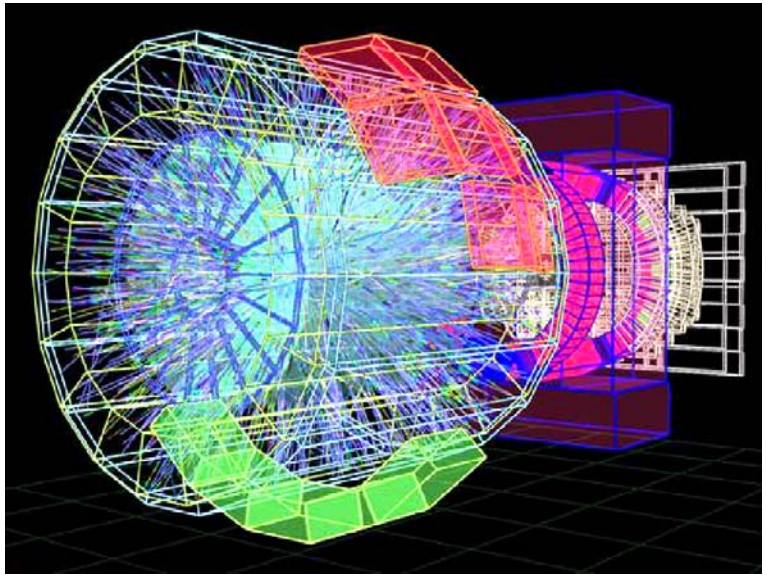
- An LCG site “JP-HIROSHIMA-WLCG” with EGEE/gLite3.0
- Current resources;
  Xeon5160(2cores@3GHz)X2cpuX38box
  =76 cores (1TFLOPS) & 42TB storage
- Additional CPU’s will be installed next week;
  Xeon5355(4cores@2.6GHz)X2cpuX32box
  =256 cores (2.7TFLOPS)
- Installing ALICE VO-Box now.
- Network B/W: MPLS 1Gbps on SINET3
- Associated Tier-1: ASGC & IN2P3
- Contact person:

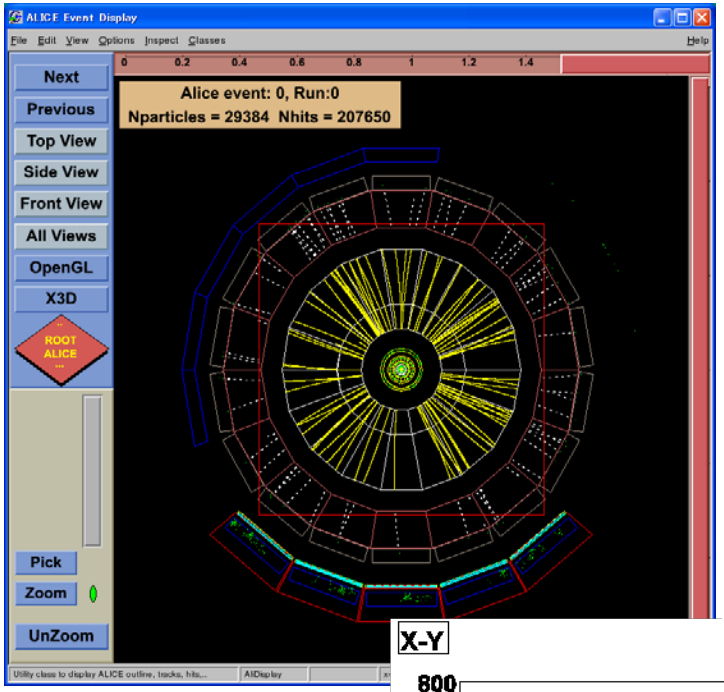


Dr. Takuma Horaguchi, Hiroshima

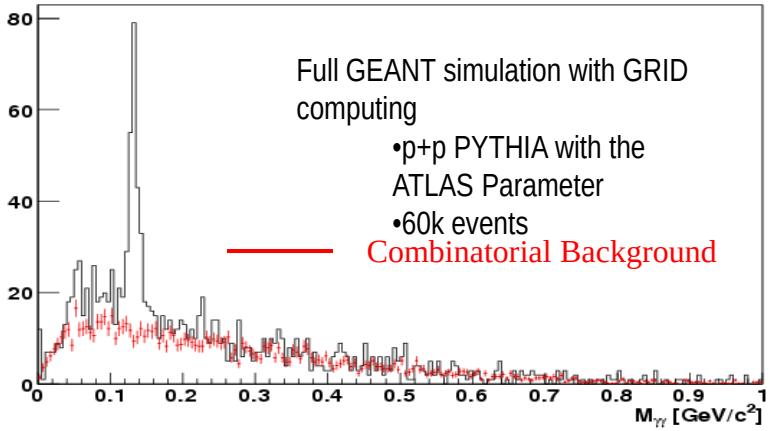
Quark Physics Laboratory
Hiroshima University, Japan

Simulation studies





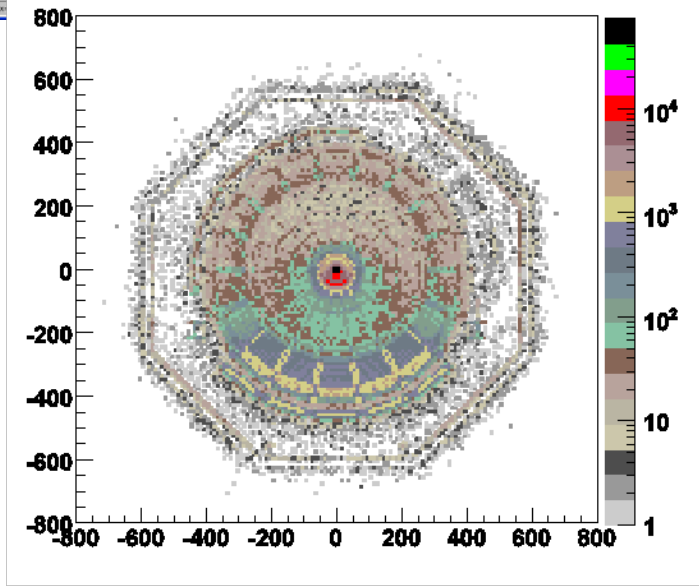
Event display with AliRoot



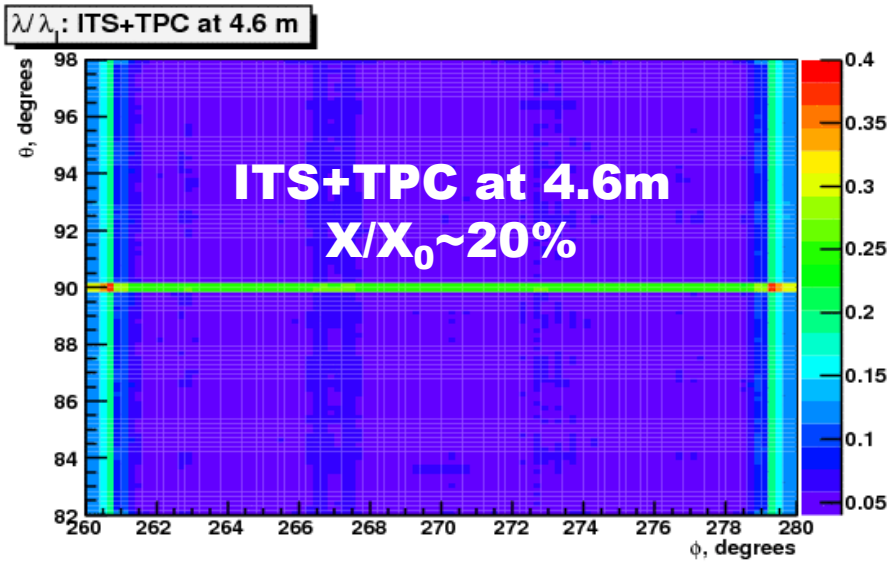
WLCG環境でのオフライン解析例

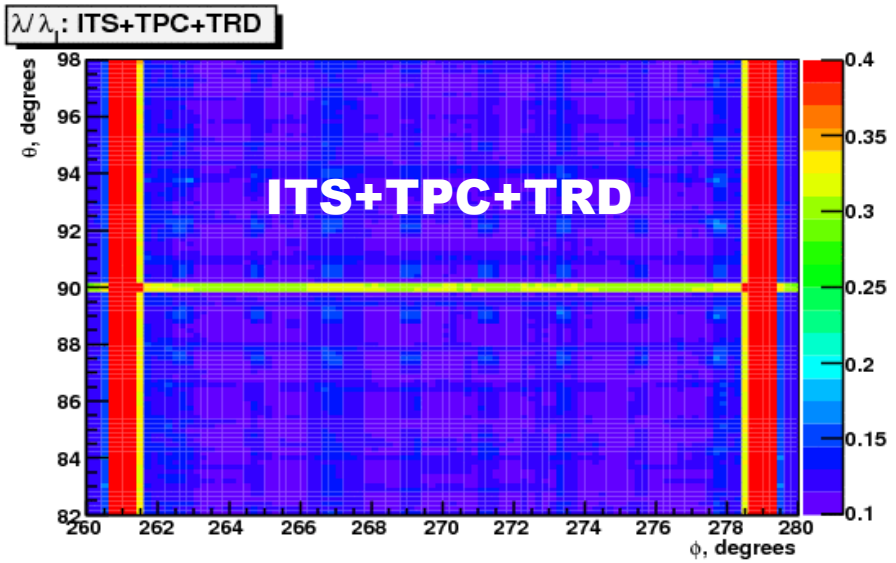
Full GEANT simulation of Mγγ with the GRID environment

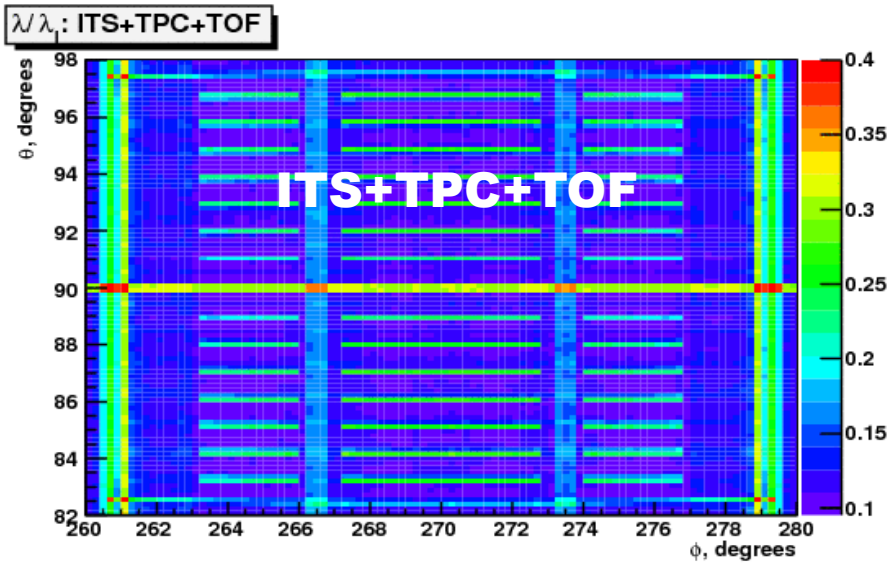
Background photon source map

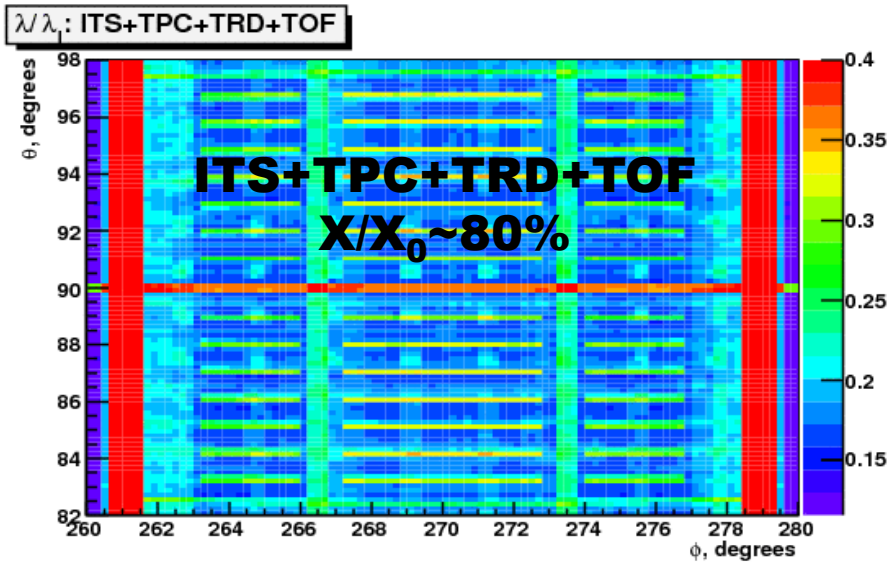


X-ray views projected on PHOS



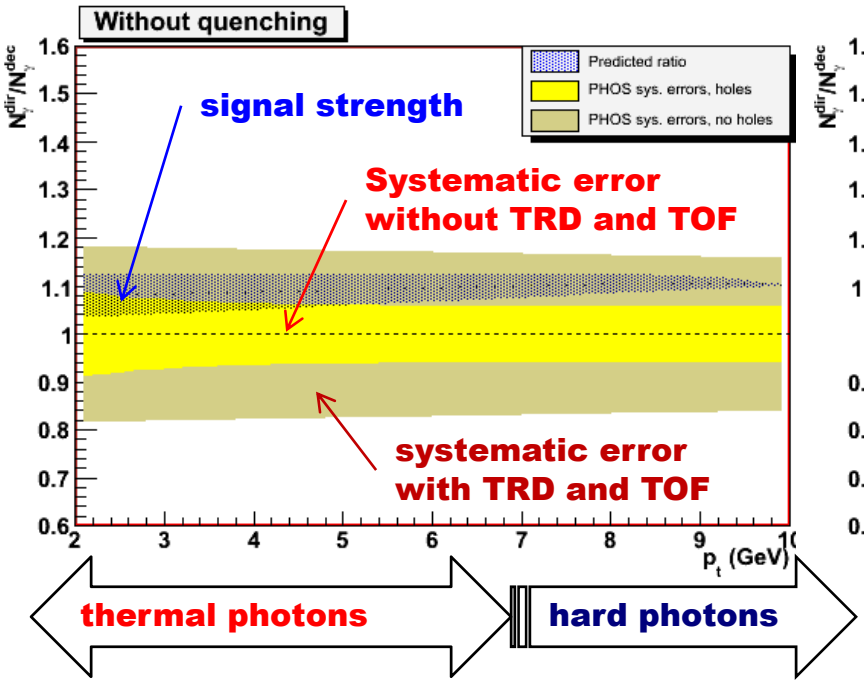


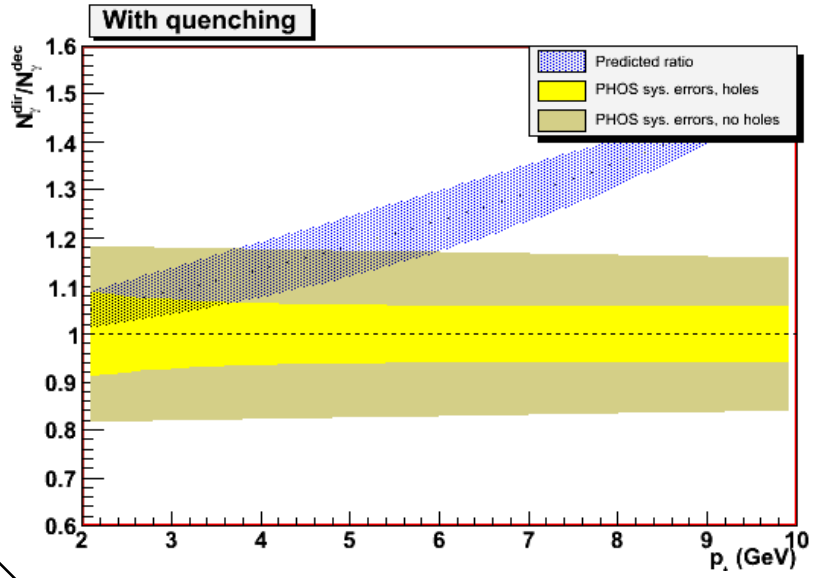


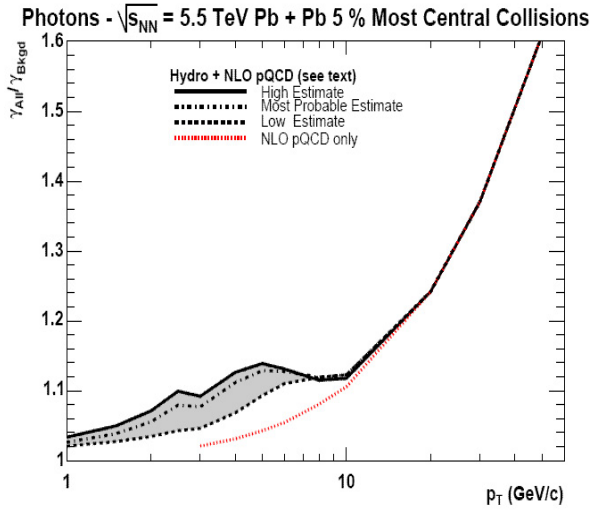


The latest news

single photon sensitivity along two scenarios; with and without jet quenching.







To save soft-photonic signals from QGP, ALICE will leave holes in TRD and TOF for 3 central PHOS modules, reducing X/X_o=80% down to ~20%.

ALICE Collaboration

~ 1000 Members

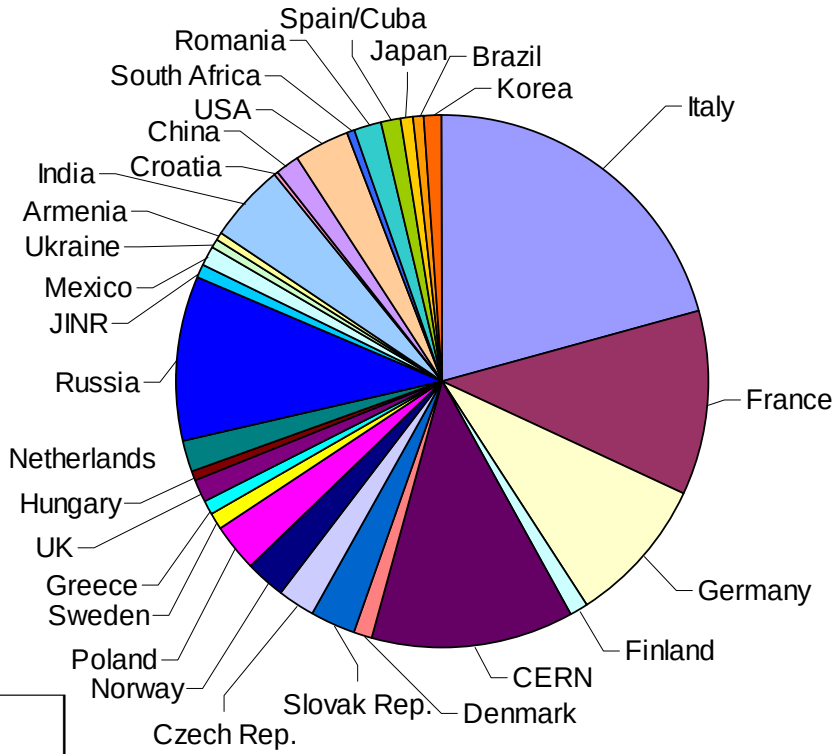
(63% from CERN MS)

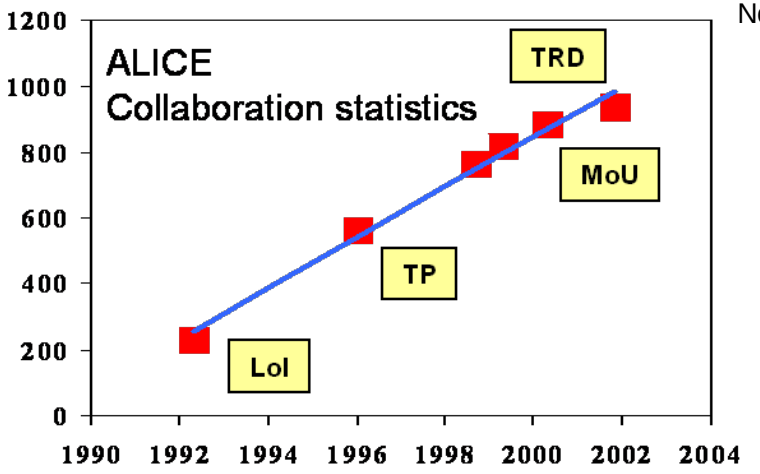
~30 Countries

~100 Institutes

~ 150 MCHF capital cost

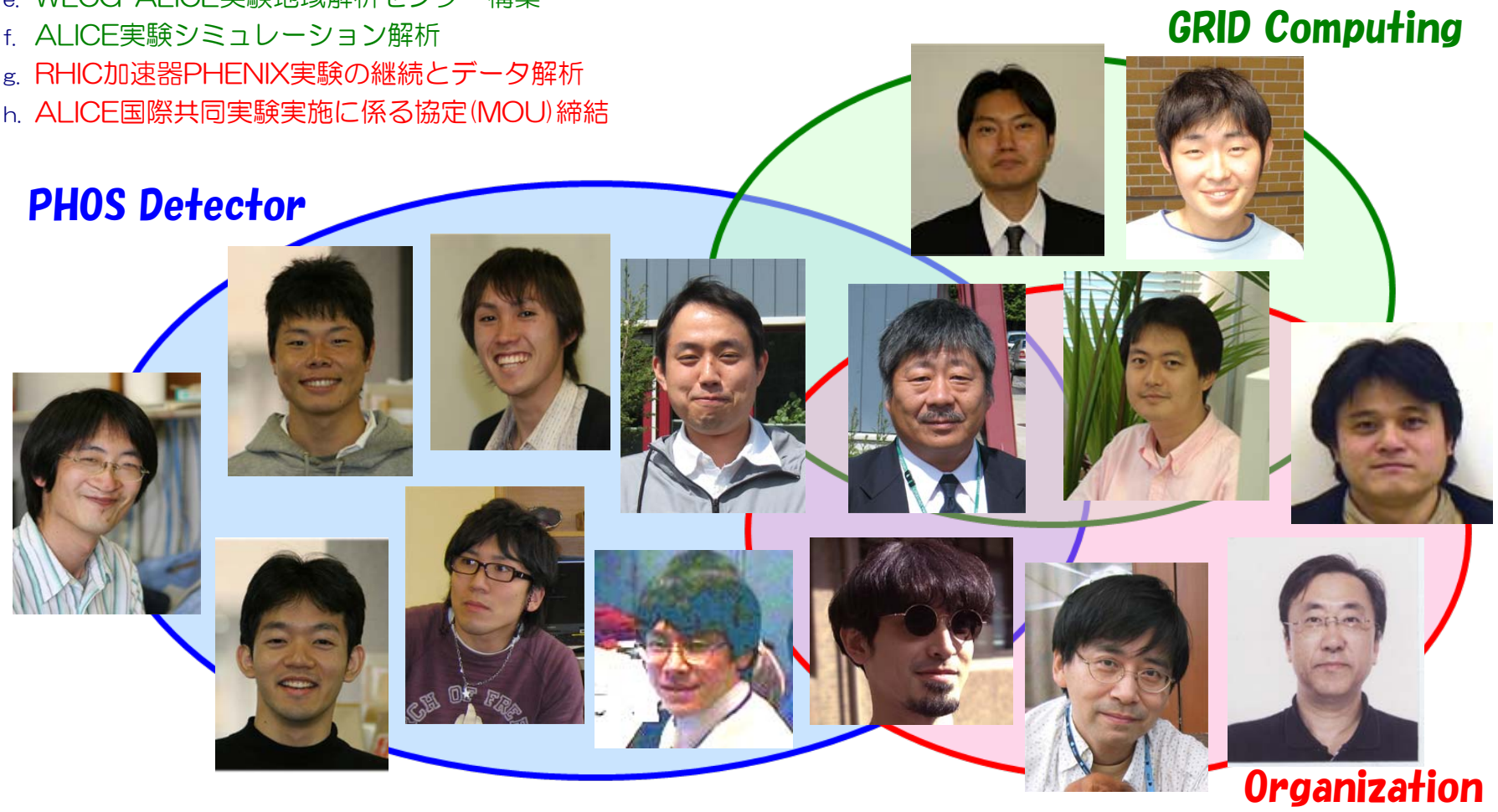
(+ 'free' magnet)





ALICE-Japan

a. PHOS検出器第１モジュールのエネルギー較正
b. PHOS検出器第２及び第３モジュール組立部品の国内生産
c. PHOS検出器総合品質検証及び機能開発国内拠点を構築
d. PHOS検出器制御システムの開発
e. WLCG-ALICE実験地域解析センター構築
f. ALICE実験シミュレーション解析
g. RHIC加速器PHENIX実験の継続とデータ解析
h. ALICE国際共同実験実施に係る協定(MOU)締結



Summary

- RHIC proven to be very successful
- not end of story; more funs now on stage
  - properties of hot and dense partonic matter
- ALICE at LHC starting *in months*
  - opening new ground for “soft” photonic probes
  - uniquely suitable for hard and/or heavy probes
  - Requesting 20% of LHC time for HI physics
- ALICE-J (Hiroshima, Tsukuba and Tokyo) in full commitment (along with RHIC)