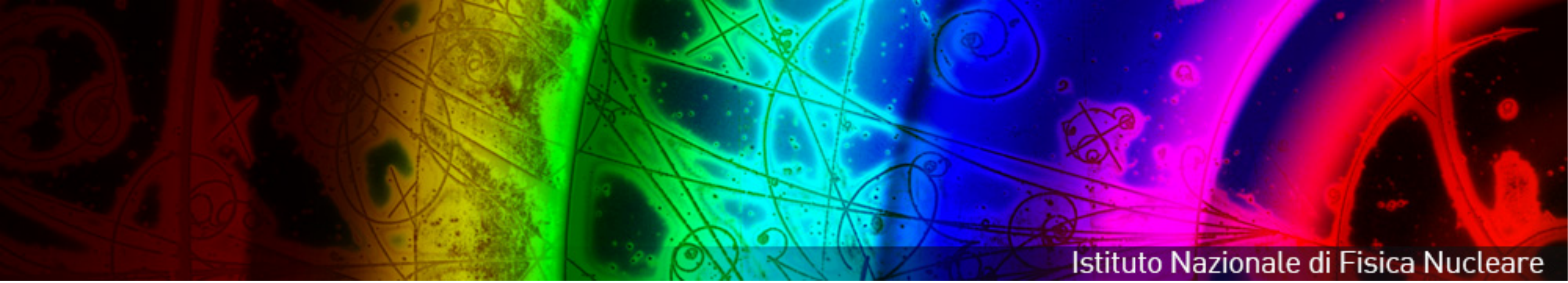
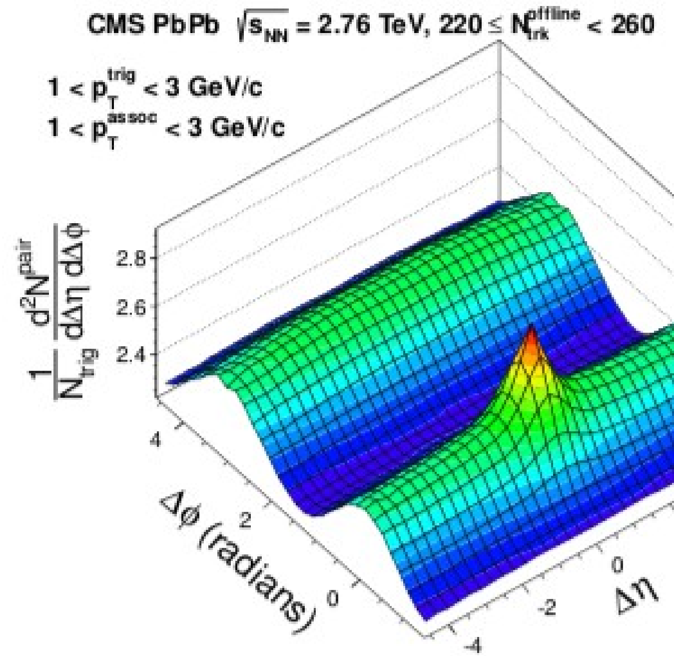


3DPDF: Future Perspectives

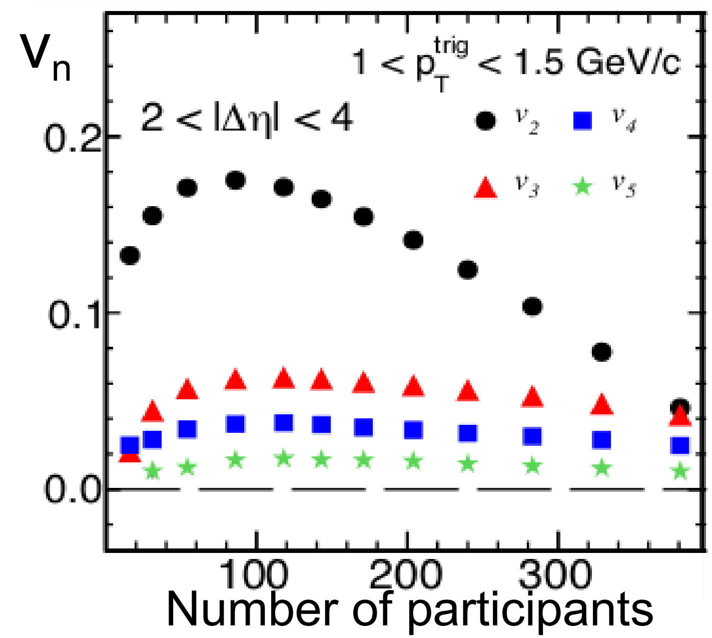
Harut Avakian
Pasquale Di Nezza

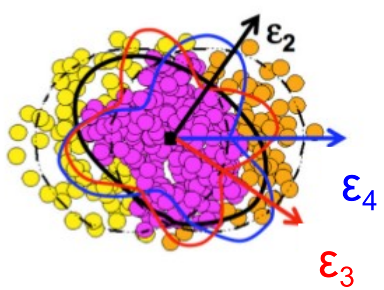
Collectivity in small systems

The ridge in A+A collisions



CMS, EPJC 72 (2012) 10052



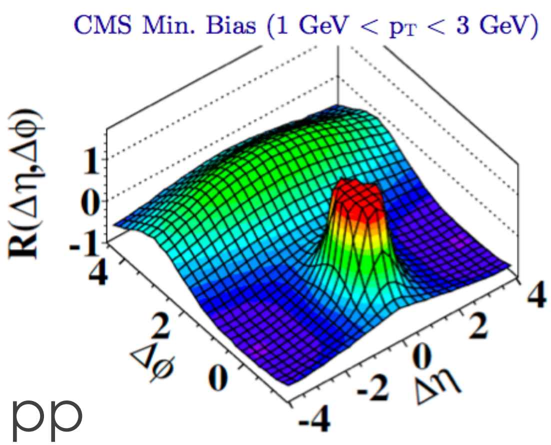


$$\frac{dN}{d\varphi} \sim 1 + 2v_2\cos[2(\varphi-\psi_2)] + 2v_3\cos[3(\varphi-\psi_3)] + 2v_4\cos[4(\varphi-\psi_4)] + 2v_5\cos[5(\varphi-\psi_5)] + \ldots$$

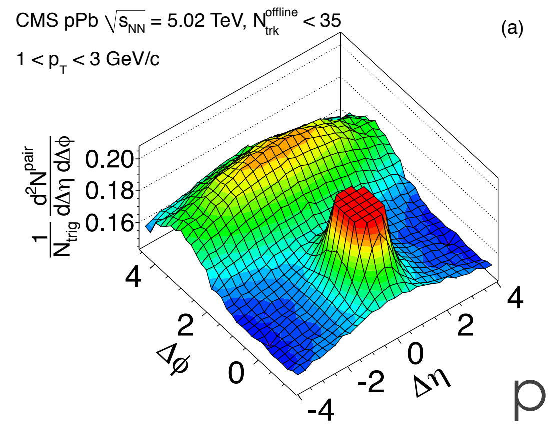
In PbPb, long-range harmonics (v_n) are explained as a result of pressure gradients created in initial stage

The ridge in A+A collisions

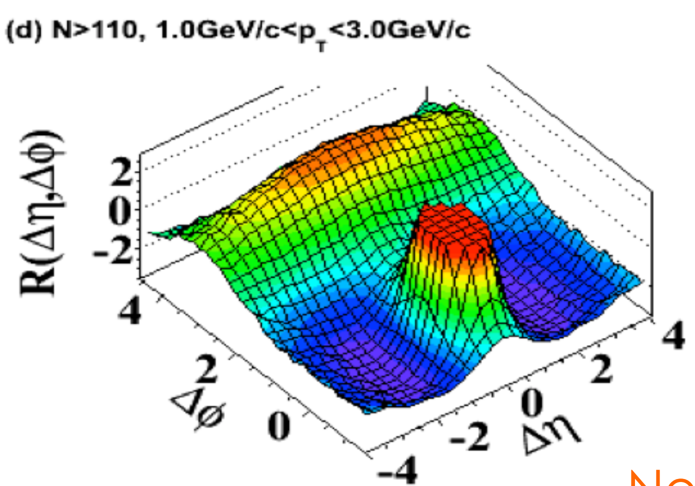
Not in pp (low multiplicity) neither in pPb (low multiplicity)



pp

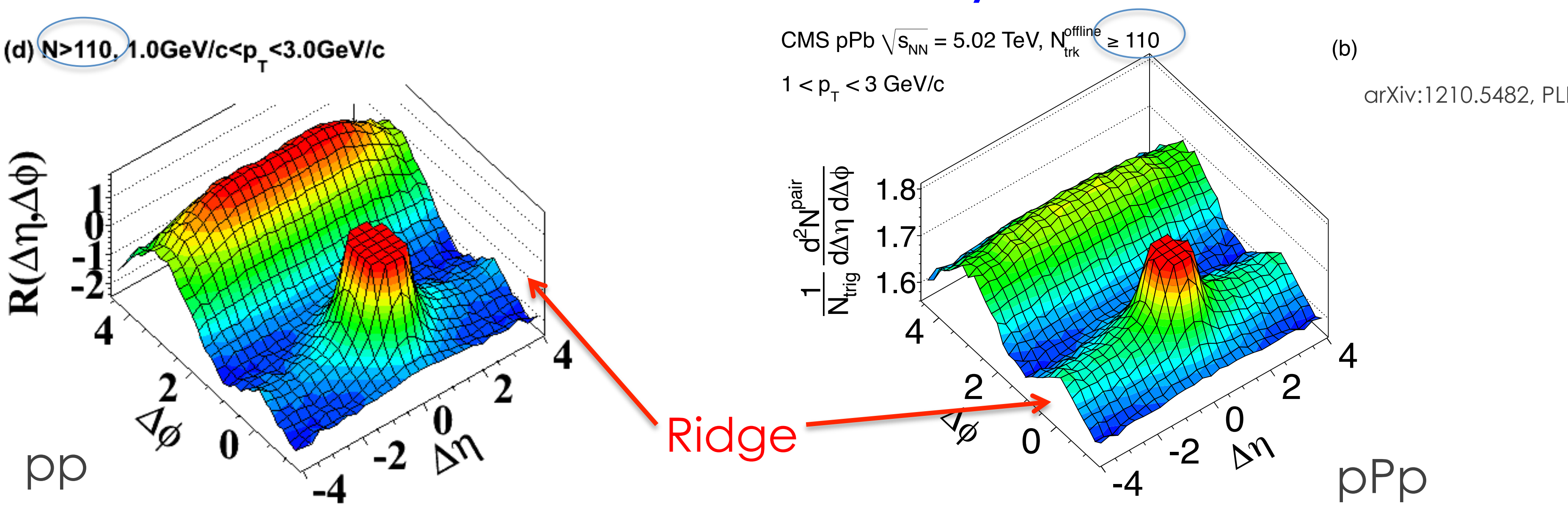


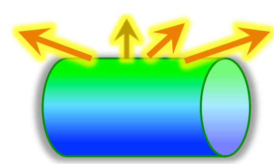
pPb



No ridge in MC

The discovery



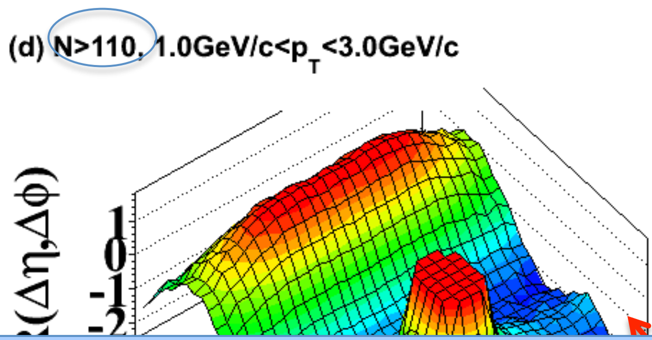


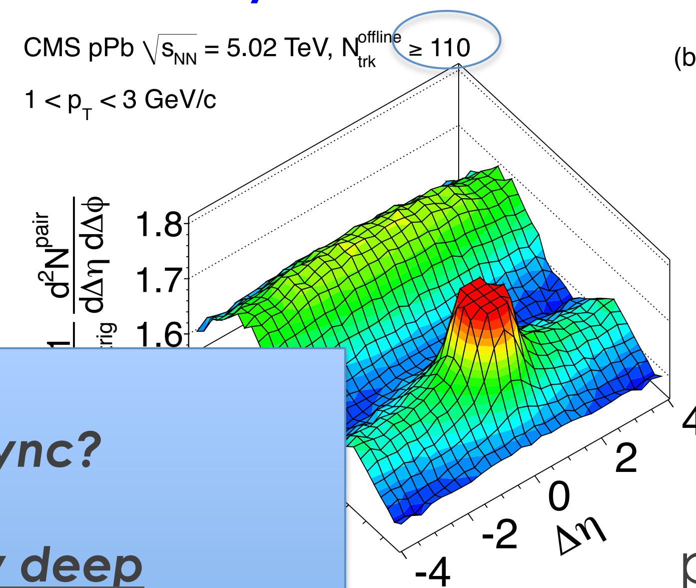
Distinct long range correlation in η collimated around $\Delta\,\Phi \approx 0$

Similar for pPb (high mult), pp (high mult) and PbPb (peripheral)

Hydrodynamic flow in pp and pPb collisions?

The discovery





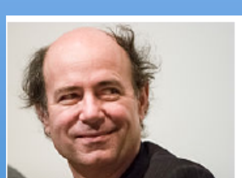
arXiv:1210.5482, PLB

pPp

Why sometimes the particles fly in sync?

"The LHC may be <u>uncovering a new deep internal structure of the initial protons</u> … at these higher energies, one is taking a snapshot of the proton with higher spatial and time resolution than ever before"

Frank Wilczek

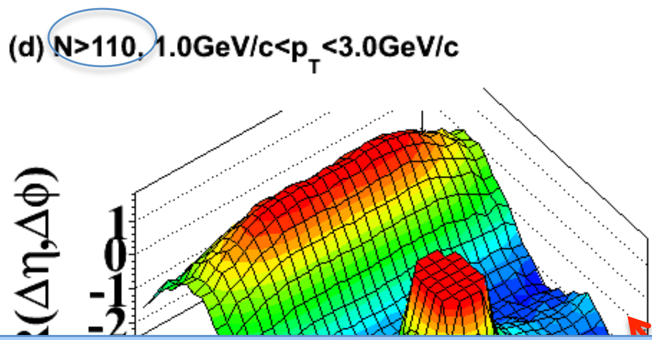


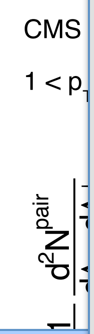
…ted around $\Delta \Phi \approx 0$

…d PbPb (peripheral)

Hydrodynamic flow in pp and pPb collisions?

The disco





Why sometimes the particles fly in sync?

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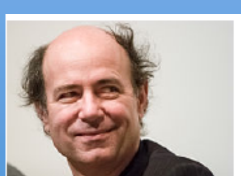
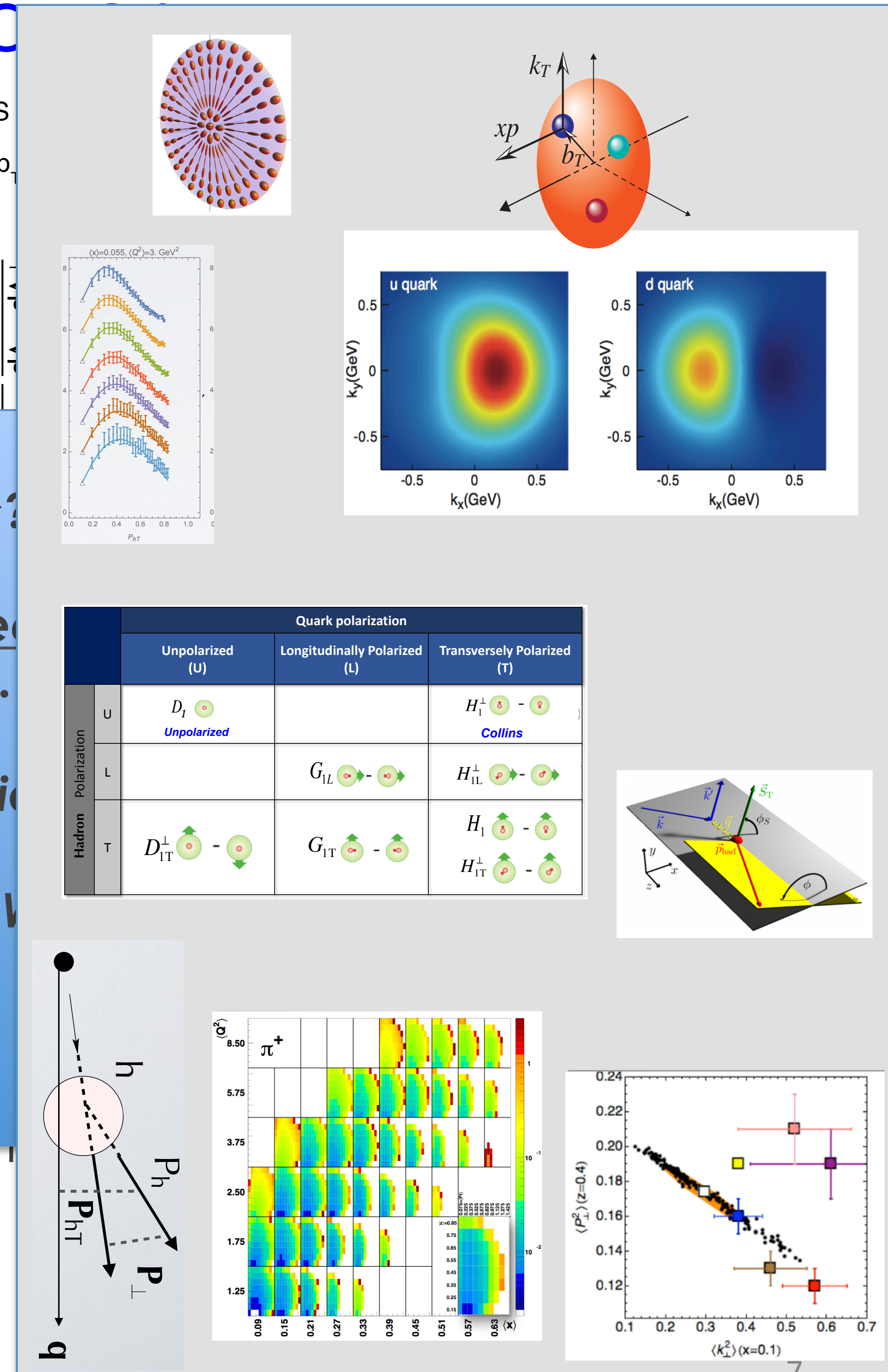
Frank W





		Quark polarization		
		Unpolarized (U)	Longitudinally Polarized (L)	Transversely Polarized (T)
Hadron Polarization	U	D_1 *Unpolarized*		$H_1^\perp$ *Collins*
	L		G_{1L}	$H_{1L}^\perp$
	T	$D_{1T}^\perp$	G_{1T}	H_1, $H_{1T}^\perp$

similar for pPb (high mult), pp (high

Hydrodynamic flow in pp and pPb

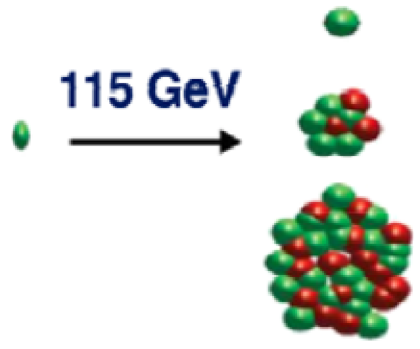

LHC
COMPASS
EIC
Electron Ion Collider: The Next QCD Frontier
J-PARC
Jefferson Lab
Thomas Jefferson National Accelerator Facility
Fermilab
E906
SeaQuest
spin
If we do not understand large SSA's we do not understand NPQCD ! (G.Goldstein)
Gauge links connecting us
Low energies
We need a bridge!

A fixed target @ LHC

- High Luminosity;
- Access to high-x domain: gluon, antiquark and heavy-quark content in the nucleon (e.g. particles BSM are at high-x) and nucleus;
- Variety of atomic mass of the target (from H to Xe);
- Polarization of the target → spin physics program at the LHC (dynamics and spin of gluons in (un)polarized nucleons);
- Heavy-ion collisions towards large rapidities;
- Parasitic data acquisition wrt collider mode.

Kinematics for a fixed target at LHC

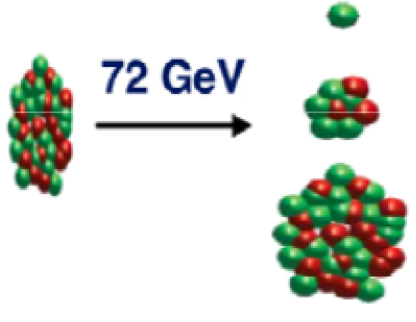
- p+p or p+A with a 7 TeV p on a fixed target



$$\sqrt{s} = \sqrt{2 m_N E_p} \approx 115\, GeV$$

$$y_{CMS} = 0 \rightarrow y_{Lab} = 4.8$$

- A+A collisions with a 2.76 TeV Pb beam

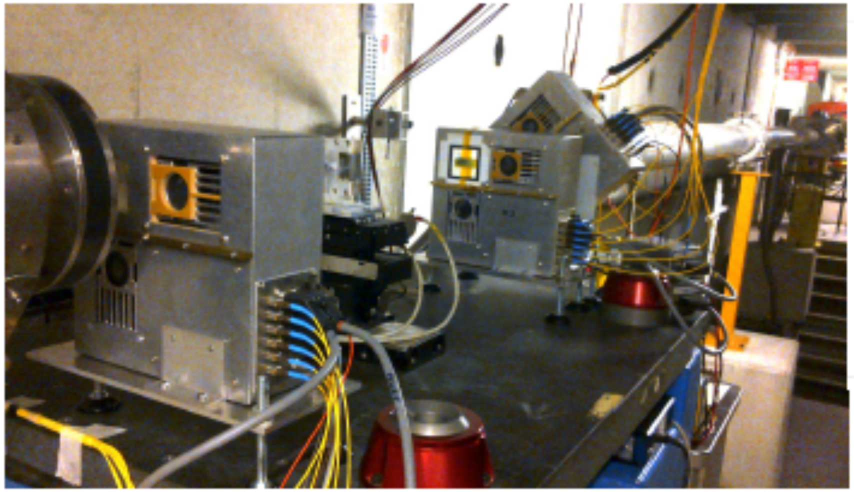


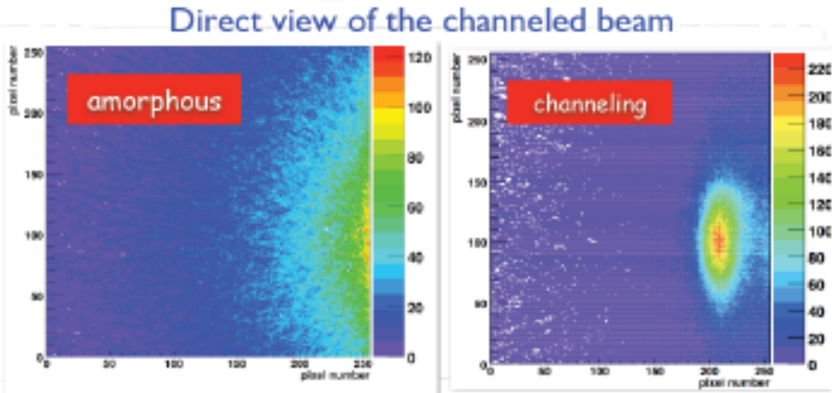
$$\sqrt{s} \approx 72\, GeV$$

$$y_{CMS} = 0 \rightarrow y_{Lab} = 4.3$$

Fixed target experiment: option I
Beam extraction using a bent crystal

H8 beam line (UA9 experiment @ SPS), 15/10/2014





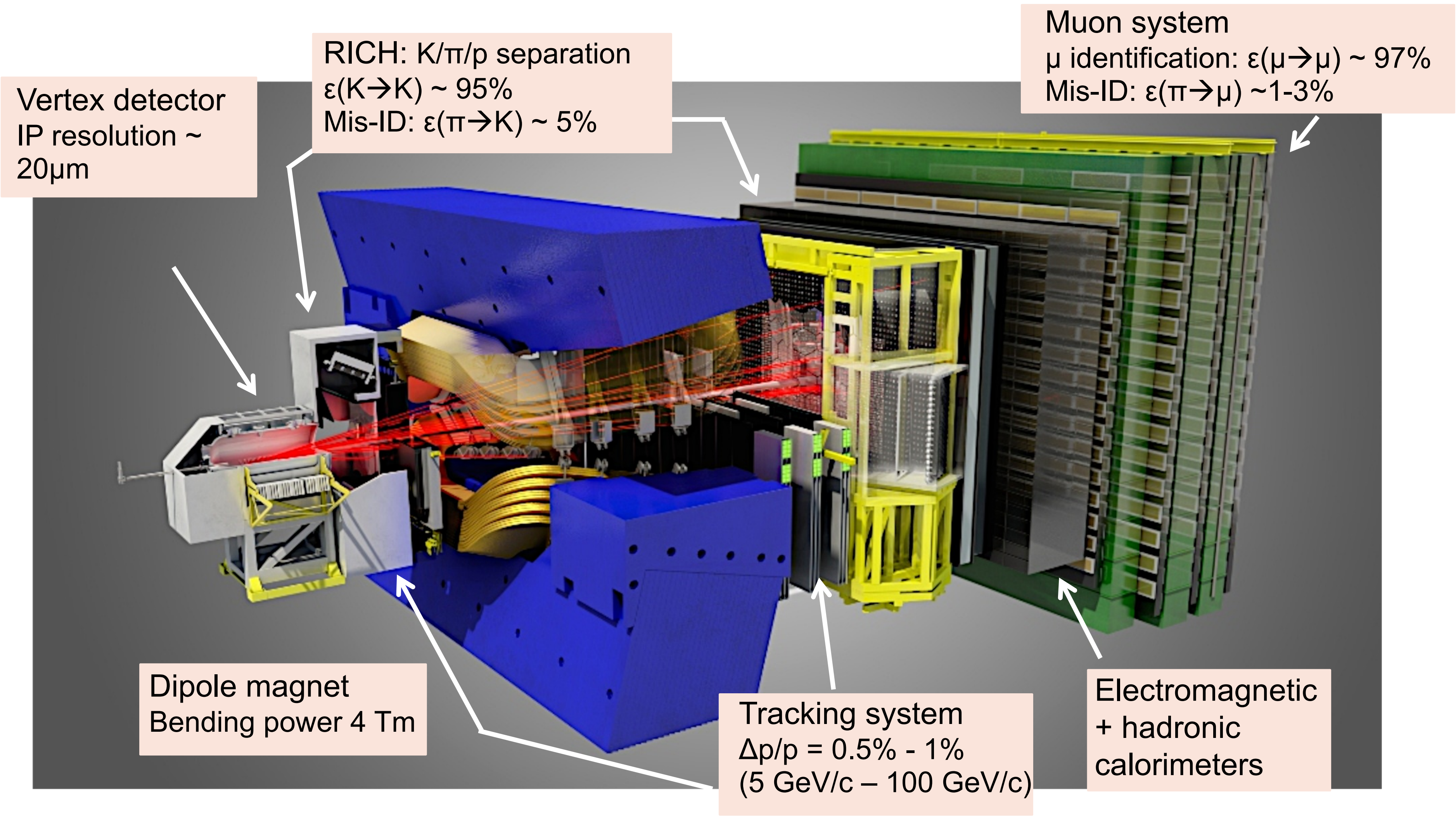
S. Montesano, W. Scandale, Joint LUA9-AFTER meeting, Nov. 2013

- AFTER@LHC: *A Fixed-Target ExpeRiment for hadron, heavy ions and spin-physics at the LHC*

The LHCb detector

JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

- Single arm spectrometer in the forward region
- **Fully instrumented in its angular acceptance (2 < η < 5)**
- VELO also provides backward coverage: -3.5 < η < -1.5
- Designed initially for b-physics but general purpose detector (fixed target, heavy-ion, EW, BSM)



HERMES target

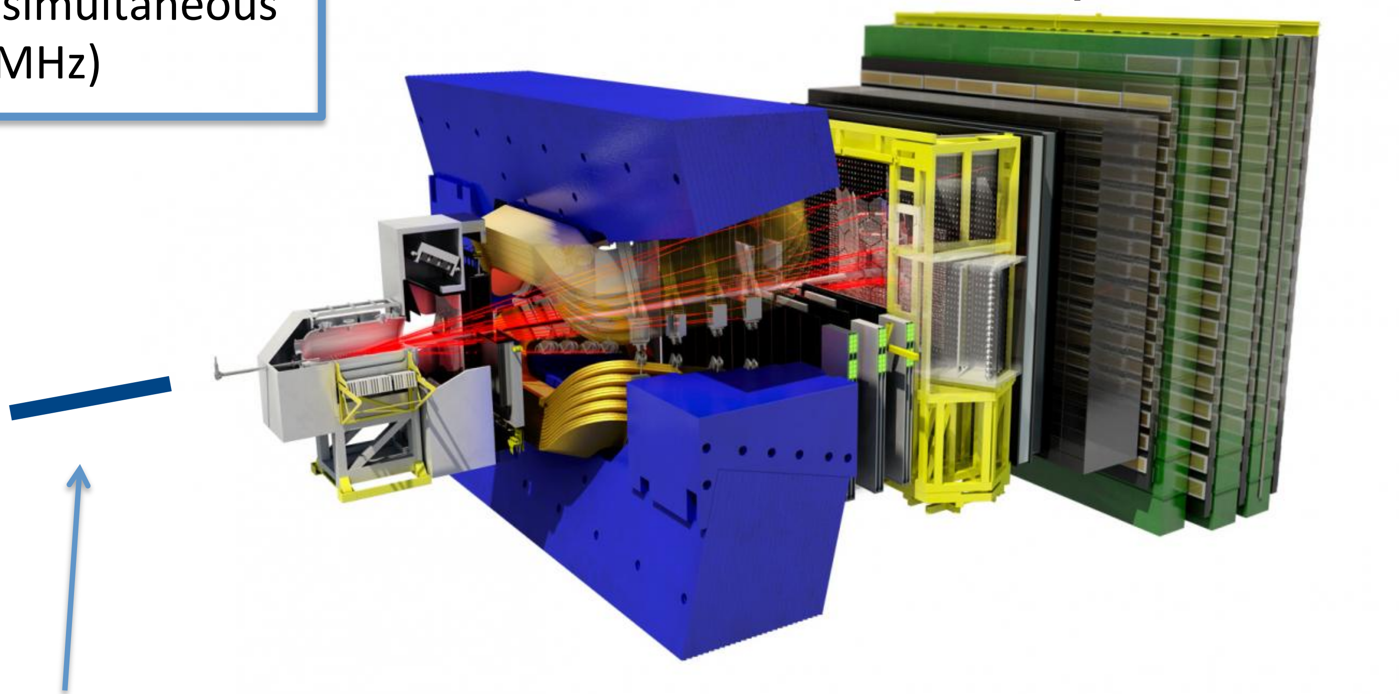
p 920 GeV

e 27.6 GeV

HERMES + LHCb

Displaced target (~11 mt), simultaneous data acquisition (up to 40 MHz)

$2 < \eta < 5$

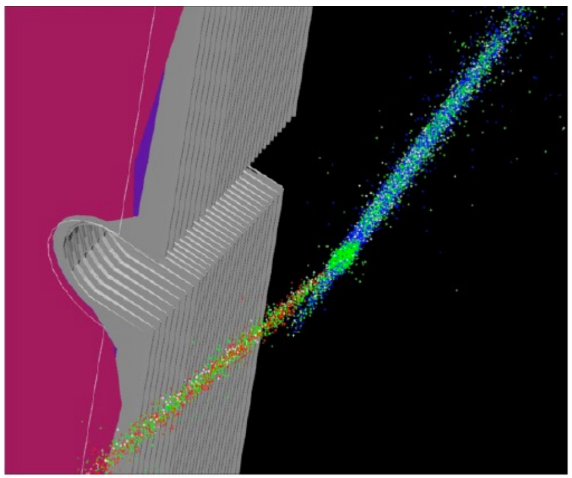


HERMES-type polarized target + LHCb – like acceptance and performance

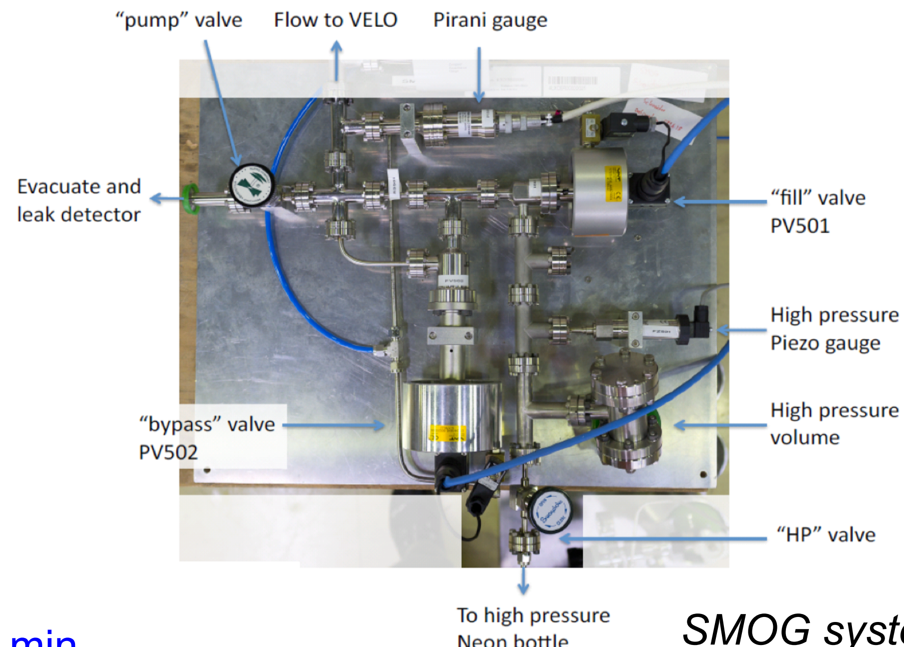
microvertexing, particle ID, μ ID, electromagnetic and hadonic cal.

The Fixed Target data taking (SMOG)

→ SMOG: System for Measuring Overlap with Gas:
- Main use so far for precise **luminosity determination**
- Low density noble gas injected in the VELO, in the interaction region
- Only local temporary degradation of LHC vacuum



Distribution of vertices overlaid on detector display. z-axis is scaled by 1:100 compared to transverse dimensions to see the beam angle.
Beam 1 - Beam 2, Beam 1 - Gas, Beam 2 - Gas.



SMOG system

- ❑ pNe pilot run at $\sqrt{s_{NN}}$ = 87 GeV (2012) ~ 30 min
- ❑ PbNe pilot run at $\sqrt{s_{NN}}$ = 54 GeV (2013) ~ 30min
- ❑ pNe run at $\sqrt{s_{NN}}$ = 110 GeV (2015) ~ 12h
- ❑ pHe run at $\sqrt{s_{NN}}$ = 110 GeV (2015) ~ 8h
- ❑ pAr run at $\sqrt{s_{NN}}$ = 110 GeV (2015) ~ 3 days
- ❑ pAr run at $\sqrt{s_{NN}}$ = 69 GeV (2015) ~ few hours
- ❑ PbAr run at $\sqrt{s_{NN}}$ = 69 GeV (2015) ~ 1.5 week
- ❑ pHe run at $\sqrt{s_{NN}}$ = 110 GeV (2016) ~ 2 days

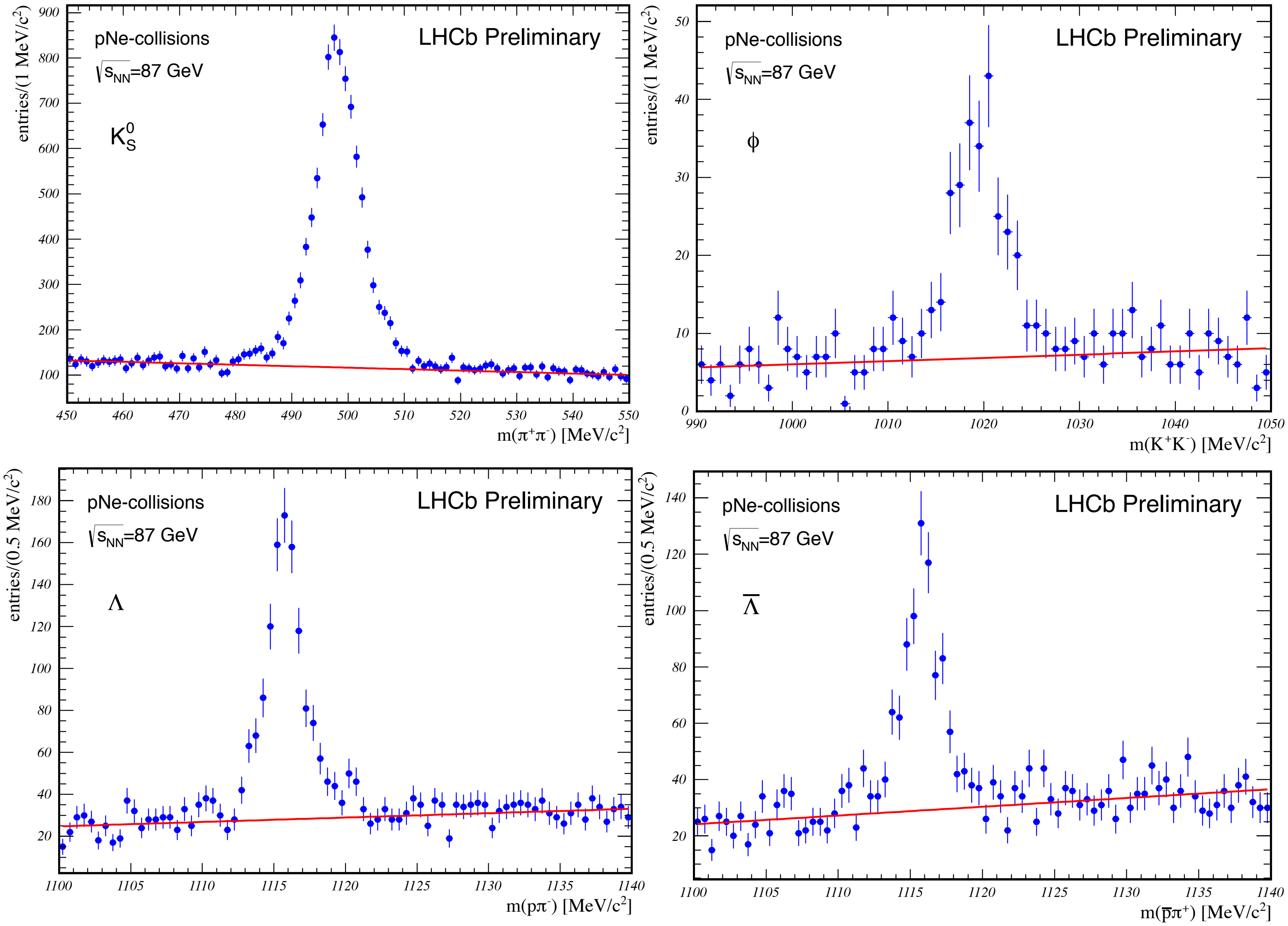
Preferred target Gas

	He	Ne	Ar	Kr	Xe
A	4	20	40	84	131

Results from p-Ne collisions

- p-Ne collisions at $\sqrt{s_{NN}}$ = 87 GeV, about 30 min of data taking (2012)

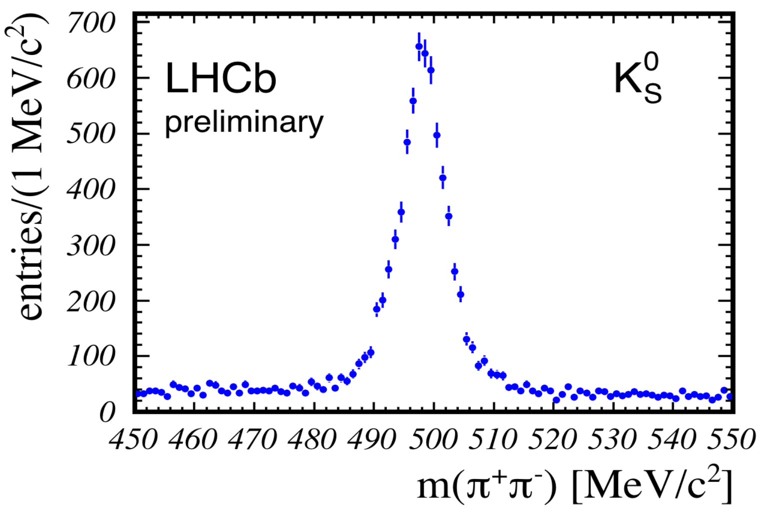
LHCb-CONF-2012-034

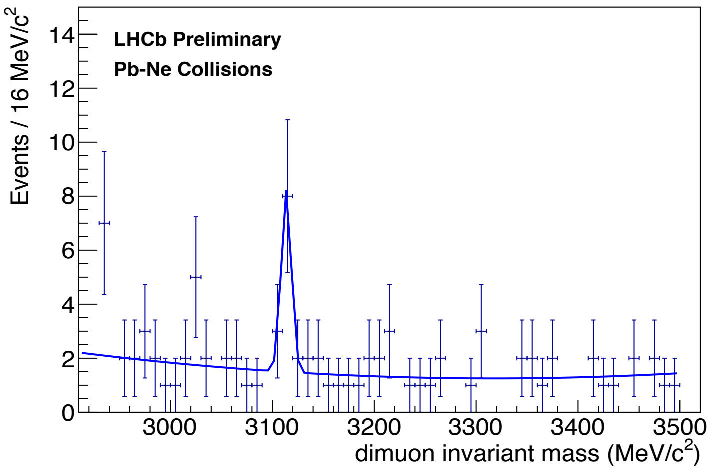


Results from Pb-Ne and p-Ne collisions

- Pb-Ne collisions at $\sqrt{s_{NN}}$ = 54 GeV, about 30 min of data taking (2013)

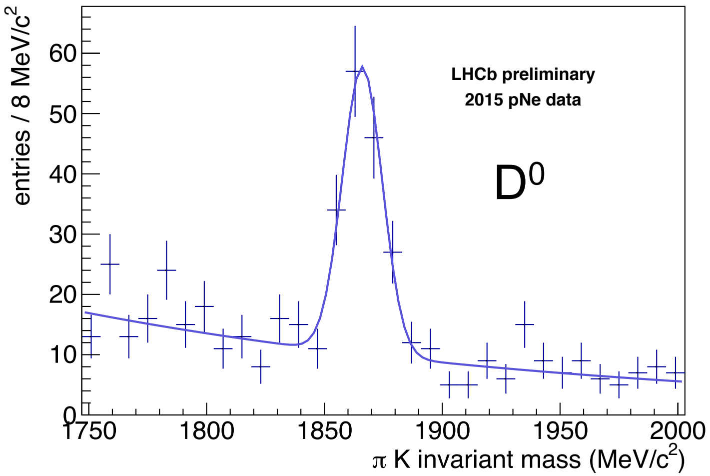
https://twiki.cern.ch/twiki/bin/viewauth/LHCbPhysics/LHCb2015PublicityPlots#SMOG_plots

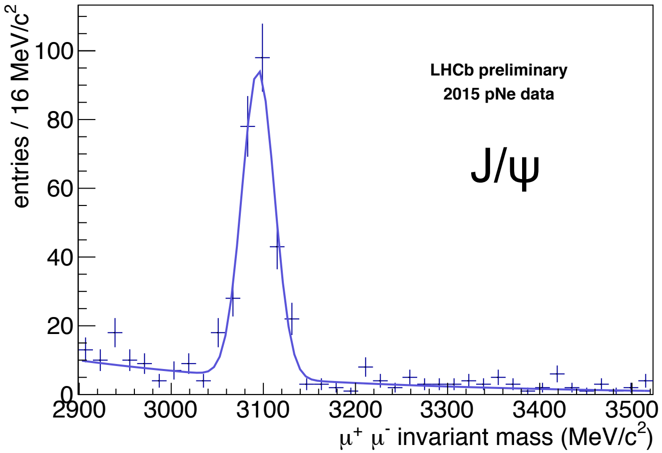




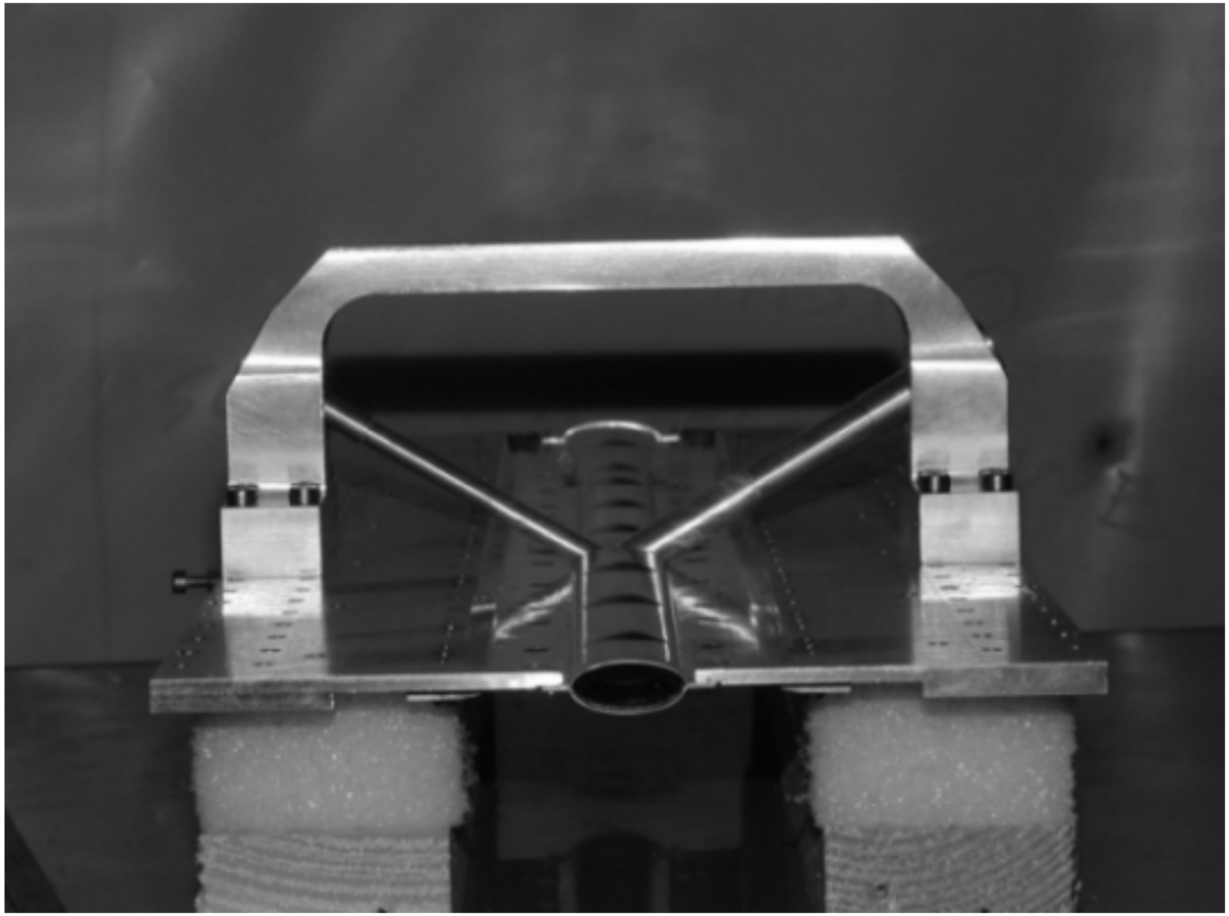
- p-Ne collisions at $\sqrt{s_{NN}}$ = 110 GeV, about 12h of data taking (2015)

https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015





The (hermes) storage cell



Material:	75 μm Al with Drifilm coating
Size: length:	400mm, elliptical cross section (21 mm x 8.9 mm)
Temperature:	100 K (variable 35 K – 300 K)

LHC beams

1σ-radius at IP (full energy): < 0.02 mm

- Negligible compared with the cell radius (> 5 mm)

Safety radius at injection (450 GeV for p): > 25 mm

- "Openable" cell required

p and Pb beams intensities @ LHC

- Protons: $I_p = 3.63 \cdot 10^{18}$ p/s @ 7 TeV
- Lead: $I_{Pb} = 4.64 \cdot 10^{14}$ Pb/s @ 2.76 TeV/u

➜ *instantaneous luminosities*

$$\mathcal{L} = N_b \cdot \nu \cdot \rho \cdot L$$

❖ numerical values:

- number of beam particles $N_b(p) = 3.2 \times 10^{14}$ and $N_b(Pb) = 4.1 \times 10^{10}$
- LHC revolution frequency $\nu = 11\,\mathrm{kHz}$
- target density $\rho = 10^{-6}\,\mathrm{mbar}$
- usable target lengths $L = 80\,\mathrm{cm}$

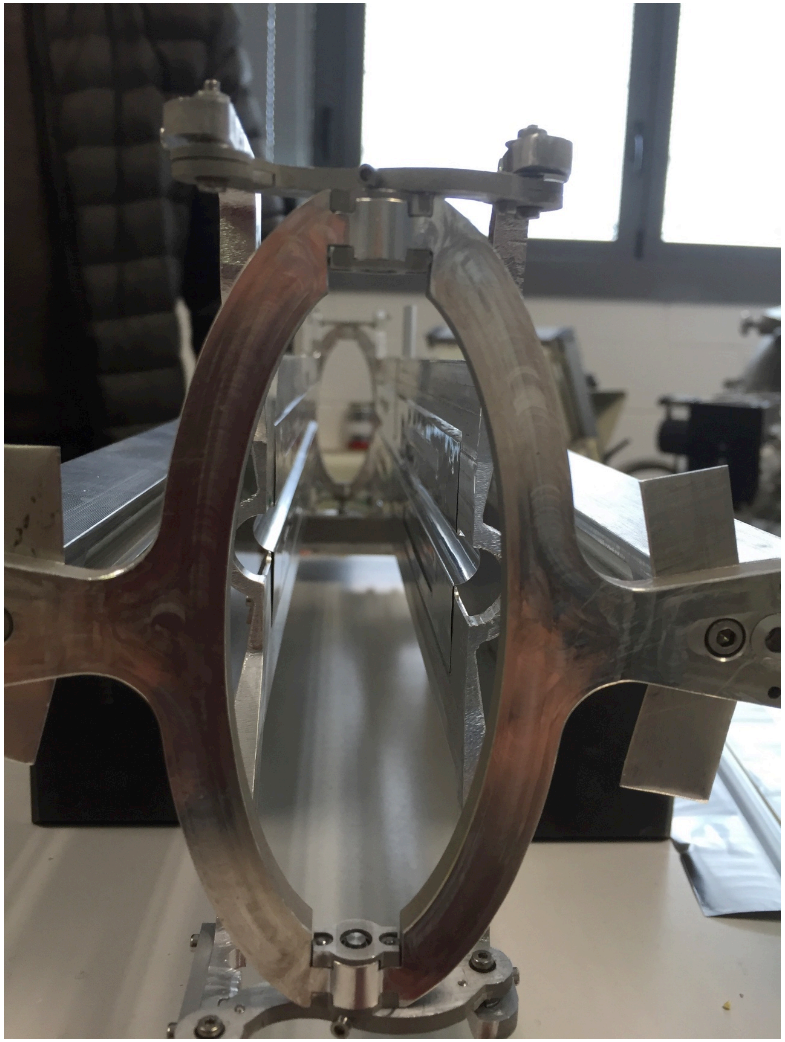
leading to: $\mathcal{L}(p\ A) \approx 8 \frac{1}{\mu b \cdot \mathrm{s}}$ and $\mathcal{L}(Pb\ A) \approx 1 \frac{1}{mb \cdot \mathrm{s}}$

Beam half-life: ≈ 10 h

- Parasitic operation requires small reduction of half-life (< 10%)

Openable storage cell development in Ferrara (Italy)

(Storage cell for 2 GeV p/d beam at COSY FZ-Juelich)



The future is near

Brainstorming on future fixed targets in LHCb

21 Dec 2016, 10:00 → 13:00 Europe/Zurich

Vidyo

P.D.N.
M.Ferro Luzzi
G.Graziani
J.P. Lansberg
P.Lenisa
L.M. Massacrier
A.Nass
E.Steffens

Workshop on LHCb Heavy Ion and Fixed Target physics

9-10 January 2017
CERN
Europe/Zurich timezone

Thank you for contributing to this stimulating meeting … first stone of the bridge!