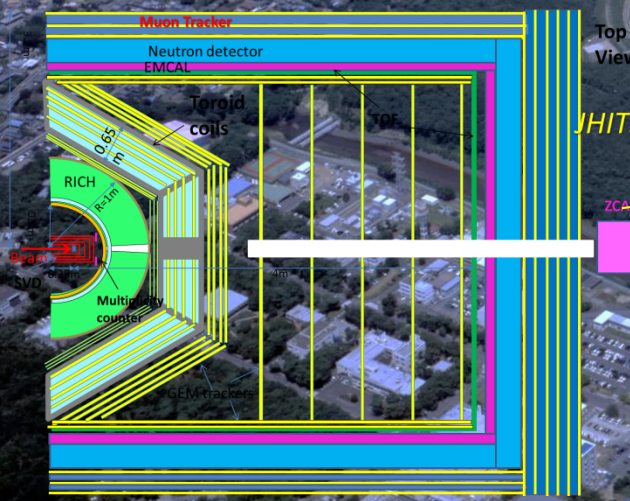
J-PARC重イオン計画に向けたALICE-O2への参加

佐甲博之(JAEA先端研)

計測システム研究会2016

2016/10/14-15

J-PARC-HI



50 GeV MR

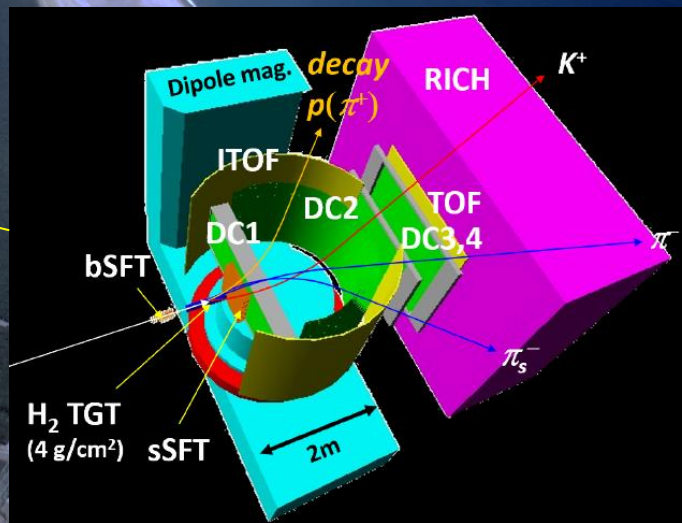
Top View

ZCAL

High-p beam line
@ Hadron Experimental Facility

J-PARC E50

$\pi^- + p \rightarrow Y_c^{*+} + D^{*-}$



J-PARC hi-pのALICE実験Online-Offline Computing(O^2)への参加

目的

J-PARCの高運動量ビームラインの実験(E50, J-PARC-HI)はALICEと同様のデータレートのデータ収集系を同時期に開発する予定。

ALICE O^2で採用しているtriggerless readout（連続信号読み出し）と、onlineデータ圧縮の技術が必要。

ALICEにassociate memberとして参入し、O^2 の開発に貢献するとともに、O^2 、DAQ の技術を J-PARC実験(E50,J-PARC-HI,その他将来の実験)に導入したい。

Associate member : 準collaborator。Collaboration feeを払わない代わりに技術的な貢献をする。論文に名前は載らない。

2016年7月より正式に参加

ALICE-O2-J-PARCグループ

- JAEA先端基礎研究センター
  佐甲博之（代表）
  佐藤進　(heavy-ion experiment)
  杉村仁志　(J-PARC K1.8 beamline DAQ)
  新博士研究員（2017年度）?
- 筑波大
  大学院生（2017年度）？(指導教官: 中條達也)
- RCNP, 大阪大
  野海博之　(E50 spokesperson)
  白鳥昂太郎　(E50 design)
  本多良太郎　(E16/E50 Readout electronics hardware)
  高橋智則　(E16/E50 DAQ)
- J-PARC センター/KEK
  小沢恭一郎　(E16/E50, MPGD detectors)
  五十嵐洋一　(J-PARC DAQ)
- 理研
  Yue Ma　(E50 CPU cluster)

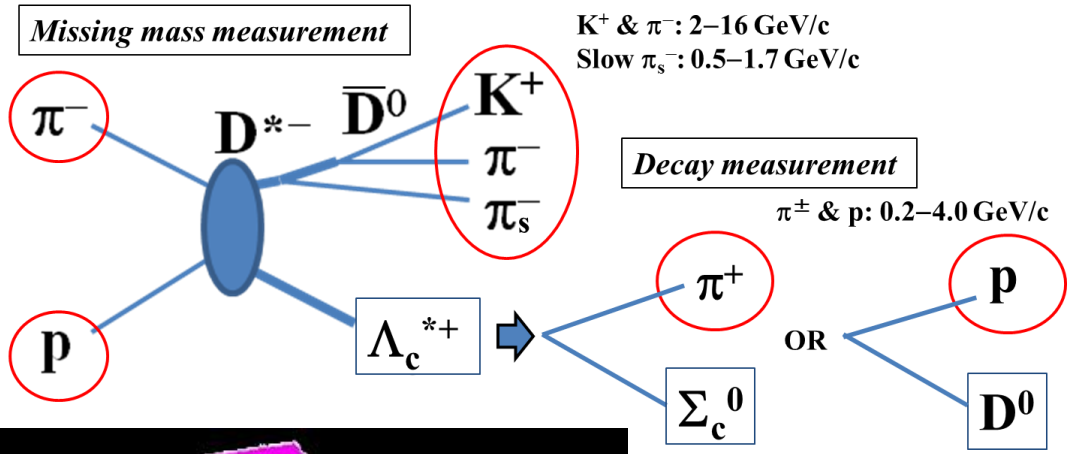
J-PARC 高運動量ビームラインを使用する実験

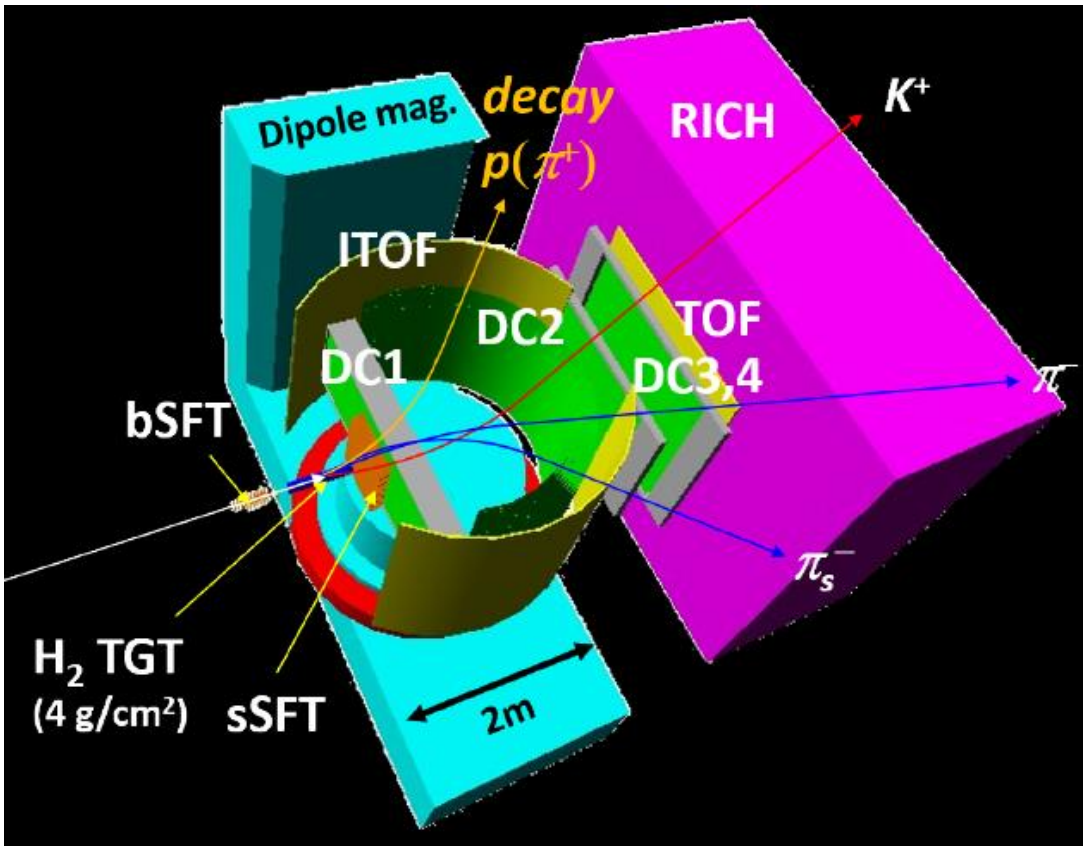
ALICE Run 3 (2021-2023)と同様のタイムスケール

	E16	**E50**	**J-PARC-HI**	**ALICE**
物理	p+A→e^+e^-	π+A→Yc+D*	Heavy-ion collision	Heavy-ion collision
開始年	2018-2020	2021-2024	>=2025	2021
データレート	0.1GB/s	10GB/s	1.2TB/s	3.3TB/s
ビームレート	10^{10}/cycle (cycle=5.5s)	6x10^7/cycle	4x10^{11}/cycle	
衝突レート	2x10^3/cycle (trigger)	4x10^6/cycle	4x10^8/cycle	50kHz
DAQ	trigger	triggerless	triggerless	triggerless

E50 : charmed baryon spectroscopy

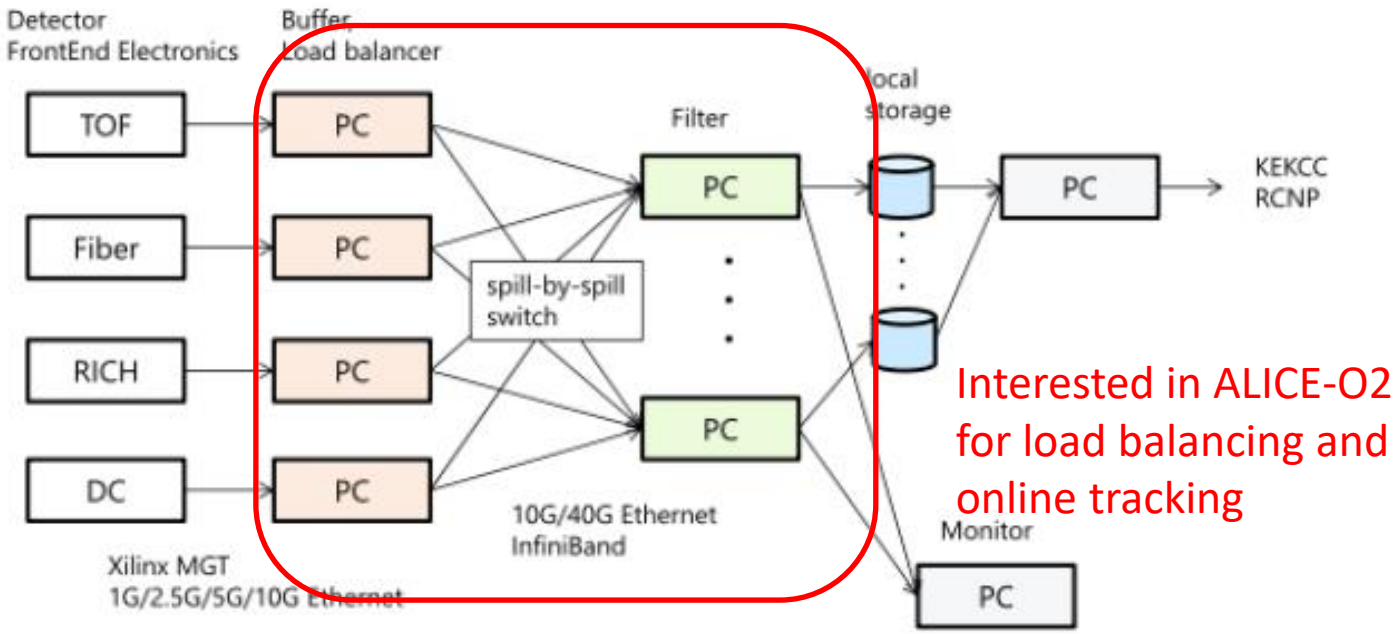
$\pi^- + p \rightarrow Y_c^{*+} + D^{*-}$ reaction
@ 20 GeV/c





J-PARC E50

Concept of trigger-less DAQ system



Interested in ALICE-O2 for load balancing and online tracking

Hardware

- Digitize all the hit signals without any trigger
- Data streaming via communication standard faster than Gbps.

Raw data rate from all the electronics **~50 GB/spill.**

Software (CPU cluster)

- Buffer PCs : Load balancer and de-randomizer.
- Filter PCs : Track reconstruction and filter the data packets.
  - Track finding : Cellular automaton
  - Track fitting : Kalman filter

J-PARC-HI

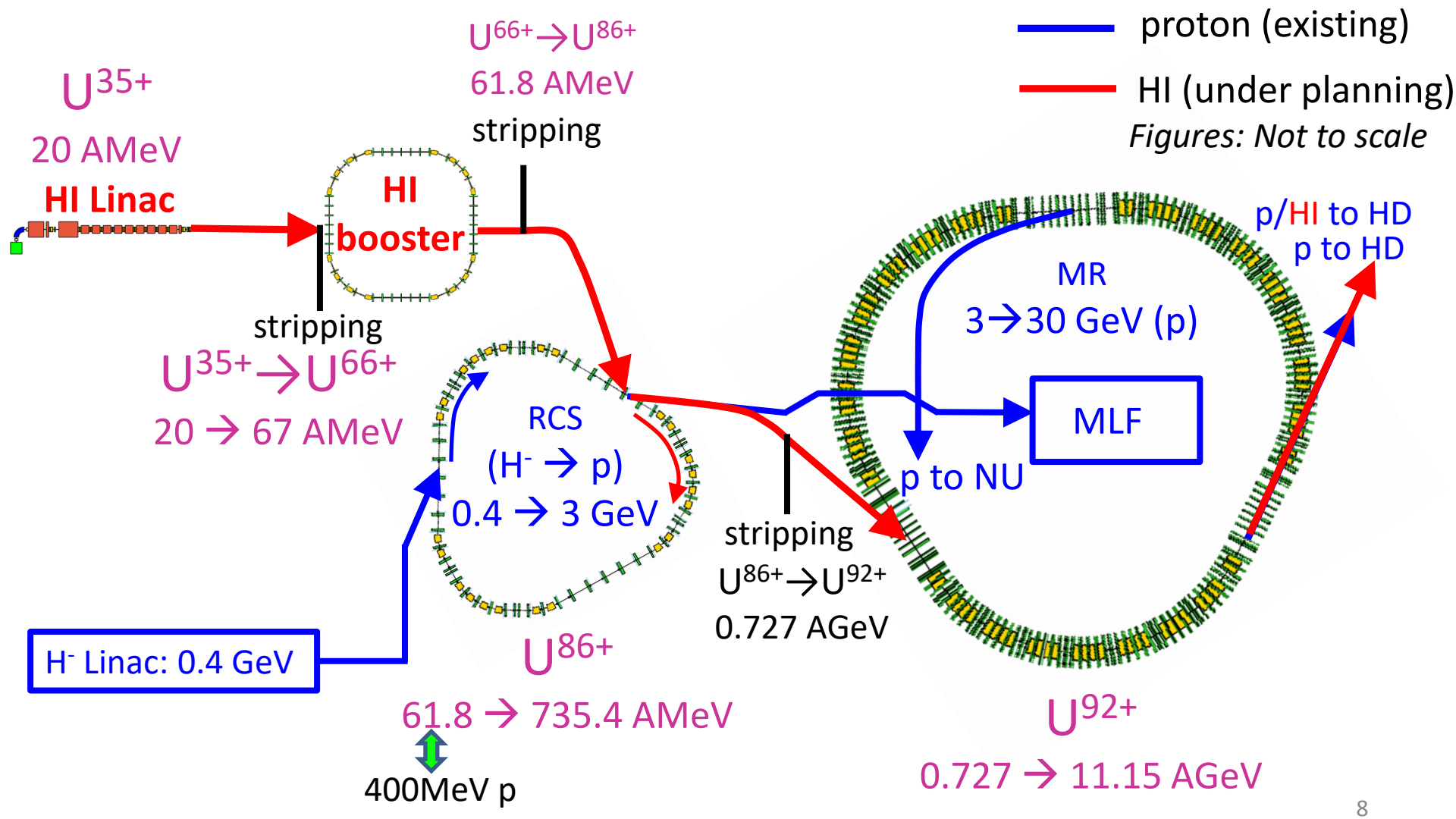
J-PARC の重イオン衝突では~5-10ρ_0の高密度物質が生成される

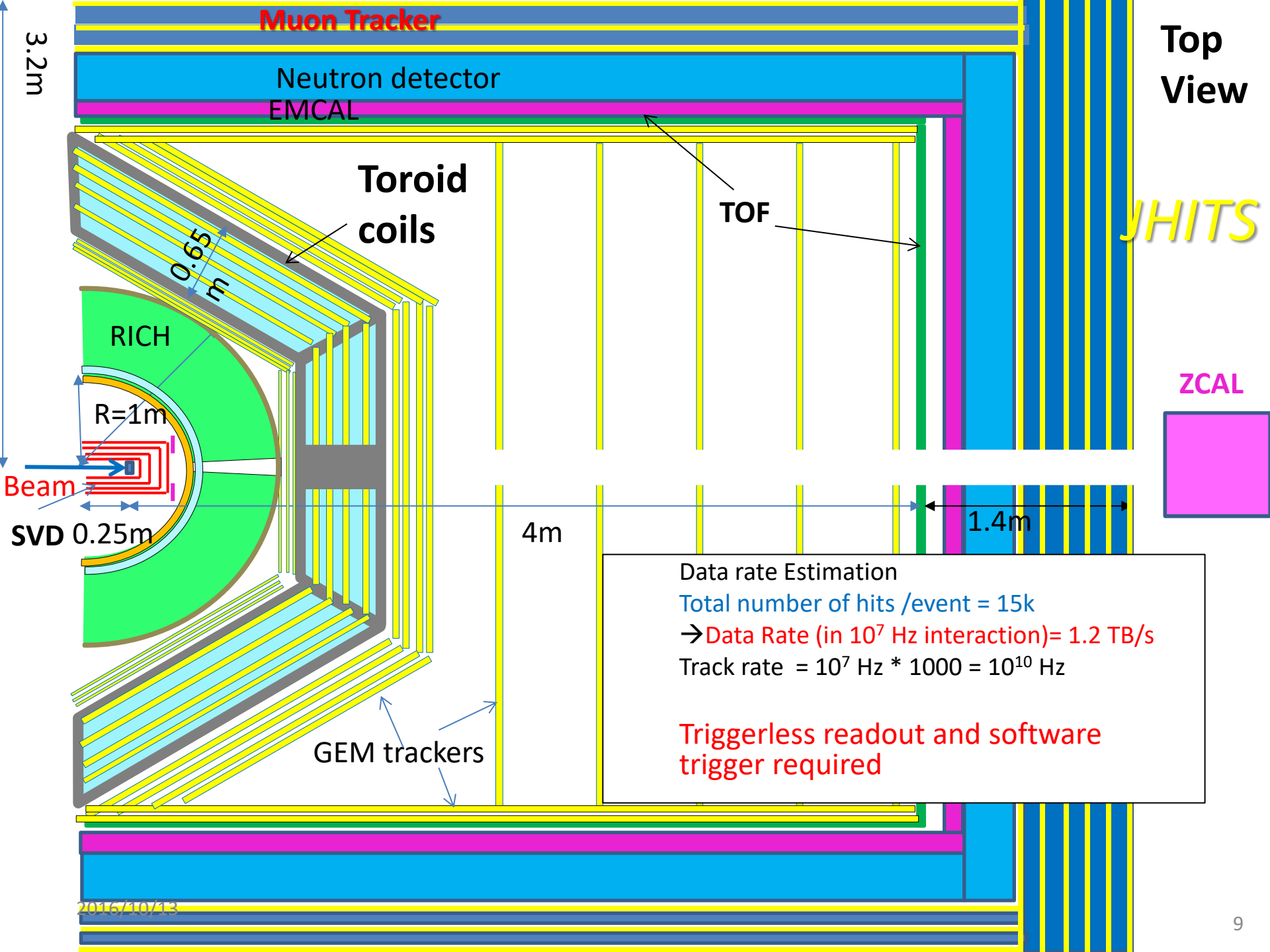
- QCD臨界点と一次相転移境界線探索
- 高密度物質の状態方程式

Ion species	p, Li, C, Si, Ar, Cu, Xe, Au(Pb), U
Beam energy	1-19 A GeV
Beam rate (world' highest)	10^{11} Hz
	10^{8} Hz interaction rate

J-PARC PACにLOIを提出 (2016年7月)

J-PARCにおける重イオン加速スキーム




Muon Tracker
Neutron detector
EMCAL
Toroid coils
TOF
3.2m
0.65 m
RICH
R=1m
Beam
SVD 0.25m
4m
1.4m
GEM trackers
Top View
JHITS
ZCAL
Data rate Estimation
Total number of hits /event = 15k
→Data Rate (in 10^7 Hz interaction)= 1.2 TB/s
Track rate = 10^7 Hz * 1000 = 10^{10} Hz
Triggerless readout and software trigger required

ALICE Run3 Upgrade (2021-2023)

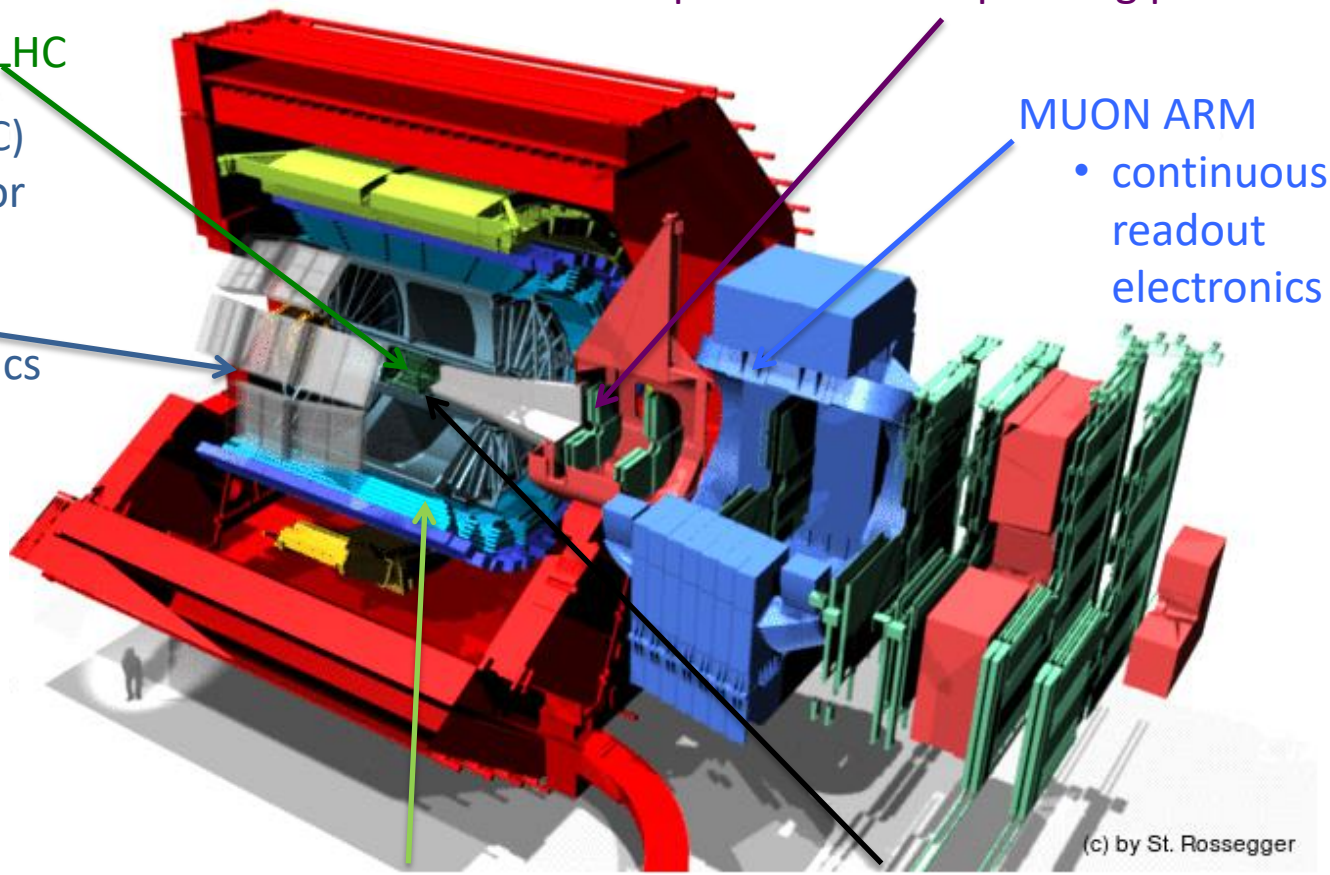
LHC after LS2: Pb–Pb collisions at up to L = 6 10^{27} $cm^{-2}s^{-1}$ ⇒ interaction rate of 50kHz

New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

Time Projection Chamber (TPC)
- new GEM technology for readout chambers
- continuous readout
- faster readout electronics

MUON ARM
- continuous readout electronics



New Central Trigger Processor

Entirely new Data Acquisition (DAQ)/ High Level Trigger (HLT)

TOF, TRD, ZDC
- Faster readout

New Trigger Detectors (FIT)

ALICE O^2 upgradeの概要

要求

1. LHC min-bias Pb-Pb at 50 kHz (#track ~ 3000)
   ~100 x more data than Run 1
2. Physics topics for ALICE upgrade
   - Rare processes(i.e. J/psi, D decays at $p_T \geq 0$)
   - Very small signal over background ratio
   - Needs large statistics of reconstructed events
   - Triggering techniques very inefficient
3. 50 kHz > TPC inherent rate (10kHz = drift time ~100 μs)
   Support for continuous read-out (TPC)

New computing system

- Read-out the data of all interactions

➔ Compress these data as much as possible online (to a few %)
by online reconstruction

➔ One common online-offline computing system: O^2

Unmodified raw data of all interactions shipped from detector to online farm in triggerless continuous mode

HI run 3.3 TB/s ⇩

First Level Processor (FLP)

Baseline correction and zero suppression
Data volume reduction by zero cluster finder.
No event discarded.
Average compression factor 6.6

500 GB/s ⇩

Event Processing Node (EPN)

Data volume reduction by online tracking.
Only reconstructed data to data storage.
Average compression factor 5.5

90 GB/s ⇩

Data Storage: 1 year of compressed data
- Bandwidth: Write/Read 90 GB/s
- Capacity: 60 PB

20 GB/s ⇕

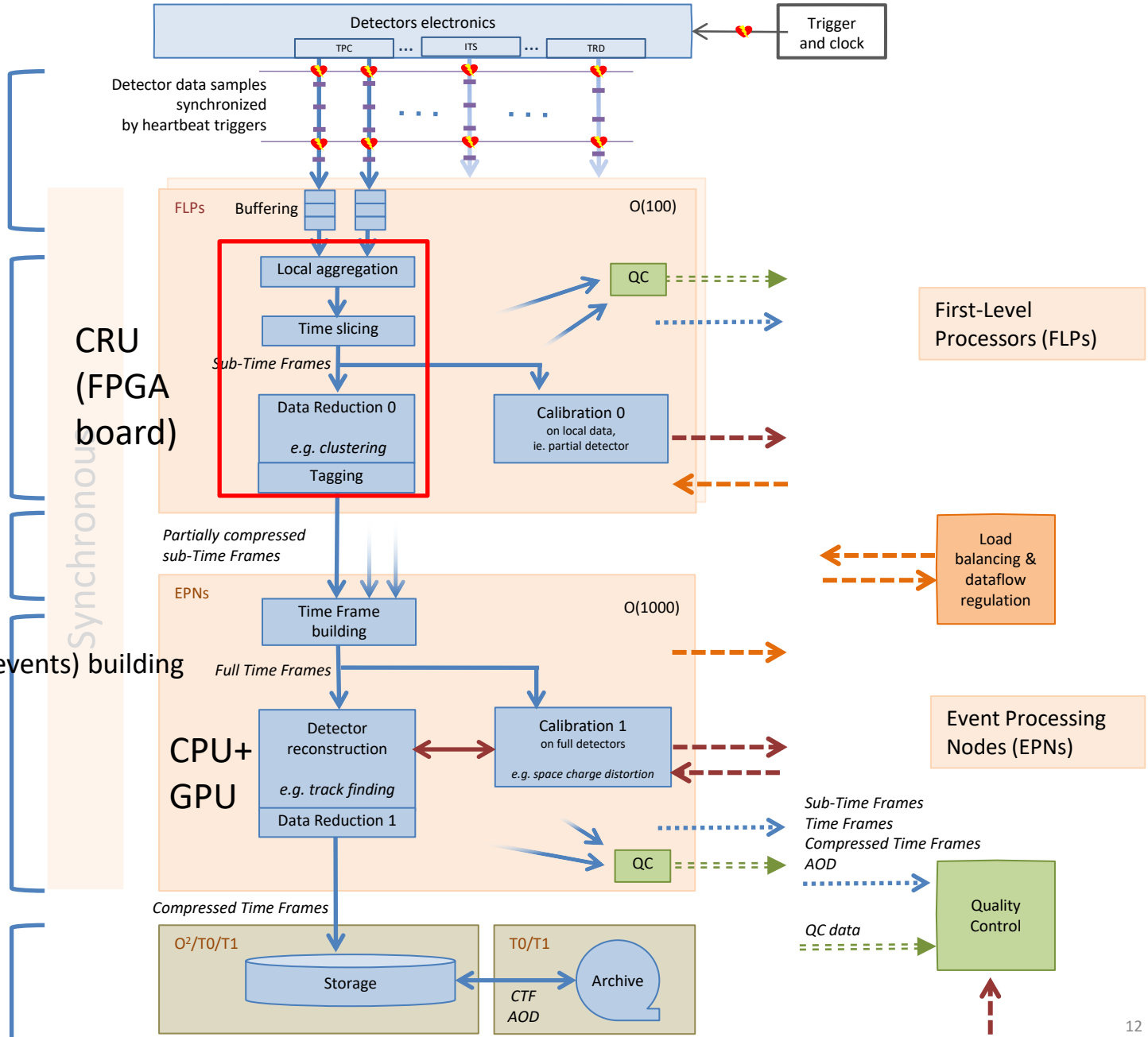
Tier 0, Tiers 1 and Analysis Facilities

⇕

Asynchronous (few hours) event reconstructionwith final calibration

ALICE-O2 data flow

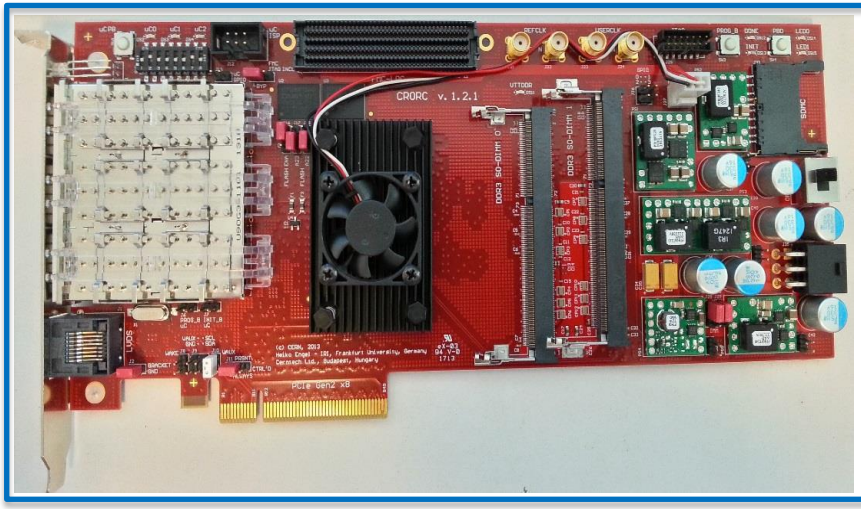
Data flow & processing (1)



F. Costa, Asian O2 workshop (July 2016)

The data stream

The receiver cards



C-RORC

12 bidir. links @ 6 Gb/s
PCIe gen2 x8
2 x RAM SLOTS
FMC connector

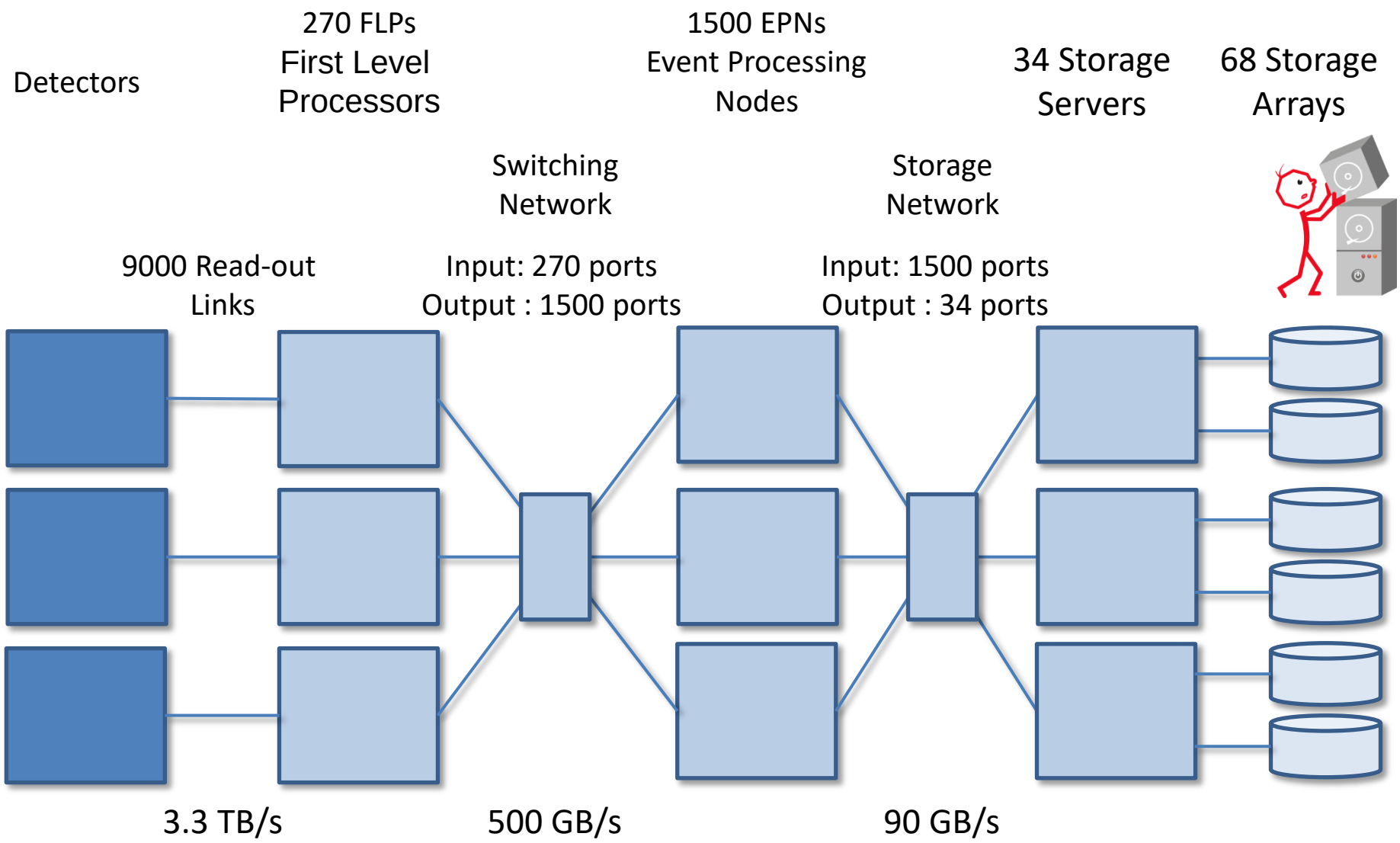
XILINX VIRTEX6 FPGA

CRU (Common Readout Unit)

48 bidir. links @ 10 Gb/s
PCIe gen3 x16

ALTERA ARRIAX FPGA

Hardware Facility



J-PARCからのO^2への貢献

- O^2 system test with CRU + FLP (JAEA)
- Load balancing between FLP and EPN (理研)

目的

- O^2 の詳細を学び、E50とJ-PARC-HIへの応用を検討
  - CRU, FLP, EPN
  - SAMPA (triggerless読出回路)
  - DAQとO^2 の設計
  - J-PARC検出器のオンライントラッキング

関連するALICE-J グループのR&D

長崎総合科学大（大山健）

- Development of CRU hardware
- R&D of fast DAQ system for J-PARC-HI
  - A research program at JAEA (Reimei) between JAEA and Nagasaki (JFY 2015 and 2016)
  - Mockup data generator PC with a FPGA evaluation board
    -(GBT protocol)→ data receiver PC with a FPGA board (2015)
  - FLP + CRU test (2017)

東大CNS（郡司卓）

- A full readout chain test of TPC (under consideration)
  TPC FEC (SAMPA) + CRU + FLP
- TPC online tracking

Coherent Contribution to O^2 from J-PARC and ALICE-J

Data flow & processing (1)

K. Oyama (NIAS)
CRU hardware

T. Gunji (CNS Tokyo)

TPC SAMPA FEC

Detectors electronics

TPC ... ITS ... TRD

Trigger and clock

Detector data samples synchronized by heartbeat triggers

Raw data input

Synchronous

FLPs Buffering O(100)

Local aggregation

Time slicing

Sub-Time Frames

Data Reduction 0

e.g. clustering

Tagging

QC

Calibration 0
on local data,
ie. partial detector

Local processing

H. Sako (JAEA)
System test of CRU+FLP

First-Level Processors (FLPs)

Y. Ma (RIKEN)

Load balancing & dataflow regulation

Partially compressed sub-Time Frames

Frame dispatch

EPNs

Time Frame building

O(1000)

Full Time Frames

Detector reconstruction

e.g. track finding

Data Reduction 1

Calibration 1
on full detectors

e.g. space charge distortion

QC

Global processing

Event Processing Nodes (EPNs)

Sub-Time Frames
Time Frames
Compressed Time Frames
AOD

QC data

Quality Control

Compressed Time Frames

O^2/T0/T1

Storage

T0/T1

Archive

CTF
AOD

Storage

JAEAでのFLP+CRUシステムテスト

目的 :FLP-CRUの詳細を学ぶ
FLP-CRUのデバッグと性能評価

テストベンチ

- PC with FLP software prototype (2 x Xeon (8core))
  - ASUS ESC4000-G3
  - 2 x Xeon 8-Core E5-2630v3
  - 64GB memory
- C-RORC board (CRUの旧バージョン）→CRU board
- TPC SAMPA FEC(triggerless読み出しボード)導入の可能性

暫定スケジュール

- 2016 年11-12月: FLP-PCを購入
- 2016年11-12月: C-RORCをALICEから借用
- 2017始め : FLP prototype +C-RORCの試験（長崎総合科学大からサポート）
- 2017終わり : CRUを購入
  FLP-CRU の試験開始

まとめ

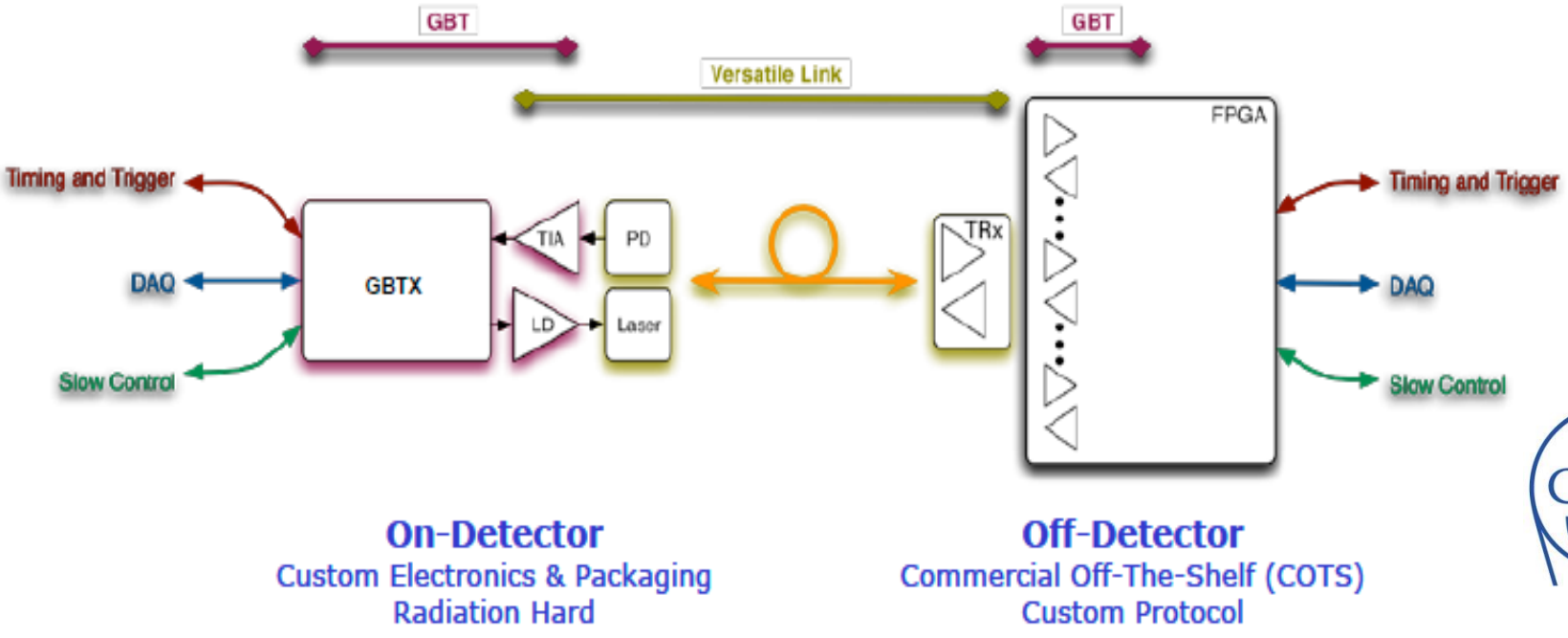
- ALICE O^2 開発は J-PARC E50 とJ-PARC-HI の要求と開発時期にマッチしている
- J-PARC high-pのグループはO^2 への貢献を行うためassociate memberとしてALICEに参入
- 最初のワークプラン
  - FLP-CRU システムテスト (佐甲、JAEA)
  - FLP-EPN間のLoad Balancingアルゴリズムの開発 (Ma, RIKEN)
- ALICE-Jとの協力
  - 東大CNS、長崎総合科学大
- Issue

  Man power

  共同研究者募集中！

GBT(GibaBit Transceiver)

Developed by
CERN electronic group



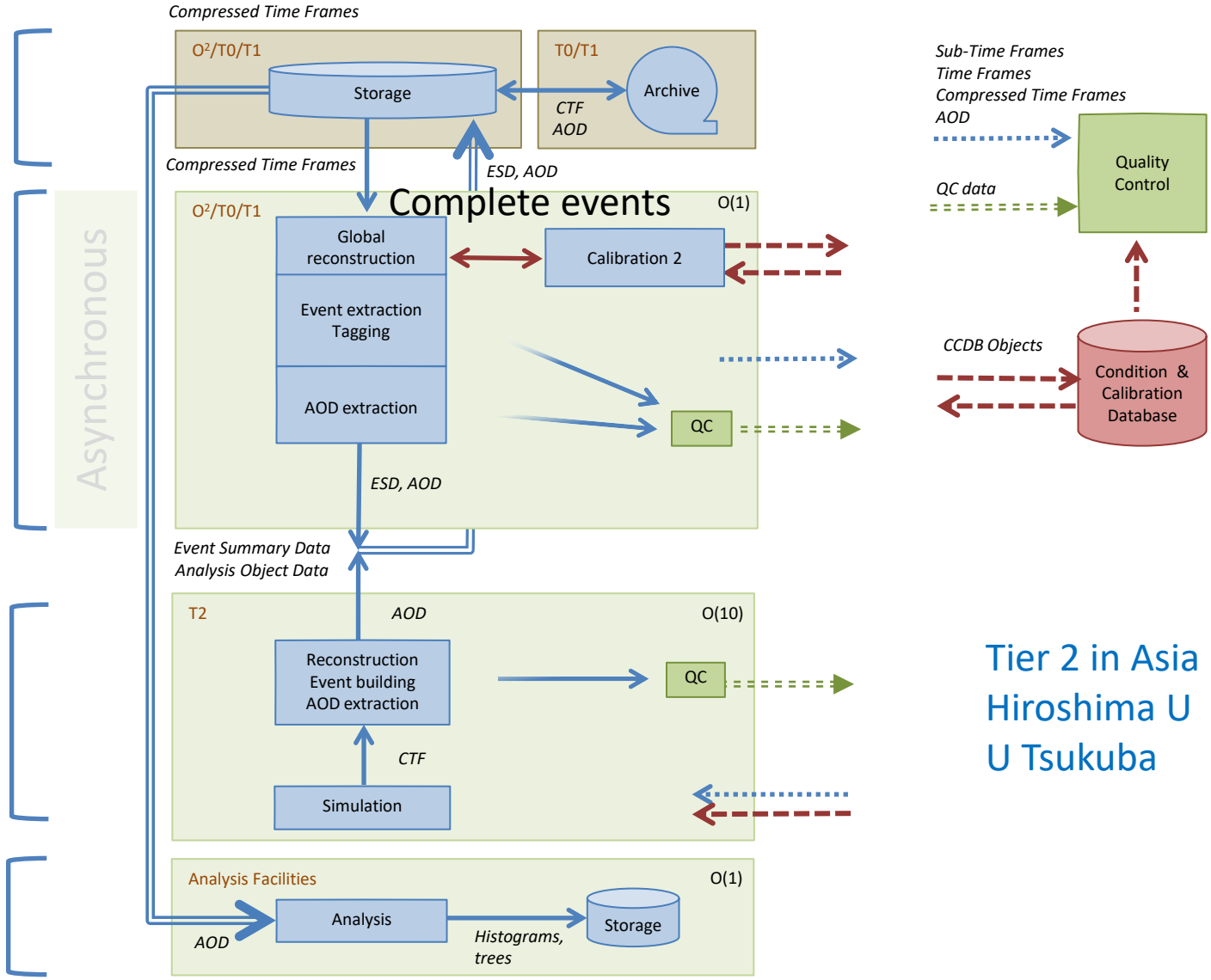
The new readout link is called GBT. It allows to transmit over a single fiber connection, at the same time, 3 streams:

- **DAQ**
- **Timing and Trigger**
- **Slow Control**

The main components are:

- The **GBTx chip** or **GBT-FPGA.**
- **Versatile link:** a point-to-point connection that can work in the harsh radiation environment of HEP experiments at CERN.

Data flow & processing (2)



Tier 2 in Asia :
Hiroshima U
U Tsukuba