XXI International Workshop on Deep Inelastic Scattering
and Related Subjects Marseille, April 22-26, 2013

# Future of DIS Experiments

## Summary from WG7 working group

Armen Buniatyan, Néstor Armesto, Franck Sabatié

## Part 1

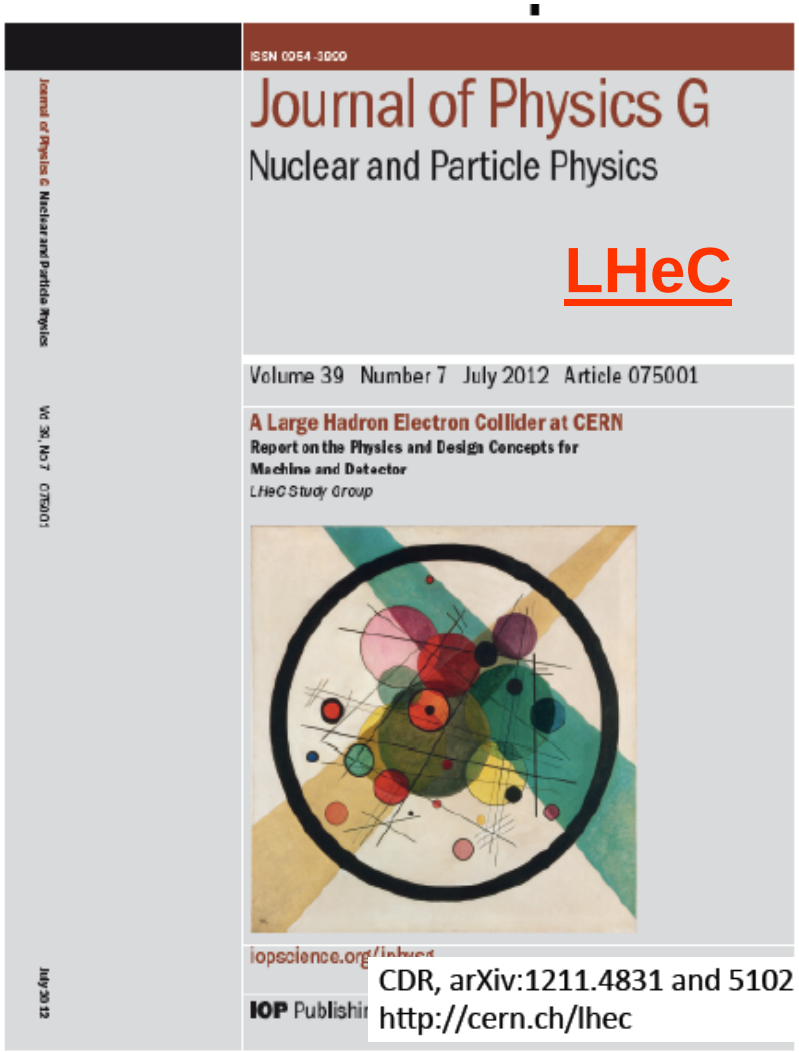
A. Buniatyan (Ruprecht-Karls-Universität Heidelberg)

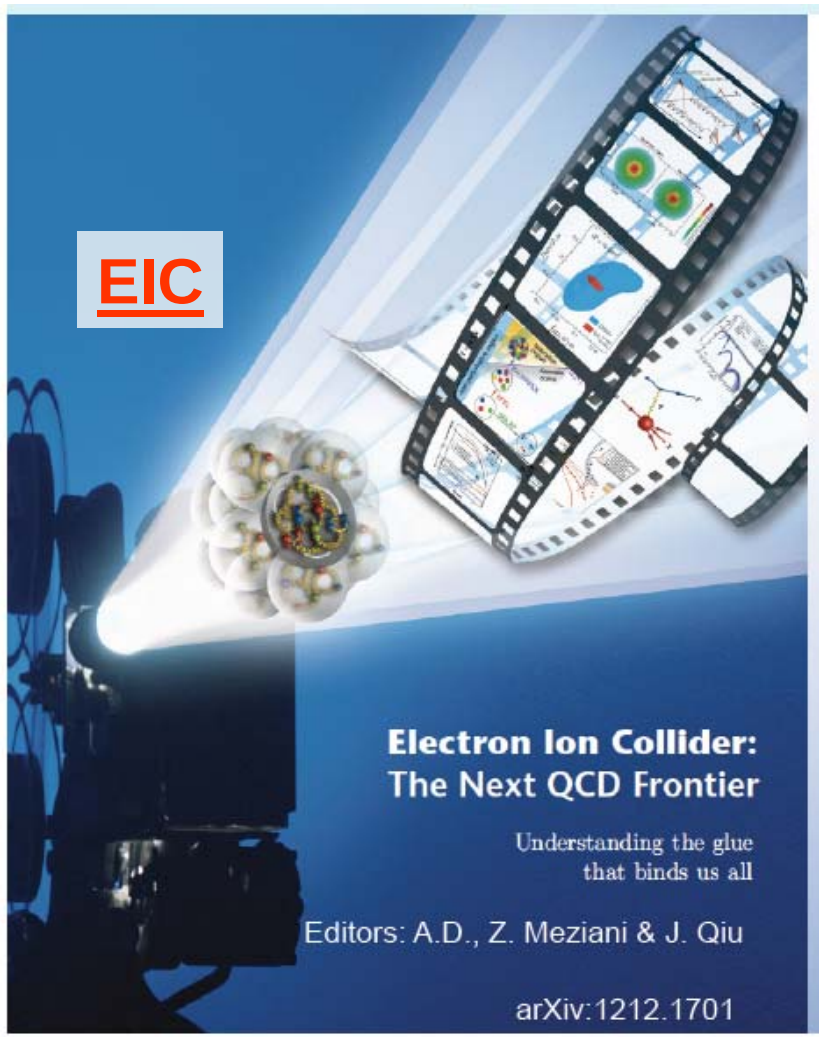
**27 presentations in our parallel sessions**

- Future ep and eA colliders, experiments and physics
- Experiments at the LHC and RHIC
- Fixed target experiments
- DPHEP - Data Preservation in High Energy Physics

**THANKS TO ALL SPEAKERS AND PARTICIPANTS !**

# Future Large Scale ep,eA Collider Facilities: LHeC/EIC



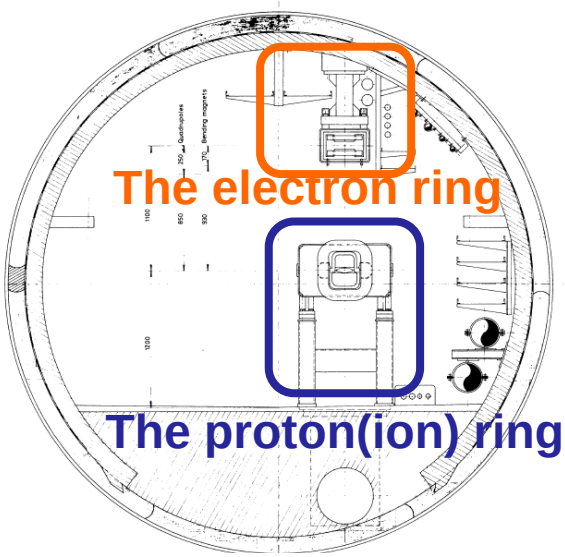



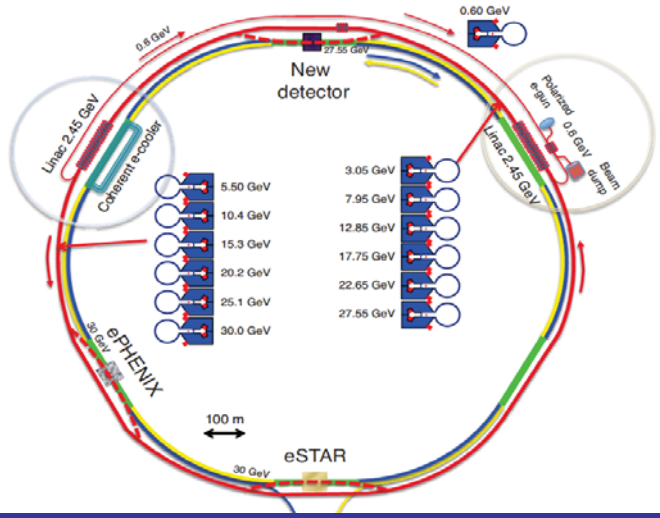

based on existing machines: LHC (CERN), RHIC (BNL), CEBAF (JLAB)

**Details in the following presentations**

# iCHEEPx – ep (eA) collider in the SPS tunnel

**iCHEEPx** – ep(eA) collider in the SPS tunnel: *an optimal facility to study the confinement phenomena*




2.45 GeV ERLs (no bypasses necessary)

6 vertically stacked recirculation passes in the arcs : 5.5, 10.4, 15.3, 20.2, 25.1, 30.0 GeV

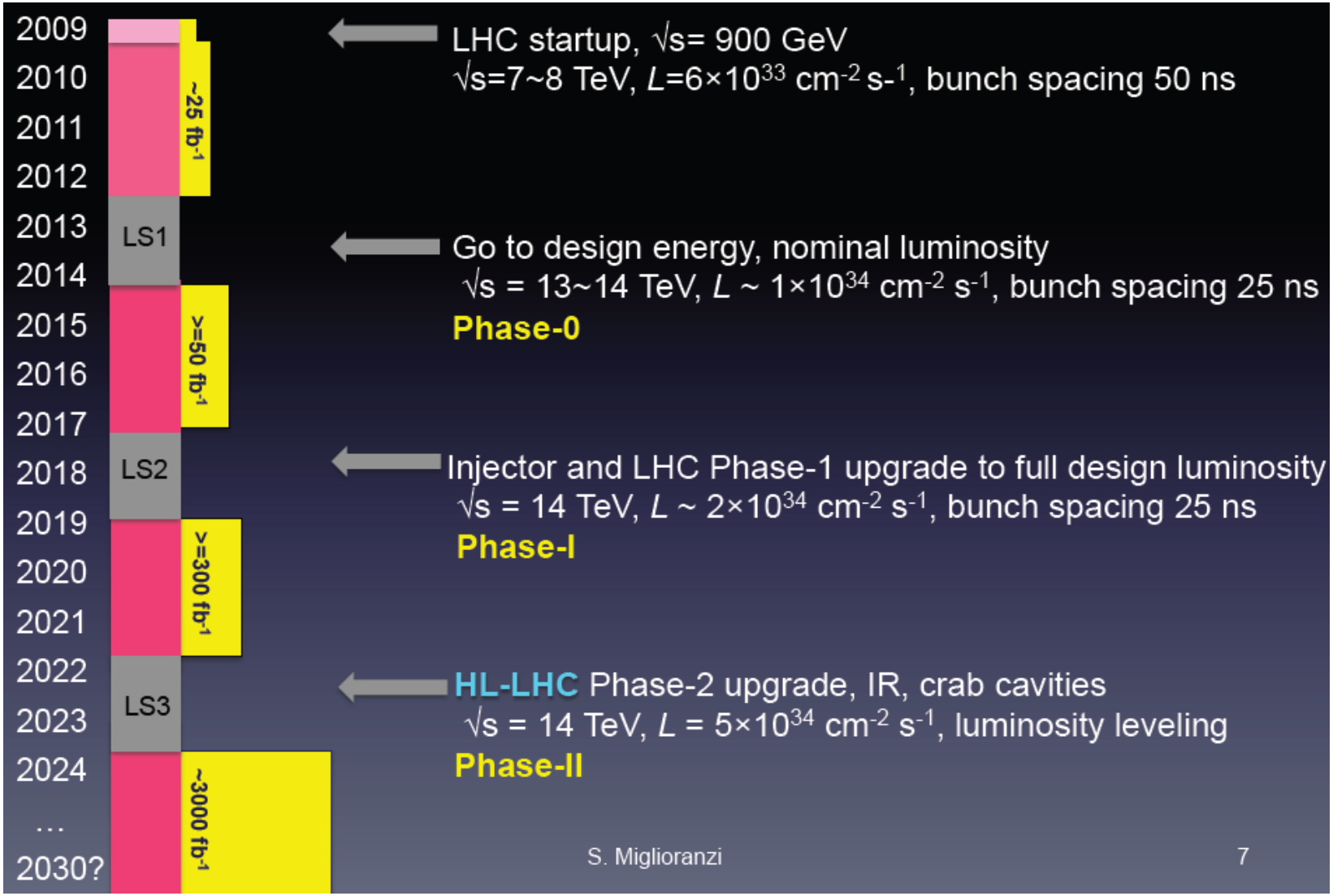
**$E_{CM}$(ep/eA) = 14-230 GeV**

(covers the energy range of eRHIC, MEIC and ENC@FAIR, overlap with PIE@LHC – easy cross-normalisation of the iCHEEP and LHC cross-sections)

*Witek Krasny*


The LHC

# The LHC upgrades




**Experiments:** Staged modifications to cope with high lumi at Phases 1 and 2

# The ATLAS upgrade

ATLAS is actively pursuing a series of upgrades to ensure continued detector efficiency and consequently optimal physics acceptance with increasing luminosity

- additional Pixel layer and other detector consolidation during shutdown (2013-14)

- major upgrades to improve Trigger capabilities during Phase-I shutdown (2018)

- replacement of the Inner Tracker, Forward Calorimeter, Electronics and Trigger/DAQ during the Phase-II shutdown (2022)

Graduated upgrade program to build on experience to improve our detector and equip it to run at up to 5 times the design luminosity ($5x10^{34}cm^{-2}s^{-1}$)

**These upgrades are essential to exploit the Physics potential at the LHC**

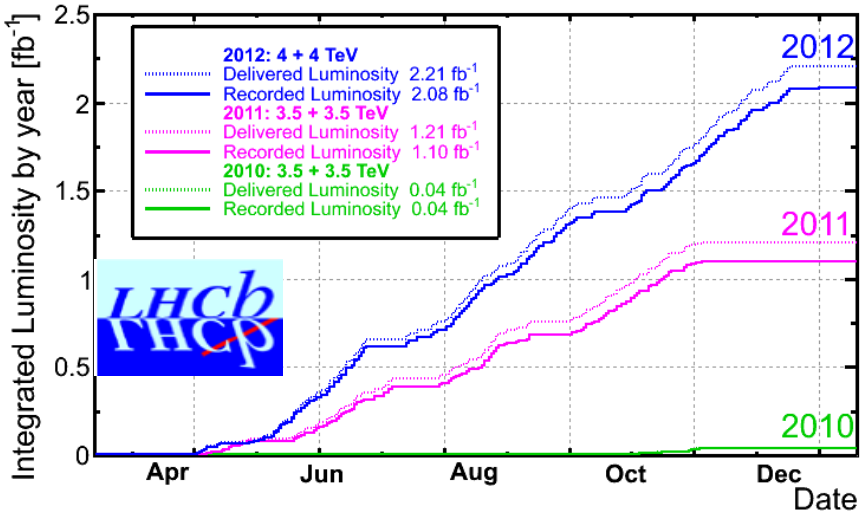
- to preserve performance while luminosity increases
- in several cases we can improve / extend the performance

*Silvia Miglioranzi*

# LHCb upgrade

LHCb has been efficiently taking data:
3.2 fb$^{-1}$ up to now

- The plan is to record 10 fb$^{-1}$ by 2018




The **Level-0 trigger** based on the signals from ECAL, HCAL and MUON detectors read at 40 MHz, operates on custom electronics, with a **maximum output rate limited to 1.1 MHz**.

➔ Plan to upgrade spectrometer by 2018 with a 40 MHz readout and a much more flexible software-based triggering system that will increase the data rate as well as the efficiency specially in the hadronic channels.

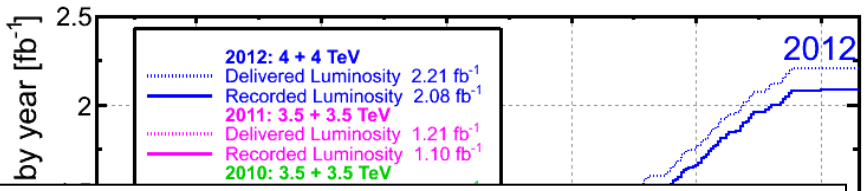
The upgrade shall take place during the Long Shutdown 2 (LS2) in 2018

Upgrade program involves readout electronics, high level trigger and network, VELO, Calorimeters, downstream tracking, Muon systems, RICH

*Umberto Marconi*

# LHCb upgrade

- LHCb has been taking data quite efficiently: 3.2 fb$^{-1}$ up to now

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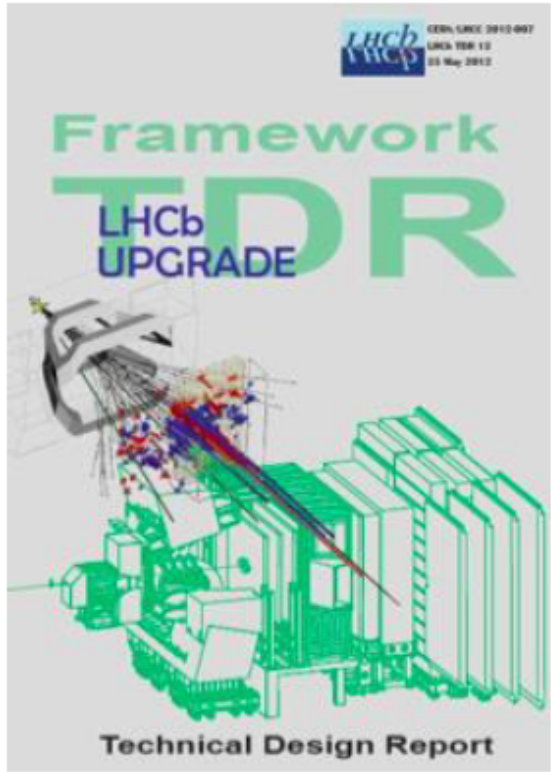
CERN/LHCC-2011-001




CERN/LHCC-2012-007

LHCb Upgrade fully endorsed by LHCC and approved by CERN Research Board

# ALICE upgrade

- Properties of partons in the Quark Gluon Plasma (QGP)
- Focus on the heavy flavors: charm and beauty
- Measurement of heavy-flavour transport parameters
- Low momentum quarkonia

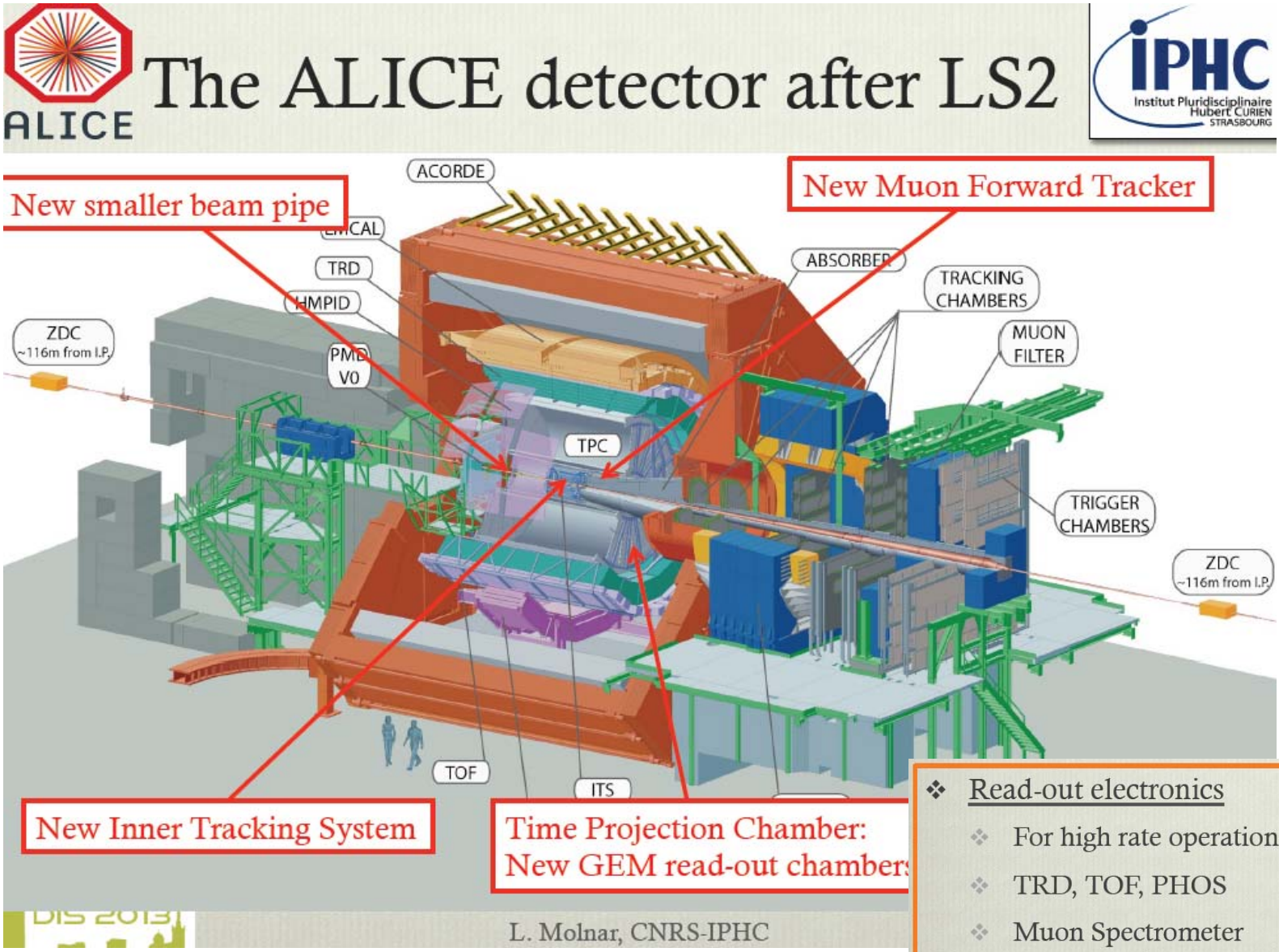
Physics goals

- Measurement of low-mass and low-$p_T$ dileptons
  - Initial temperature, equation of state
  - Chiral symmetry restoration, thermal radiation
- Jet quenching and fragmentation (with PID)
  - Parton color charge, mass, energy dependence of energy loss
- Heavy-nuclear states (eg. $^4$He) and hyper-nuclei (eg. $^5{}_{\Lambda\Lambda}$H)

- Most physics signals of interest are rare but not triggerable
  - Low $p_T$, high combinatorial background
- Increase rate capabilities for minimum bias heavy-ion collisions
  - ALICE runs at high luminosity
    - Record minimum bias Pb-Pb at 50kHz → physics program requires 10 nb$^{-1}$ of integrated luminosity wrt. the current goal of 1 nb$^{-1}$
    - Factor 100 increase in statistics (for untriggered probes)

*Levente Molnar*

# ALICE upgrade




- Read-out electronics
  - For high rate operations
  - TRD, TOF, PHOS
  - Muon Spectrometer

*Levente Molnar*

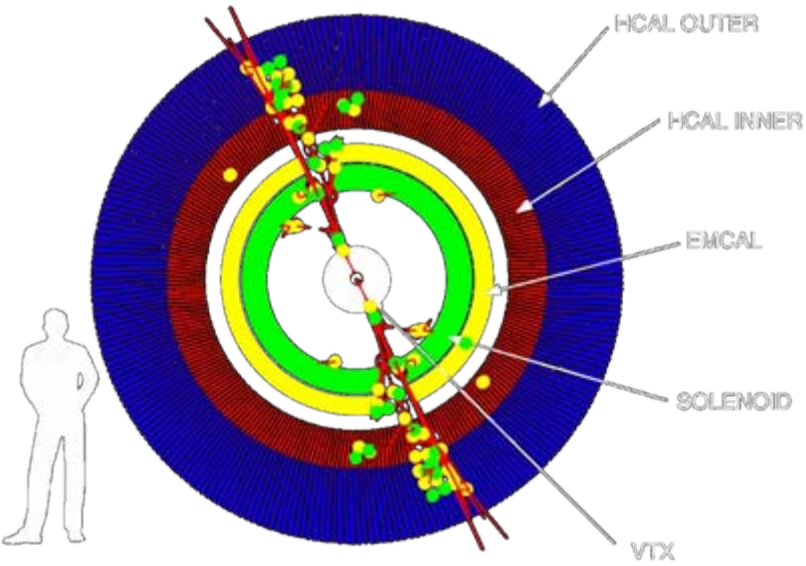
# PHENIX upgrade at RHIC → sPHENIX

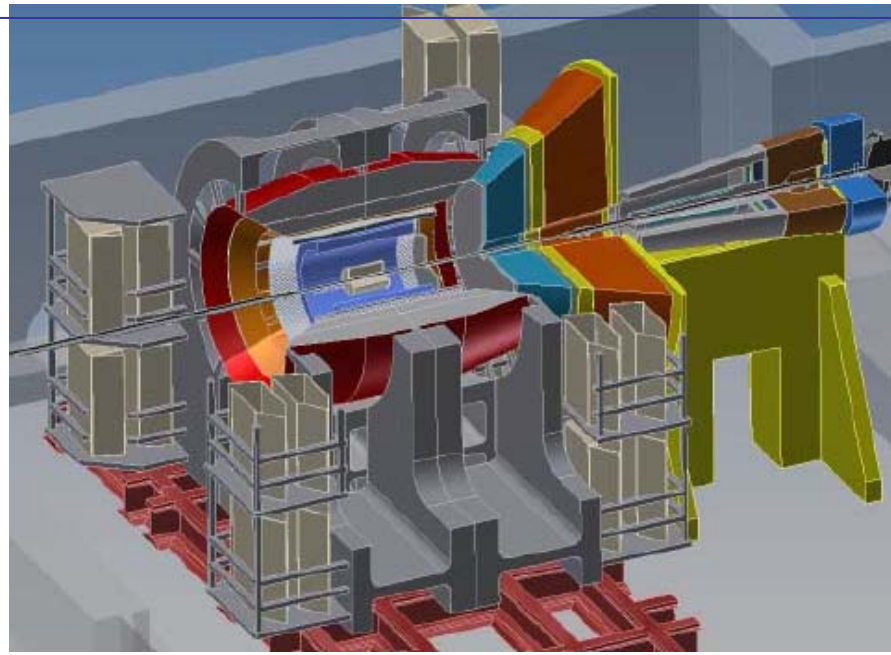
Major Upgrade to PHENIX for enhanced physics programs ; taking advantage of significant technology advances

Toward building a coherent understanding of strongly interacting QGP:
Heavy ion physics, spin structure of the nucleon with polarised pp and dAu, precision jet measurements

http://arxiv.org/abs/arXiv:1207.6378

- Compact jet detector at mid-rapidity with high-rate capability
  - Mid-rapidity tracking and preshower
  - Forward upgrade



*Yuji Goto*

sPHENIX upgrade proposal submitted to DOE

# Fixed Target Experiments





# The COMPASS-II program

**DVCS & HEMP measurements**
Transverse Imaging of the proton
Beam charge & spin
sum, difference and asymmetry
GPD H, later GPD E
Tests in 2008-9, 1-month run in 2012
Data taking 2016 & 17

**Drell-Yan measurements**
Sivers PDF
Boer Mulders PDF
Test of factorization approach
Data taking 2015

Upgrade existing
COMPASS Spectro
@ CERN/SPS

**SIDIS expts**
PDFs and Frag.F
s(x), Kaon FF
Data taking
in parallel

**Primakoff expts**
π and K Polarizability
Chiral Dynamics
Data taking 2012

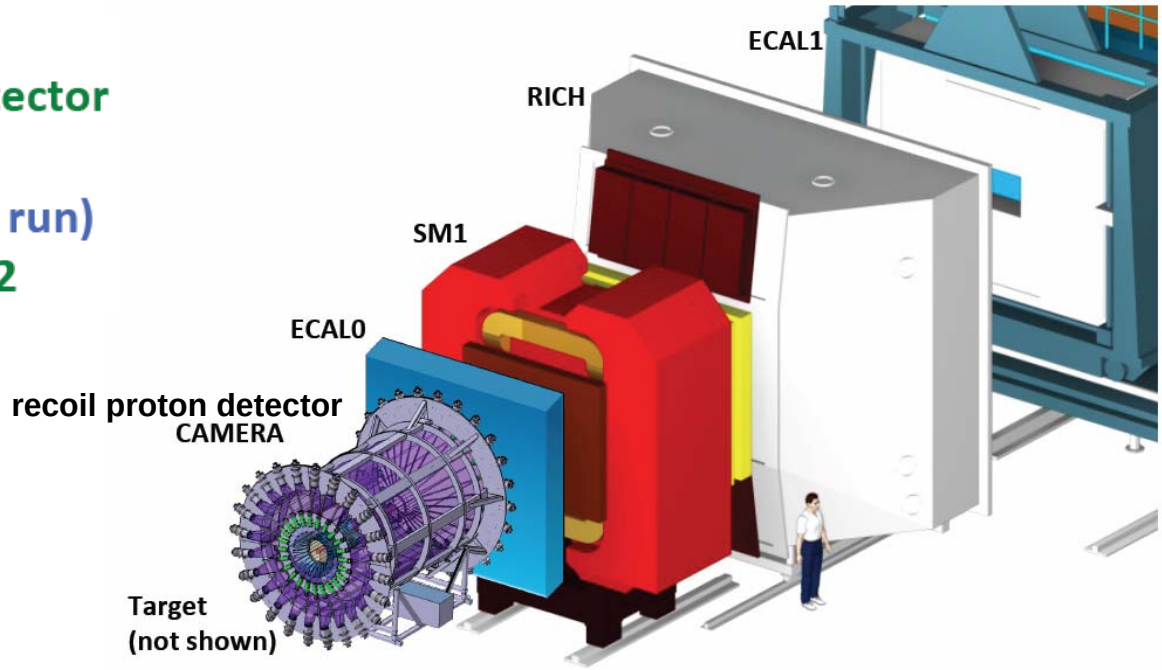
Proposal submitted to CERN: 05/2010
Approval 12/2010

*Etienne Burtin, Michela Chiosso*

# COMPASS-II at SPS

## Upgraded Spectrometer

- ✓ 2.5m LH2 target
- ✓ 4m ToF Recoil particle detector
  - ✓ CAMERA
- ✓ ECAL0 (1/4 avail. for 2012 run)
- ✓ Rearrangement of ECAL1,2



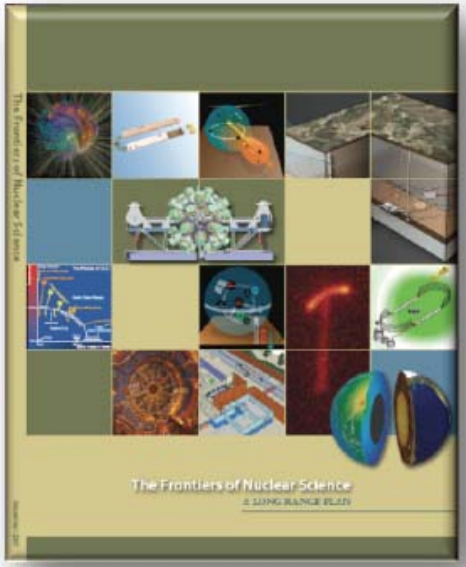

| | |
|---|---|
| 2014 | Single polarised Drell-Yan with $\pi^-$ beam --> TMDs (Sivers and Boer-Mulders) sign change |
| 2015+16 | DVCS with $\mu^+$ and $\mu^-$ beams on unpolarised protons |
| in parallel | unpolarised SIDIS --> PDFs, TMDs, FFs (in particular for strange) |

*Etienne Burtin, Michela Chiosso*

Second year of Drell-Yan data taking?

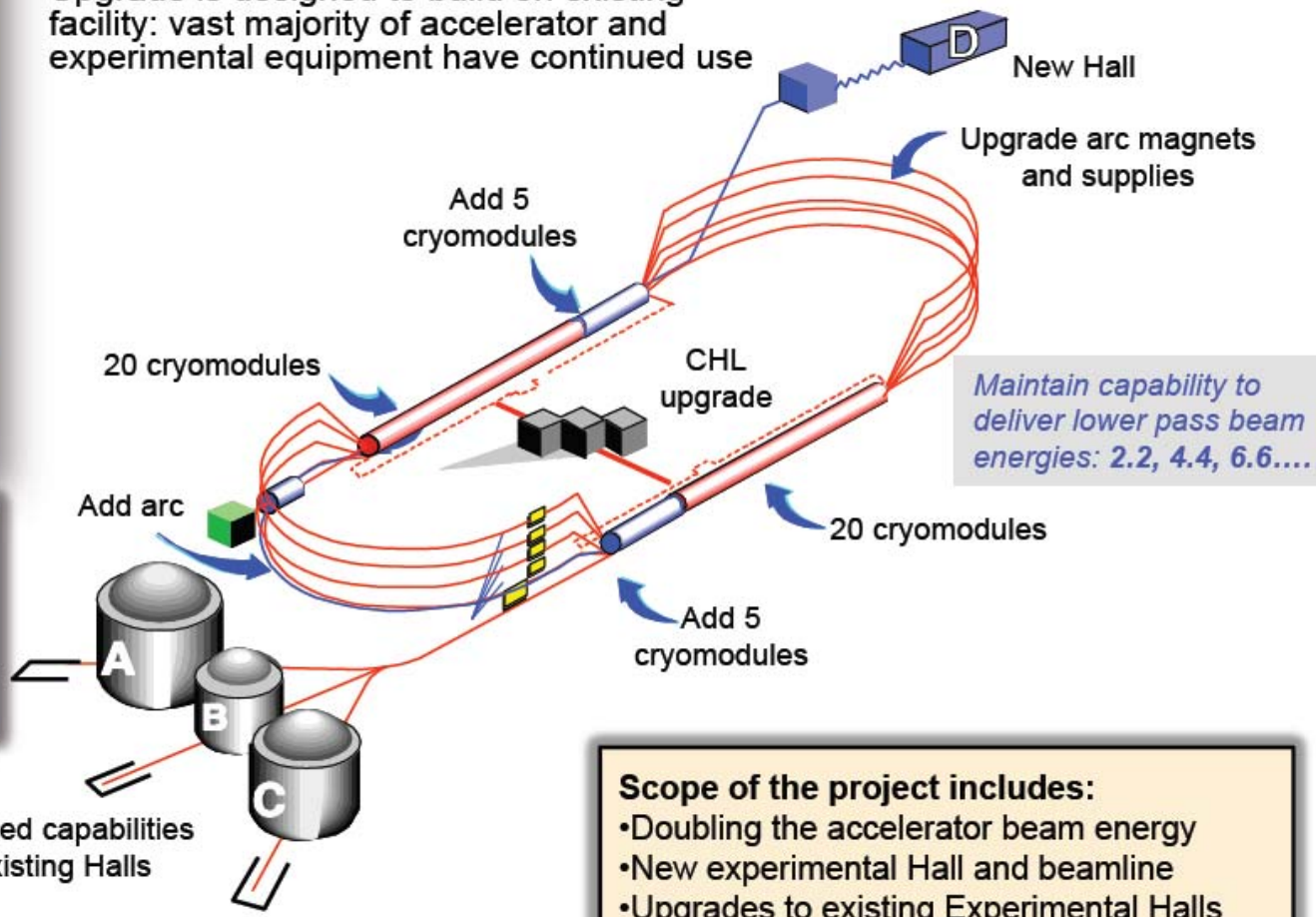
...beyond 2016 --> TMDs (Sivers, Boer-Mulders, and Pretzelosity), transversity PDF

# Physics with the 12 GeV Upgrade at JLab




The completion of the 12 GeV Upgrade of CEBAF was ranked the highest priority in the 2007 NSAC Long Range Plan.

Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use




*Maintain capability to deliver lower pass beam energies: **2.2, 4.4, 6.6....***

**Scope of the project includes:**
- Doubling the accelerator beam energy
- New experimental Hall and beamline
- Upgrades to existing Experimental Halls

*Cynthia Keppel*

# Physics with the 12 GeV Upgrade at JLab

- Project 75% Complete, 88% Obligated
  - Civil (92%) ; Accelerator (88%) ; Physics Equip (~60%)
- We expect to be running beam to Hall A in February 2014 and Hall D later in the year
- Large user involvement in 12-GeV detector construction
- 7+ years approved, Halls have prepared initial schedule

## 12 GeV Approved Experiments by Physics Topic

| Topic | Hall A | Hall B | Hall C | Hall D | Total |
|---|---|---|---|---|---|
| The Hadron spectra as probes of QCD (GluEx and heavy baryon and meson spectroscopy) | | 1 | | 1 | 2 |
| The transverse structure of the hadrons (Elastic and transition Form Factors) | 4 | 3 | 2 | | 9 |
| The longitudinal structure of the hadrons (Unpolarized and polarized parton distribution functions) | 2 | 2 | 5 | | 9 |
| The 3D structure of the hadrons (Generalized Parton Distributions and Transverse Momentum Distributions) | 5 | 10 | 3 | | 18 |
| Hadrons and cold nuclear matter (Medium modification of the nucleons, quark hadronization, F N-N correlations, hypernuclear spectroscopy, few-body experiments) | 3 | 2 | 6 | | 11 |
| Low-energy tests of the Standard Model and Fundamental Symmetries | 2 | | | 1 | 3 |
| **Total** | **16** | **18** | **16** | **2** | **52** |

More than 7 years of approved experiments

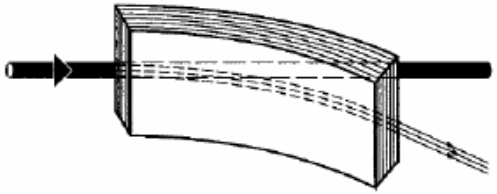
*Cynthia Keppel*

# A Fixed Target Experiment using LHC beam: AFTER @ LHC

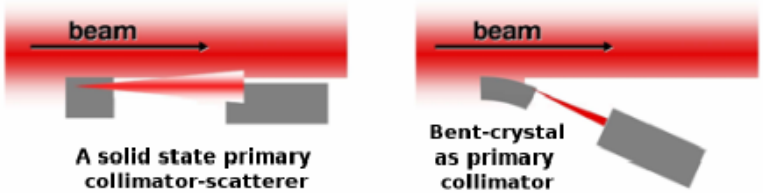
## The beam extraction

★ The LHC beam may be extracted using "Strong crystalline field"
**without any decrease in performance of the LHC !**

E. Uggerhøj, U.I Uggerhøj, NIM B 234 (2005) 31, Rev. Mod. Phys. 77 (2005) 1131



★ Illustration for collimation




★ Tests will be performed on the LHC beam:
LUA9 proposal approved by the LHCC

no performance decrease of the LHC

- Proposal : insertion in the halo (7σ) of the proton LHC beam
  - here with a deflection 0.275 mrad
  - extraction eff. (multi pass) ~ 50% LHC beam loss ⇛ $5.10^8$ p/s extracted
  - nosity (1 cm thick target) : 0.1 to 0.6 $fb^{-1}$ in p–H(A), 7 to 25 $nb^{-1}$ in Pb–A

[ E Uggerhoj and U.I. Uggerhoj, NIM B 234 (2005) 31 ]

[S. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg, Phys. Rep. 522 (2013) 239 ]

*Andry Rakotozafindrabe*

# A Fixed Target Experiment using LHC beam: AFTER @ LHC

Use LHC beams on fixed target :

- LHC 7 TeV proton beam
  - $\sqrt{s}$ ~ 115 GeV : p–p, p–d, p–A

comparable to RHIC energies

- LHC 2.76 TeV lead beam
  - $\sqrt{s}$ ~ 72 GeV : Pb–p, Pb–A
- benefit from typical advantages of a fixed target experiment
  - high luminosity, high boost ($y_{CMS}$=4.8 @ 115 GeV), target versatility, target polarisation
- multipurpose experiment, modern detection techniques

spin physics

PDF and nPDF at large $x_B$

Cold Nuclear Matter effects

W, Z prod. near threshold

Ultra Perif. Collisions

QGP studies, high precision heavy quarkonium observatory, high $p_T$ jets

diffractive physics



*Andry Rakotozafindrabe*

# A Fixed Target Experiment using LHC beam: AFTER @ LHC



PROCEEDINGS OF SCIENCE

## A Fixed-Target ExpeRiment at the LHC (AFTER@LHC) : luminosities, target polarisation and a selection of physics studies

J.P. Lansberg*, V. Chambert, J.P. Didelez, B. Genolini, C. Hadjidakis, P. Rosier
*IPNO, Université Paris-Sud, CNRS/IN2P3, F-91406, Orsay, France*
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*INFN Sez. Torino, Via P. Giuria 1, I-10125, Torino, Italy*
S.J. Brodsky
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*IRFU/SPhN, CEA Saclay, 91191 Gif-sur-Yvette Cedex, Fra*
U.I. Uggerhøj
*Department of Physics and Astronomy, University of Aarhu*

We report on a future multi-purpose fixed-target exp
beams extracted by a bent crystal. The multi-TeV LHC
target experiments ever performed. Such an experimen
Target ExperRiment", gives access to new domains of p
that of collider experiments, in particular at RHIC a
luminosity at AFTER using typical targets surpasses
magnitude. Beam extraction by a bent crystal offers
collimated high-energy beam, without decreasing the
mode also has the advantage of allowing for spin me
an access over the full backward rapidity domain up
reachable luminosities, the target polarisation and a
and deuterium targets.

Physics Reports 522 (2013) 239–255
Contents lists available at SciVerse ScienceDirect
Physics Reports
journal homepage: www.elsevier.com/locate/physrep
ELSEVIER

## Physics opportunities of a fixed-target experiment using LHC beams

S.J. Brodsky [a], F. Fleuret [b], C. Hadjidakis [c], J.P. Lansberg [c,*]
[a] SLAC National Accelerator Laboratory, Stanford University, Menlo Park, CA 94025, USA
[b] Laboratoire Leprince Ringuet, Ecole polytechnique, CNRS/IN2P3, 91128 Palaiseau, France
[c] IPNO, Université Paris-Sud, CNRS/IN2P3, 91406 Orsay, France

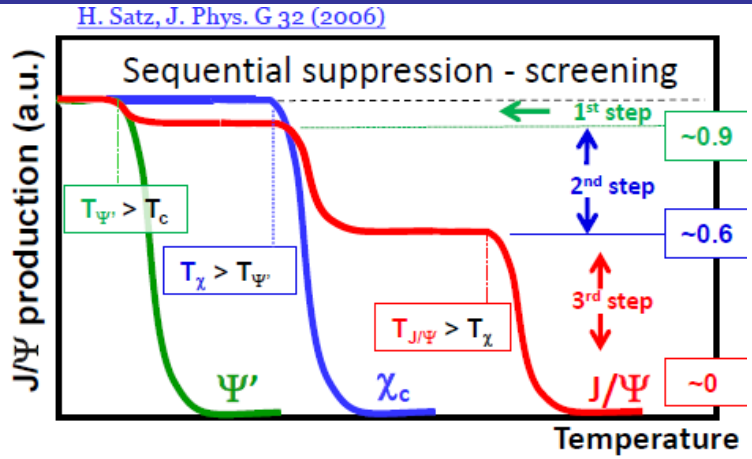
- webpage after.in2p3.fr
- workshops :
  - ✓ 10 days at Trento earlier in February 2013
    `http://indico.in2p3.fr/event/AFTER@ECTstar`
  - ✓ next : 3 days, probably in mid October, at CERN
  - ✓ next large workshop : 2014, January 12-17, at Les Houches
- Looking for partners !
- Target schedule : installation during LHC Long Shutdown 3

# Charmonia in Heavy Ion Collisions - CHIC

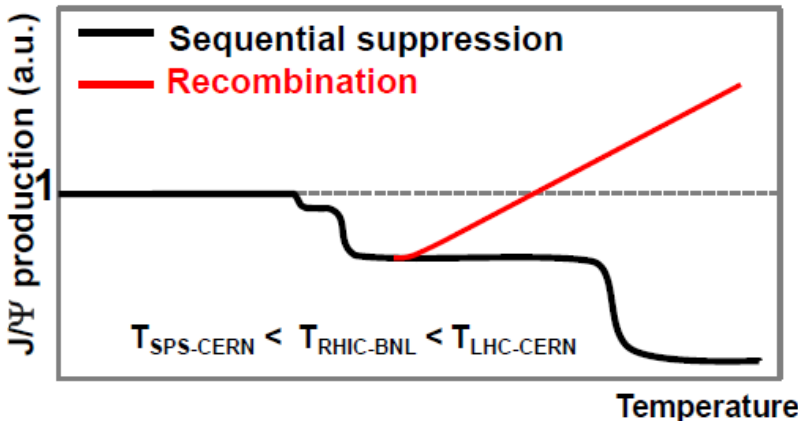
- **Possible QGP effect:**
  **color screening**
  - **Quarkonium color screening** is a prediction of **lattice QCD**.
  - Because of feed-downs and different dissociation temperature, **sequential suppression** should show up.

| | |
|---|---|
| *Feed-downs contributing to J/Ψ inclusive yield* | **60%** direct J/Ψ |
| | **+ 30%** $\chi_c \rightarrow J/\Psi+\gamma$ |
| | **+ 10%** $\Psi' \rightarrow J/\Psi + X$ |
| | **Inclusive J/Ψ yield** |

H. Satz, J. Phys. G 32 (2006)




- **Other possible QGP effect:**
  **$c\bar{c}$ recombination**
  - **c and $\bar{c}$ quarks can combine** to form a J/Ψ.
  - Requires a large number of $c\bar{c}$ pairs
    ➔ **RHIC energies? LHC energies?**




Experimental results for J/Psi production:

| | | |
|---|---|---|
| – NA50 | (PbPb@SPS) | observed an *anomalous* suppression |
| – PHENIX | (AuAu@RHIC) | observed a similar suppression (than NA50) |
| – ALICE | (PbPb@LHC) | observed a smaller suppression for low $p_T$ J/Ψ |
| – CMS | (PbPb@LHC) | observed a larger suppression for high $p_T$ J/Ψ |

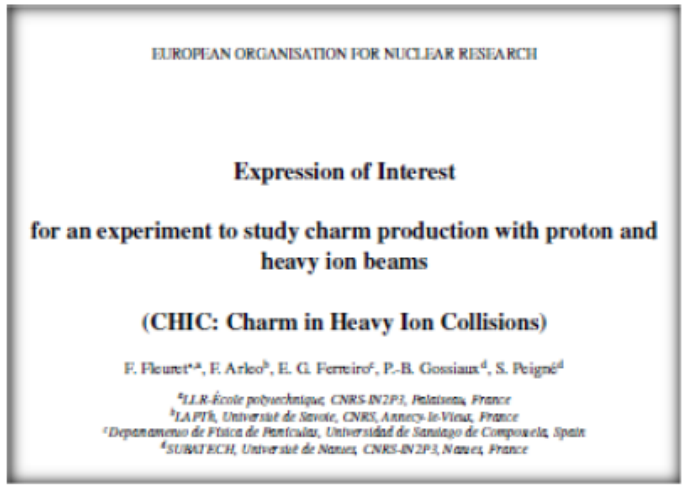
➔ Unclear picture

To test sequential suppression with charmonia need to go to SPS –
➔ recombination is negligible; must measure J/Ψ, Ψ', $\chi_c$

*Frédéric Fleuret*

## Submitted to SPSC (oct. 2012)

Expression of Interest
Submitted to SPSC – oct.2012
CERN-SPSC-2012-031



EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

**Expression of Interest**

**for an experiment to study charm production with proton and heavy ion beams**

**(CHIC: Charm in Heavy Ion Collisions)**

F. Fleuret[a,*], F. Arleo[b], E. G. Ferreiro[c], P.-B. Gossiaux[d], S. Peigné[d]

[a]LLR-École polytechnique, CNRS-IN2P3, Palaiseau, France
[b]LAPTh, Université de Savoie, CNRS, Annecy-le-Vieux, France
[c]Departamento de Física de Partículas, Universidad de Santiago de Compostela, Spain
[d]SUBATECH, Université de Nantes, CNRS-IN2P3, Nantes, France

Draft MINUTES on the 108th Meeting of the SPSC
15-16 January 2013
CERN-SPSC-2013-008

The SPSC has received an expression of interest to study charm production with proton and heavy ion beams. The SPSC recognizes the **strong physics motivation** of a study that addresses **central open questions** about the **color screening** of charmonium in heavy ion collisions and about **cold nuclear matter effects**. For a comprehensive investigation, an extension including open charm production would be desirable.

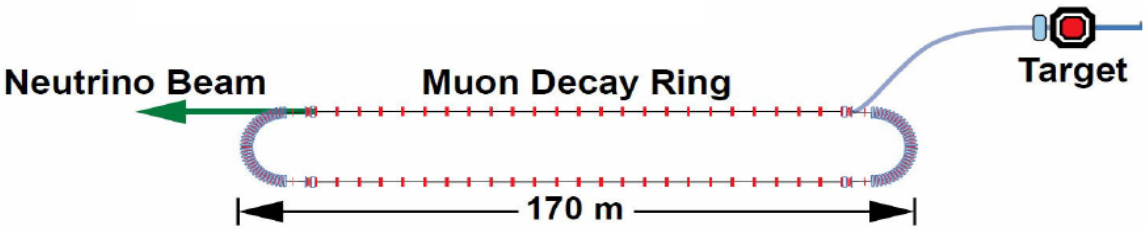
For further review, the SPSC would require a letter of intent with information about the experimental implementation and the **collaboration** pursuing it.

- **Timeline**
  - From $T_0$ (3 labs involved): ~ 5 Years for full simulation and final design (2 years), construction and installation (2 years), commisionning (1 year)

*Frédéric Fleuret*

# ν-Nucleus Scattering with νSTORM

## ν from 'neutrino factory'




- $\pi^+$ enter ring, decay to $\mu^+$
- Only $\mu^+$ make it around the ring.
  - Second 'lap' is pure muons, which decay.

$$\mu^+ \rightarrow \bar{\nu}_\mu + \nu_e + e^+ \text{ or } \mu^- \rightarrow \nu_\mu + \bar{\nu}_e + e^-$$

**3 Goals**

- An accelerator and detector technology test bed:
  - Toward Neutrino Factory & Muon Collider
- A final answer to the sterile ν anomaly of LSND & MiniBooNE.
- ν cross-section measurements:
  - Improvements for all neutrino types.
  - Especially true for $\nu_e$.
  - A ν "Light Source".

*Ian Taylor*

# ν-Nucleus Scattering with νSTORM

FNAL or CERN: either site is feasible

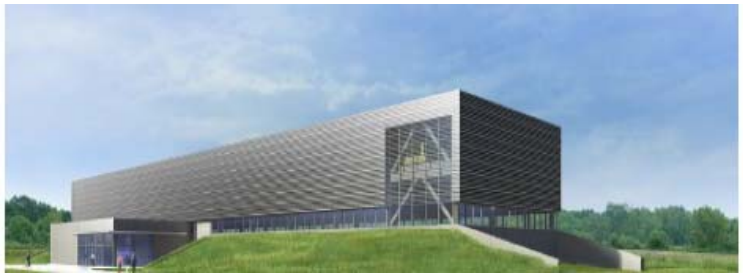
Proposals are being prepared for facilities at either FNAL or CERN

FNAL LOI: arXiv:1206.0294 CERN EOI: SPSC-EOI-009

The νSTORM Facility would have three near detector slots @ 20m FNAL, @300m CERN.

- Experimental collaborations would construct and install detectors.

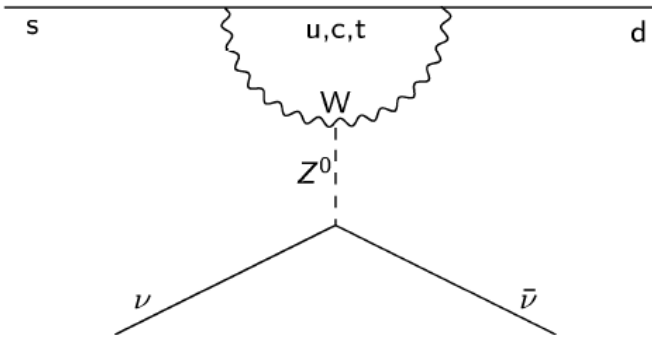
- Sterile ν search near detector.
- Test of ND for future long baseline experiment.
- Dedicated to ν cross-section detectors



*Ian Taylor*

# NA62: Rare Kaon Decays at SPS : K→ πνν

NA62 – fixed target experiment @ SPS



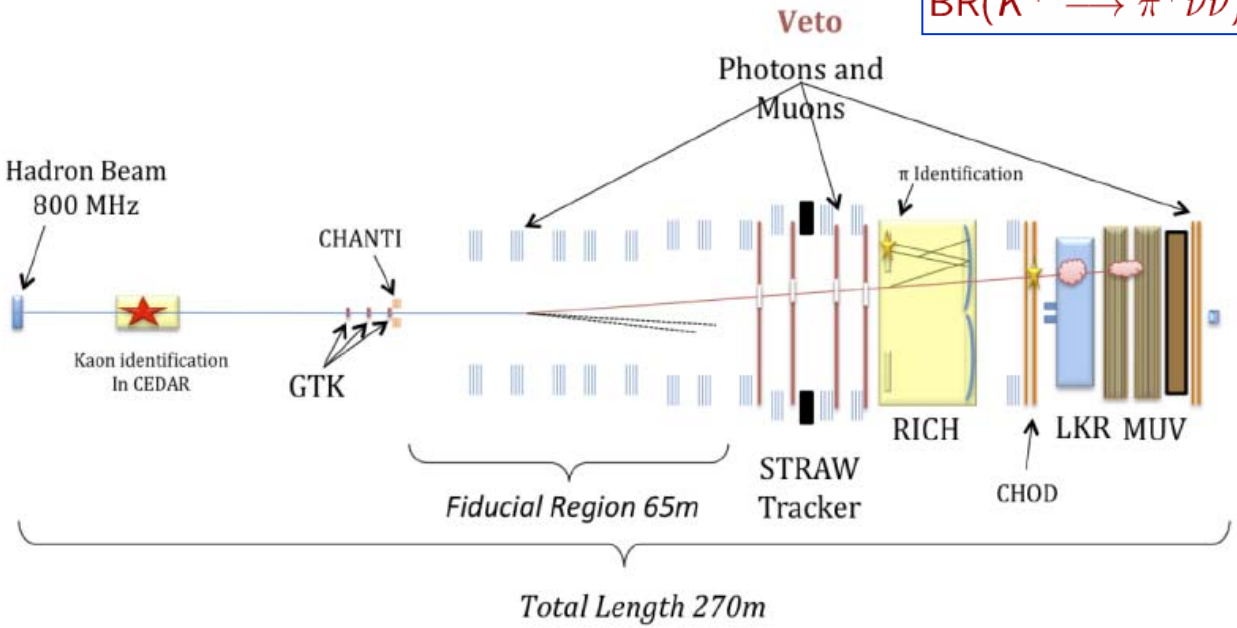

**Primary beam**

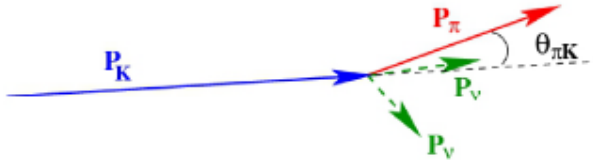
- 400 GeV/c protons from SPS on beryllium target
- $3 \times 10^{12}$ protons/pulse on target

**Secondary beam**

- 75 GeV/c kaons ($\Delta P/P \sim 1\%$)
- $\sim 6\%$ of $K^+$
- Rate beam tracker 750 MHz, area 16 $cm^2$

$$BR(K^+ \longrightarrow \pi^+ \nu\bar{\nu}) = (7.81 \pm 0.75 \pm 0.29) \times 10^{-11}$$




Goal: collect O(100) events in 2 years → 10% precision on BR
Start data taking in 2014

*Antonio Cassese*

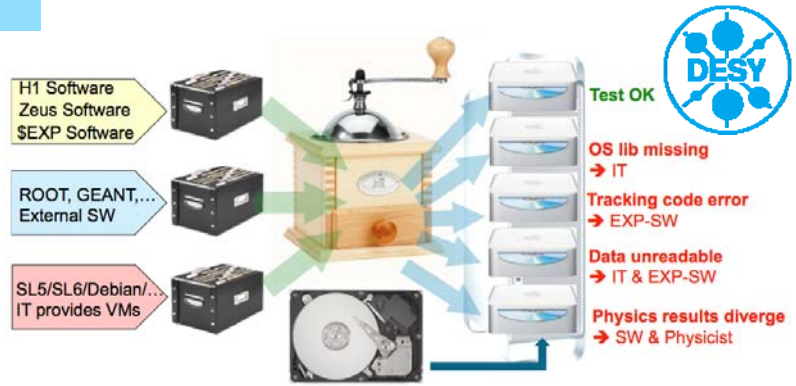
# Data Preservation in High Energy Physics

- DPHEP Study Group well established in HEP community, most labs/experiments involved now
- Large scale publication 2012, **arXiv:1205.4667**
- Transition in 2013: Study Group to Collaboration

| Preservation Model | | Use Case | |
|---|---|---|---|
| 1 | Provide additional documentation | Publication related info search | Documentation |
| 2 | Preserve the data in a simplified format | Outreach, simple training analyses | Outreach |
| 3 | Preserve the analysis level software and data format | Full scientific analysis, based on the existing reconstruction | Technical Preservation Projects |
| 4 | Preserve the reconstruction and simulation software as well as the basic level data | Retain the full potential of the experimental data | |

DPHEP Study Group for Data Preservation and Long Term Analysis in High Energy Physics

- The physics case for data preservation
  - Long term completion of an existing physics program
  - Cross-collaboration, combinations of physics results
  - **To revisit old measurements or perform new ones**
  - Newly developed techniques, new theoretical models
  - Use in scientific training, education, outreach
  - **Unique data sets available: energy, initial states**




**Novel technological solutions investigated to ensure the possibility of long term analysis**

*David South*

# Big Thanks to all speakers !

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Apologies if time prevented me from doing justice to your work in the summary