Attività di analisi a Pisa

LHCb Italy Meeting – October 13, 2015

M.J. Morello (SNS and INFN-Pisa) on behalf of Pisa-Group

Pisa analysis activities

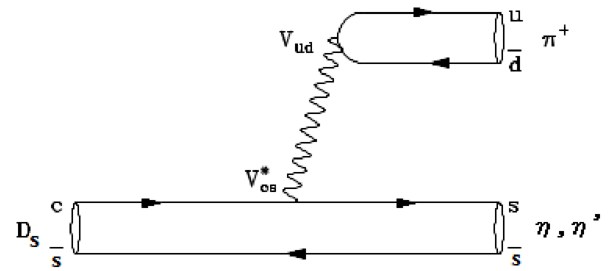
- CPV in charm decays
  - A_{CP} in $D^{+}/D^{+}_{s} \rightarrow \eta(')\pi+$ with $3fb^{-1}$
  - Measurement of $A_{\Gamma}(D^{0} \rightarrow h^{+}h^{-})$ with $3fb^{-1}$
- Search of rare decays
  - Optimization of the sensitivity for the $B^{0} \rightarrow \mu^{+}\mu^{-}$
- Fully involved in:
  - T&A Group: task on "*Investigate tracking asymmetries*"
  - B Hadron & Quarkonia WG: S. Stracka is the Trigger Liason.
  - Simulation Group: R. Cenci is in charge as co-convener of the group.

$D^+/D^+_s \to \eta^{(\prime)}\pi^+$ decays

- Channels still partially known (so far only domain of e^+e^--machines).
  - BFs(D+ channels) ~15–30%.
  - $\sigma(A_{CP})$ ~1–4%, still far from sensitivity necessary to look for CPV (<1%).
- $D^+_s \to \eta^{(\prime)}\pi^+$
  - Aplitude $\propto V_{ud} V_{cs}^*$ (CF),
  - CPV(SM) negligible.
- $D^+/ \to \eta^{(\prime)}\pi^+$
  - Amplitude $\propto V_{ud} V_{cd}^*$ (SCS)
  - CPV(SM):
    - -0.21×10^{-3} (for η')
    - 0.37×10^{-3} (canale η)

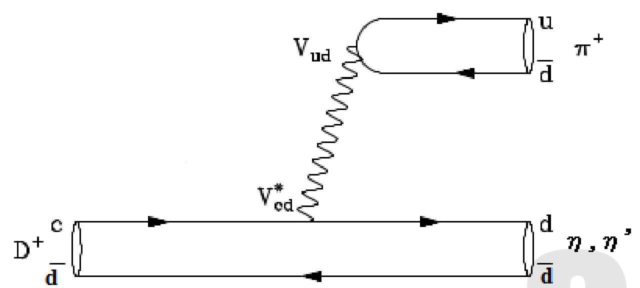
[Phys. Rev. D 85, 034036 (2012)]

$BF(D^+_s \to \eta\pi^+) = (1.83 \pm 0.15)\%$
$BF(D^+_s \to \eta'\pi^+) = (3.94 \pm 0.33)\%$



(a) $D_s^\pm \to \eta^{(\prime)}\pi^\pm$ CF decay.

$BF(D+ \to \eta\pi^+) = (0.353 \pm 0.021)\%$
$BF(D+ \to \eta'\pi^+) = (0.467 \pm 0.029)\%$



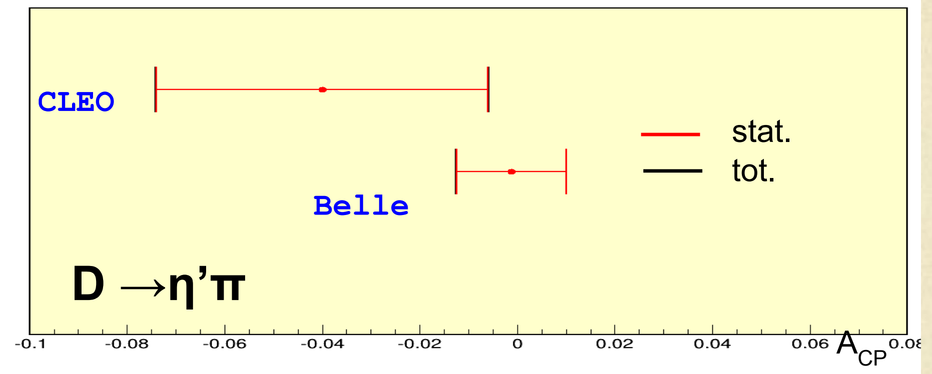
(b) $D^\pm \to \eta^{(\prime)}\pi^\pm$ SCS decay.

$D^+/D^+_s \to \eta^{(\prime)}\pi^+$: current status

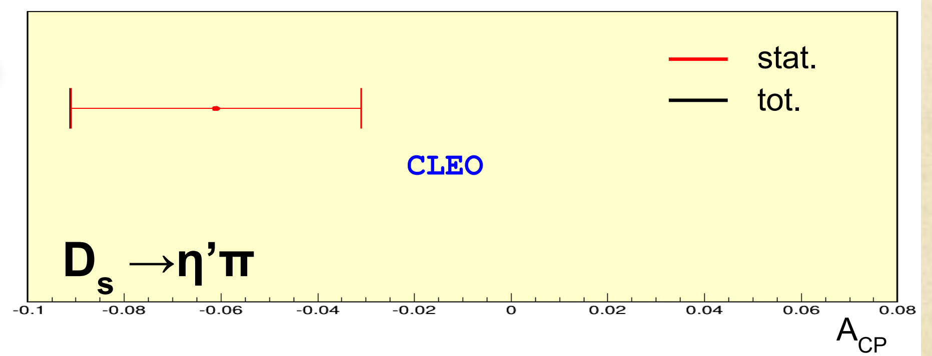
Only available experimental information comes from e+e⁻-machines.

Belle: (-0.12 ± 1.12 ± 0.17)%
[PRL 107, 221801]

CLEO: (-4.0 ± 3.4 ± 0.3)%
[PRD 81, 052013]



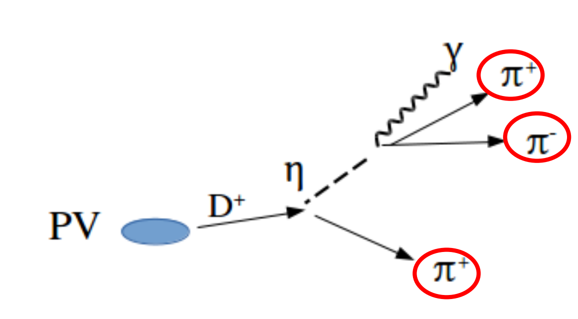
CLEO: (-6.1 ± 3.0 ± 0.3)%
[PRD 81, 052013]



Signal yelds:
~1k-3k CLEO, ~6k Belle

Never observed at hadronic collisions.

$D^+/D^+_s \to \eta^{(\prime)}\pi^+$ at LHCb in RunI



- No dedicated trigger lines in Run I.
  - Used lines conceived for $D^+ \to 3h$ decays
  - Not optimal for $D^+/D^+_s \to \eta^{(\prime)}\pi^+$.
- Trigger configuration based on a-priori considerations about "simplicity" and "safety", aiming at the reduction as much as possible of any bias for A_{CP} measurements.
- At L0, HLT1 no requirements on bachelor π in order to avoid possible detection charge asymmetries;
  - Level0
    - Sample 1: `eta_L0Hadron_TOS`
    - Sample 2: `(D_L0Hadron_TIS||D_L0Photon_TIS||D_L0PhotonHi_TIS) ^ !eta_L0Hadron_TOS`
  - HTL1: `Hlt1TrackAllL0` requiring to be TOS all $\eta^{(\prime)}$ daughters.
  - HLT2 : D candidates TOS wrt `Hlt2CharmHadD2HHH`.

$D^+/D^+_s \to \eta^{(\prime)}\pi^+$ – Analysis in a nutshell

- Stripping originally designed for $D^+ \to \pi^0\pi^+$ ($\pi^0 \to e^+e^-\gamma$)
  - StrippingD2PiPi0_eegammaPiEta(Prime)PromptLine for $D_{(s)} \to \eta^{(\prime)}\pi$ with $\eta^{(\prime)} \to \pi^+\pi^-\gamma$.
- Beam spot constrain and $\eta^{(\prime)}$ mass constrains using DTF in order to distinguish D and Ds signals from background, especially for the η.
- Offline selection requirements:
  - Basic cuts (large p, E and IP of daughter particles) + fiducial cuts (LHCb-ANA-2011-059).
  - optimized on $\sigma(A_{CP})$: $\eta^{(\prime)}$ mass window, χ^2 of DTF, PIDK of bachelor pion, γCL photon confidence level.
- Simultaneous maximum likelihood fit to extract signal yields and A_{CP}.
- Systematics: L0-trigger selection, peaking backgrounds, $\eta^{(\prime)}$K and $\phi\pi$ contaminations, fit model, contamination from secondary charm decays.

$D^+/D^+_s \to \eta^{(\prime)}\pi^+$ – Preliminary results

People: Mocci (Master Thesis), Punzi, Stracka.

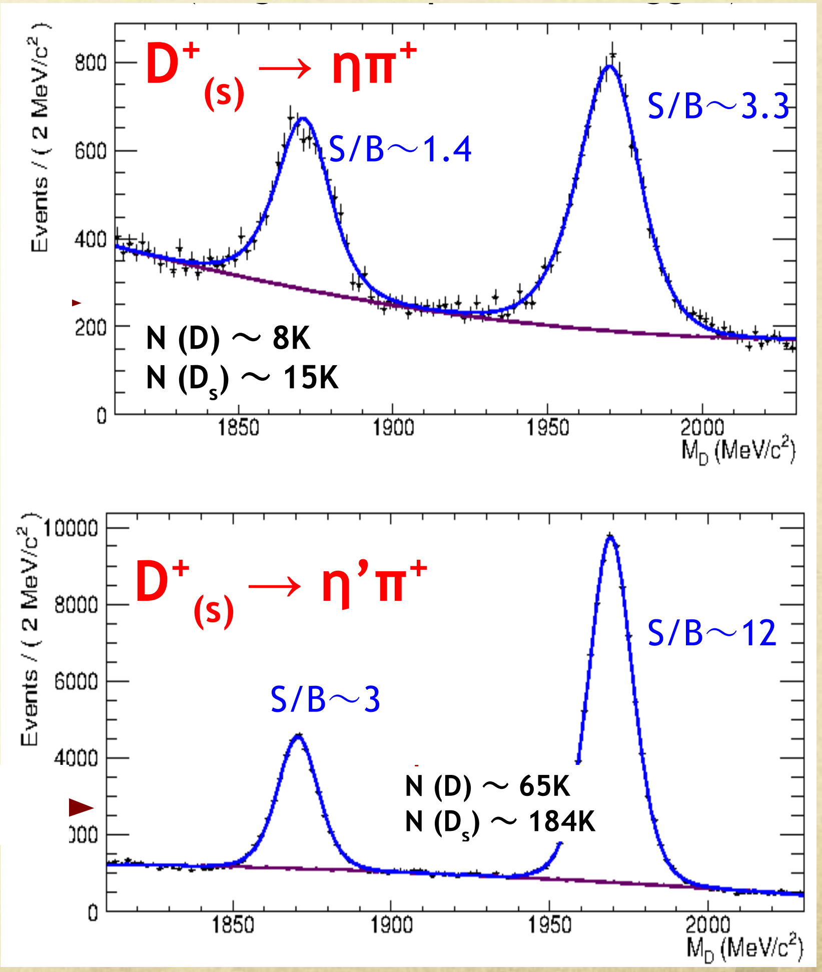
$$A_{raw} = \frac{N_D - N_{\bar{D}}}{N_D + N_{\bar{D}}} \simeq A_{CP} + A_{pr} + A_{det}$$

- Production and detection terms removed by subtracting raw A_{CP} from control samples:
  - $D^+ \to K_S\pi^+$, $D^+_s \to \phi\pi^+$.

ΔA_{CP} ($D^+ \to \eta'\pi^+$) (3 fb^{-1}) = (x.x ± 0.6 (*stat*) ± 0.5 (syst)) x 10^{-2}

ΔA_{CP} ($D^+_s \to \eta'\pi^+$) (3 fb^{-1}) = (x.x ± 0.3 (*stat*) ± 0.5 (syst)) x 10^{-2}

- Much better than current world averages.
- Measurement with $\eta\pi$ will be finalized soon.
- As a consequence, a dedicated trigger line has been introduced in Run II, with substantially larger efficiency. A further gain of an order of magnitude in yields is expected.
- Details will be soon published in LHCb-ANA-2015-057, to go into WG review.

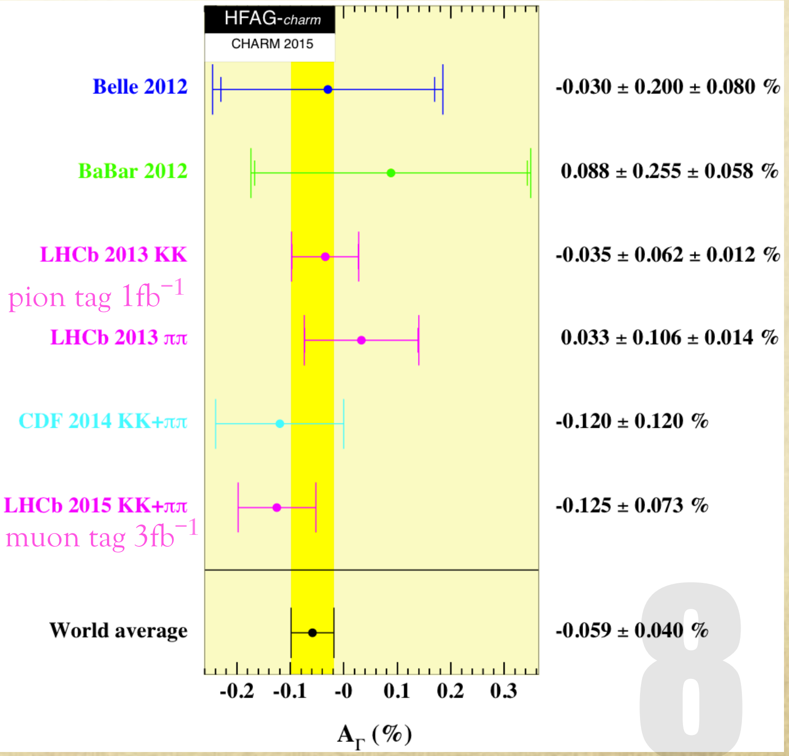


$A_\Gamma(D^0 \rightarrow h^+h^-)$ with $3fb^{-1}$

$$A_\Gamma \equiv \frac{\hat{\Gamma}(D^0 \to h^+h^-) - \hat{\Gamma}(\overline{D}^0 \to h^+h^-)}{\hat{\Gamma}(D^0 \to h^+h^-) + \hat{\Gamma}(\overline{D}^0 \to h^+h^-)} \simeq \eta_{CP}\left[\frac{1}{2}(\mathcal{A}_{\rm m} + \mathcal{A}_{\rm d})y\cos\phi - x\sin\phi\right]$$

where h=K,π and $1/\hat{\Gamma} = \frac{\int t\,\Gamma(t)\,dt}{\int \Gamma(t)\,dt}$ is the effective lifetime

- One the most important measurement in charm physics. A look into the (far) future, already to level of $<10^{-3}$.
- Binned method:
  - Measure A_{raw} in bins of D^0 proper decay time, fitting Δm simultaneously for D^0 and antiD^0 .
  - extract A_Γ from a linear fit of $A_{raw}(ct)$.
  - Use high statistics mode Kπ to keep under control (time-dependent) detector-induced charge asymmetries at level of 10^{-4}.



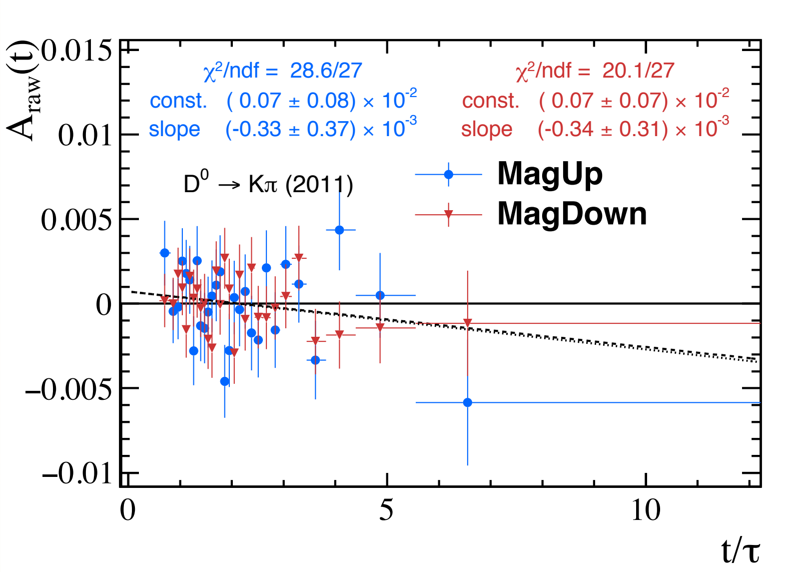
$A_\Gamma(D^0 \rightarrow h^+h^-)$ with $3fb^{-1}$

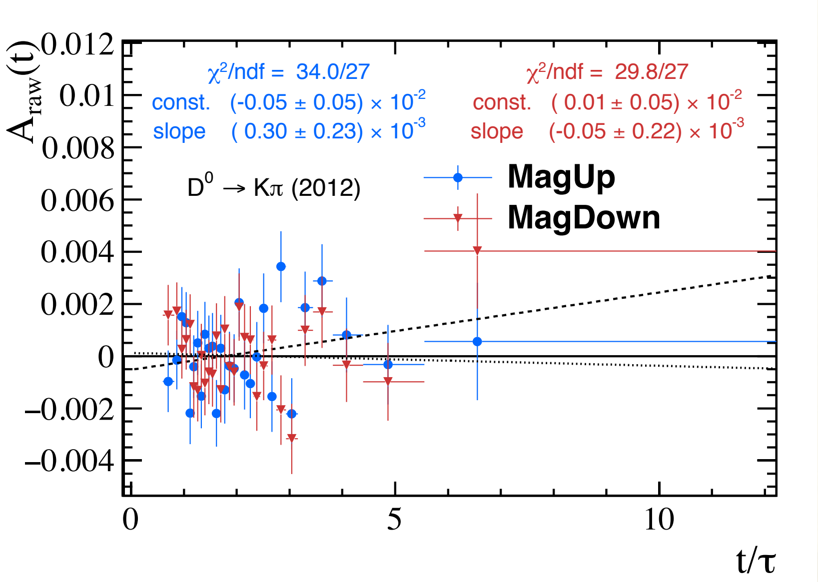
People: Marino (PhD Thesis), Morello, Punzi.

$$A_{\rm raw}(t) = \frac{N(D^0;t_i) - N(\overline{D}^0;t_i)}{N(D^0;t_i) + N(\overline{D}^0;t_i)} = A_0 - A_\Gamma \frac{t}{\tau}$$

Time-independent term: production, detector, etc.. Only an offset.

Time-dependent term





Expect $\sigma_{stat}(KK)$~3.6×10^{-4} and $\sigma_{stat}(\pi\pi)$~6.1×10^{-4}.

For more details see next talk by Pietro Marino.

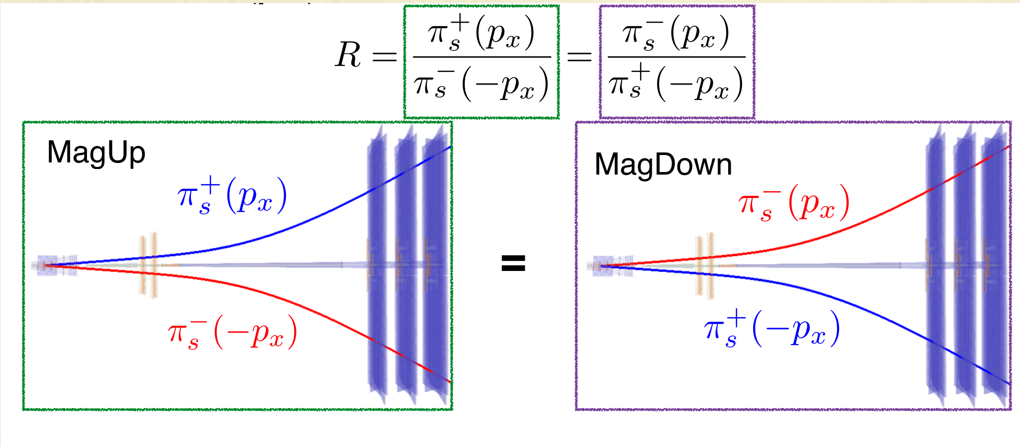
Soft pion charge asymmetries

Pisa group contributes to the T&A group in studying charge tracking asymmetries for slow particles. From tasks list:

Investigate tracking asymmetries (taken)

Task name	**Investigate tracking asymmetries**
Lead (tools, or other) group	Tracking and alignment
Other relevant groups (if any)	Everybody
Task description	Tracking asymmetries that do not cancel between magnet up and down are observed in the detector both at low and high momentum. This affects reconstruction of massive objects (i.e. W+) or slow particles in Charm and B decays.
Estimated total effort required (FTE)	1.0 FTE for 1 year.
Deadline	before 2014 reprocessing.
People/groups currently involved	Pisa
Past studies from	Patrick Koppenburg.
New effort required?	Yes. Patrick has spotted the problem, but doesn't have time to study it in detail.
Other comments	Somebody interested in CPV in Charm would be a perfect candidate to study reconstruction of low momentum tracks, while somebody from EW group should study the high-momentum case.

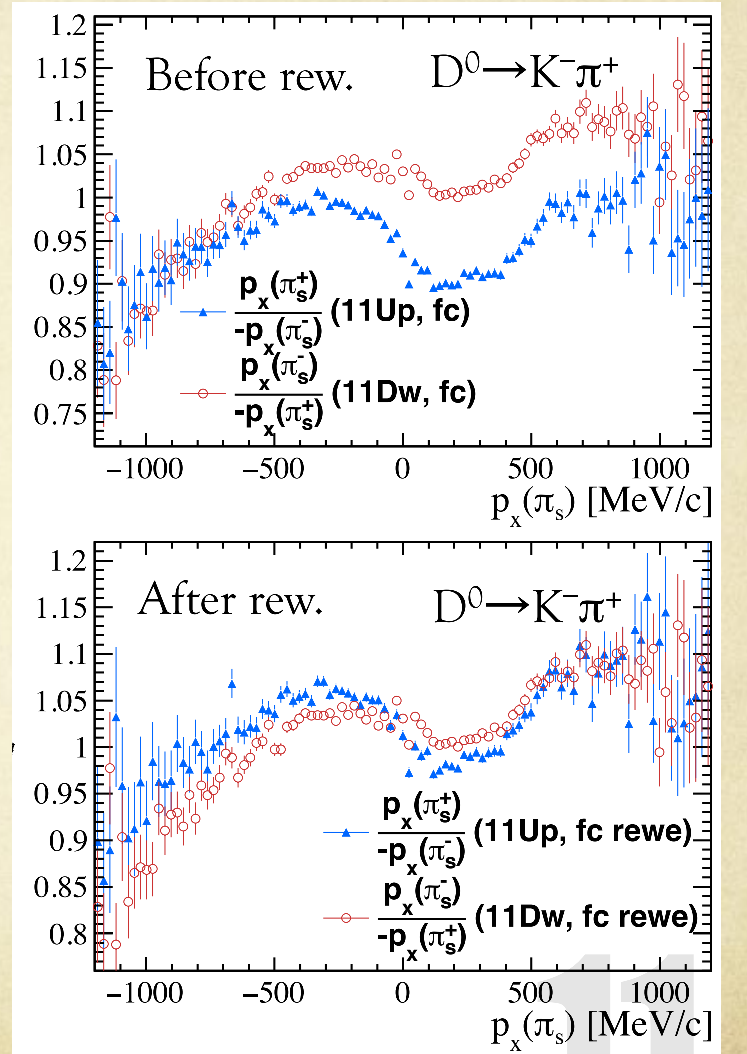
Soft pion charge asymmetries



R must be the same by construction between MagUp and MagDown (assuming no production asymmetry and the same run "conditions").

Observed differences largely due to the different interaction region (different beam crossing angle).

Improved the precision of cancellation mechanism by reweighting (x-z)- coordinates of the PV. See Pietro's talk at the T&A Group (Oct 10, 2015).



People: Marino, Morello, Punzi, Walsh.

$B^0_{(s)} \rightarrow \mu^+\mu^-$

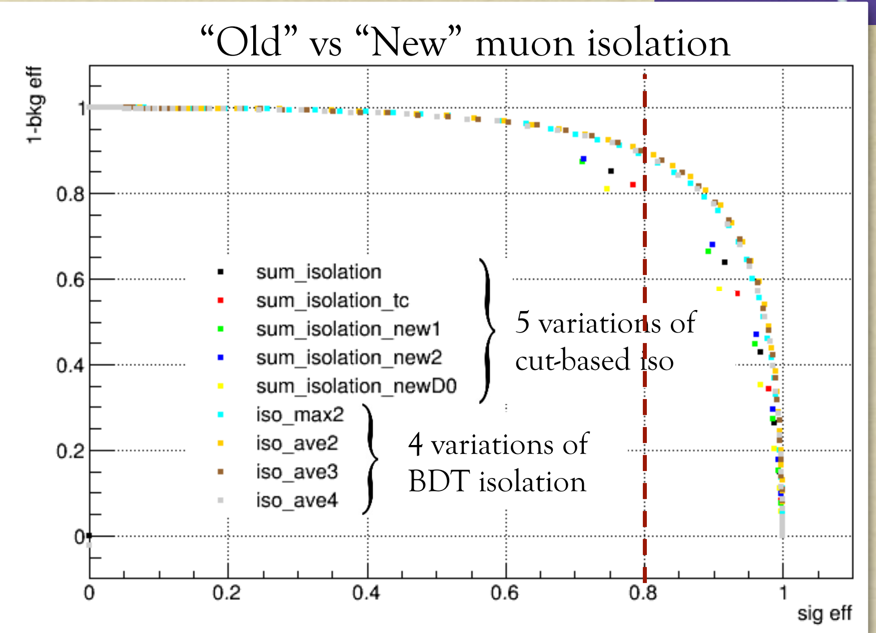
- In preparation of new measurement in RunII effort focused on the optimization of the sensitivity for the $B^0 \rightarrow \mu^+\mu^-$ decay mode.
  - control of systematics in the determination of the peaking background,
  - optimization of the rejection cuts for both the peaking background and the combinatorial background.
- Recent progress (LHCb-INT-2014-047) involves:
  - improved determination of the hadron PID misidentification probabilities,
  - usage of a new PID selection in the rejection of peaking background,
  - introduction of more performant isolation variables in the rejection of the combinatorial background.
- Development of new tools to help improvements in combinatorial background rejection.

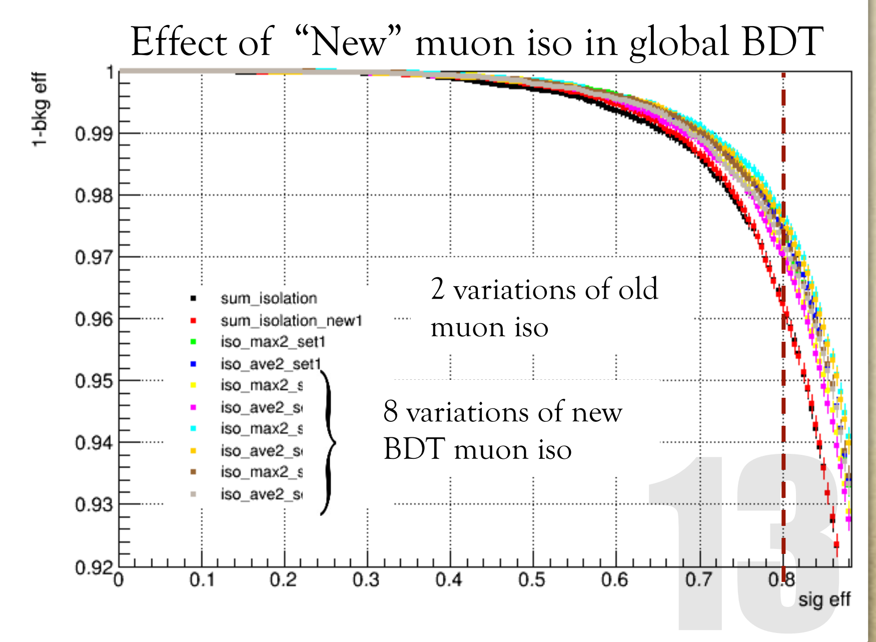
People: M. Rama.

Fruitful collaboration with Frascati people leaders in the $B^0_{(s)} \rightarrow \mu^+\mu^-$ effort.

B→μμ - IsoBDT

- "New" vs "Old" muon isolation.
  - Used a multivariate classifier (BDT) instead of a cut-based approach.
  - Input variables: Old + Δφ, Δη, pt, realative charge and PID variable.
- At signal eff.~80% → backg rej. moves from 80% to 90%.
- When used in the global BDT, improvement still in there (35-40% more background rejection at 80% of signal eff.). Sensitivity to $B^0_s(B^0)$ improves by a factor 1.05(1.07).
- To further improve performances, studies on VELO and upstream tracks are ongoing (so far used only Long tracks).



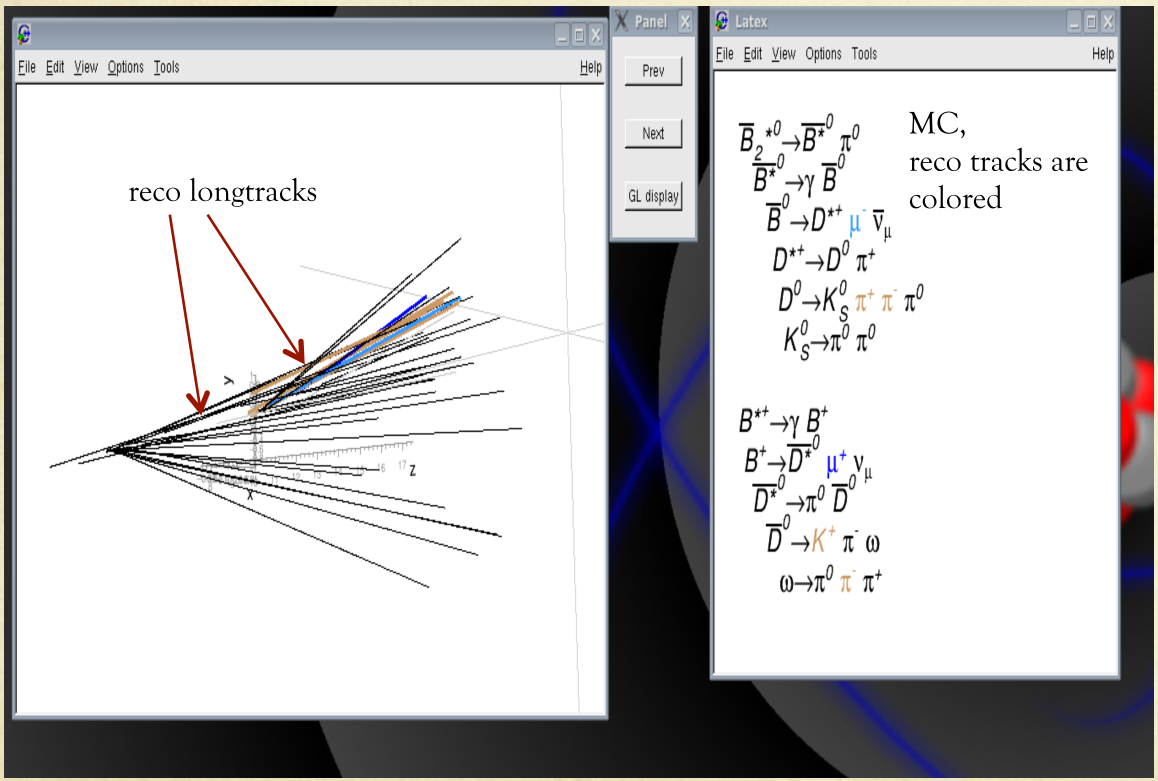


$B^0_{(s)} \to \mu^+\mu^-$ - New tools

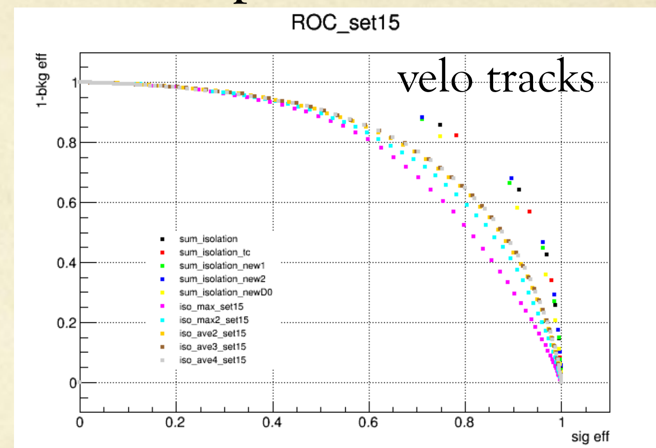
- Development of new tools to further improves the background rejection:
  - A toy event display at ntuple level
    - to compare the properties of signal and background events and look for possible additional discriminating features.
  - A signal-like data sample
    - data-based optimization of global BDT, accounting more precisely for different LHC/detector running conditions, study the isolation properties of signal vs background in data-like environment, etc.
- As a by-product of the signal-like data sample is the "vertexing tool" at the ntuple level.
  - Allowing the test of new ideas (i.e. isolation) without the need of re-running DaVinci (it needs full DST events).

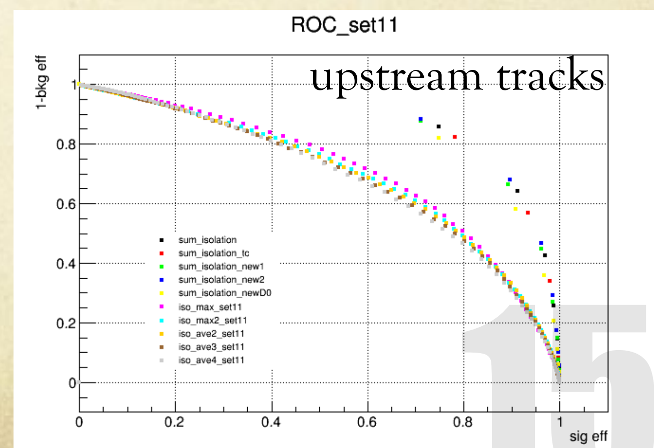
$B^0_{(s)}\to\mu^+\mu^-$ - New tools

toy event display



IsoBDT with VELO and upstream tracks





Pisa effort in simulation

- Riccardo Cenci in charge as convener of the Simulation from early 2015
- Main activities to be coordinated: **Tuning**
  - Tuning of generators using data through Professor and Rivet plugins.
  - Tuning of materials and geometry using displaced vertices.
- Other activities:
  - Release and validation of Sim09.
  - Preparation for future releases and migration to Geant4 v10.
  - Focus also on need of larger MC samples for Run2 analyses (particle gun, parametric simulation, multi-thread, etc).

Conclusions&Perspectives

- Pisa activity is variegated and impacts several fields of the experiment:
  - charm physics, rare decays, tracking, simulation and trigger.

- Both A_{CP} $D^+/D^+_s \rightarrow \eta(')\pi^+$ and of $A_\Gamma(D^0 \rightarrow h^+h^-)$ with $3fb^{-1}$ are in good shape and they will go into WG review by the end of the year.

- Achieved a significant progress in facing the challenge of charge asymmetries and magnetic field reversion mechanism.

- Achieved an improved sensitivity (by a factor of 5-7%) in the $B \rightarrow \mu^+\mu^-$ analysis, by exploiting better information from muons isolation.

backup

Sommario errori sistematici

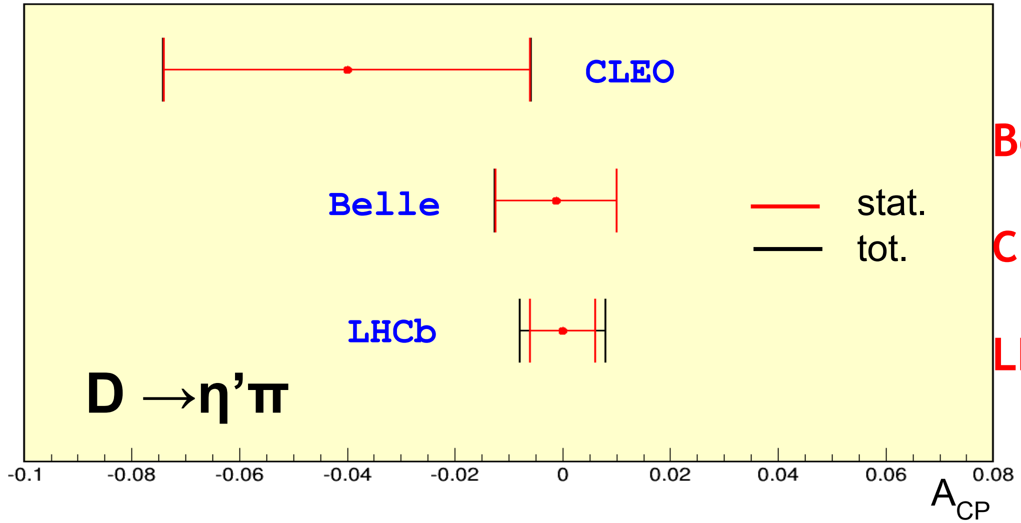
Incertezze sistematiche sulle asimmetrie CP per il campione a $\sqrt{s}$= 7 TeV:

Systematic effect	$A_{raw}(D^+ \to \eta'\pi^+)$	$A_{raw}(D^+_s \to \eta'\pi^+)$
Trigger asymmetries	0.03%	0.03%
Fit model	0.4%	0.4%
K contamination	0.1%	0.2%
ϕ contamination	0.2%	0.0%
D from *B* decays	0.03%	0.06%
Production asymmetry	0.18%	0.10%
Total uncertainty	0.5%	0.5%

- Incertezze sistematiche più influenti: modello di fit, contaminazione K-ϕ.
- Per il campione a $\sqrt{s}$=8 TeV è ragionevole aspettarsi risultati simili.

Precisioni LHCb, CLEO, Belle

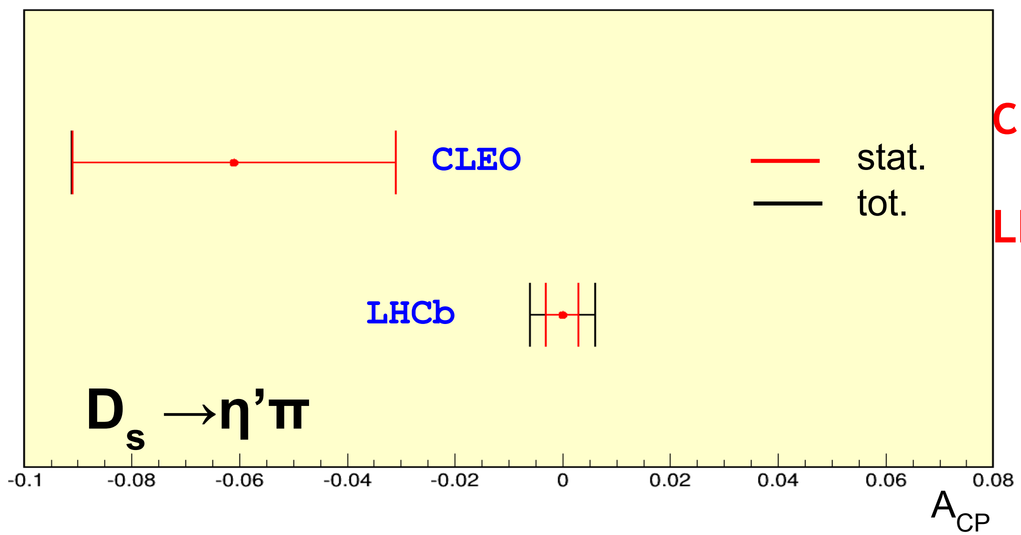
I valori delle asimmetrie per LHCb sono fissati a zero perché ancora *blind*.



Belle: (-0.12 ± 1.12 ± 0.17)%

CLEO: (-4.0 ± 3.4 ± 0.3)%

LHCb: (x.x ± 0.6 ± 0.5)% (3 fb^{-1})

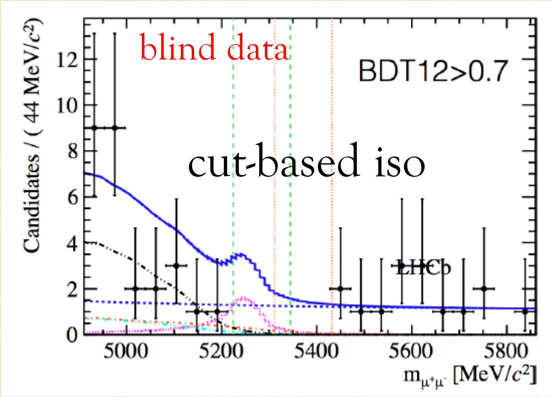


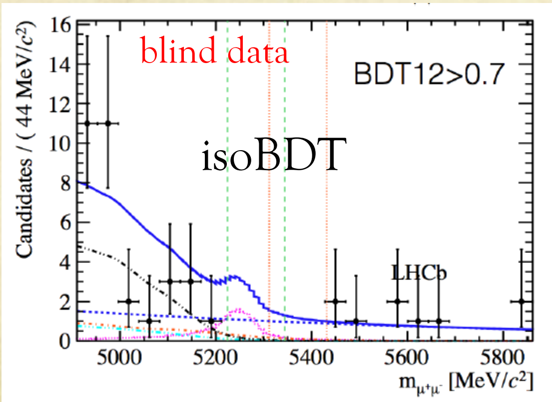
CLEO: (-6.1 ± 3.0 ± 0.3)%

LHCb: (x.x ± 0.3 ± 0.5)% (3 fb^{-1}

Ulteriore miglioramento verra' dai dati del Run II che e' ora in corso.

BDT 2013 vs BDT with new muon isolation





from LHCb-INT-2014-047

		B^0, 30 fb^{-1}		B^0_s, 3 fb^{-1}		
2013	BDT12 & DLL	1.77		4.81		
	$BDT12_{iso}$ & DLL	1.85	1.05	5.20	1.07	new muon isolation
	$BDT12_{iso}$ & $ProbNN_1$	1.87	1.06	5.23	1.08	
	$BDT12_{iso}$ & $ProbNN_2$	1.94	1.10	5.37	1.11	
	$BDT12_{iso}$ & $ProbNN_3$	2.08	1.18	5.43	1.12	new muon isolation + better PID
	$BDT12_{iso}$ & $ProbNN_4$	2.06	1.16	5.28	1.09	
	$BDT12_{iso}$ & $ProbNN_5$	2.04	1.15	4.95	1.02	
	$BDT12_{iso}$ & $ProbNNnop_3$	2.08	1.18	5.42	1.12	
	$BDT12_{iso}$ & $ProbNNnop_4$	2.06	1.16	5.29	1.09	
	$BDT12_{iso}$ & $ProbNNnop_5$	1.96	1.11	5.06	1.05	

absolute significance

relative change compared to 2013 expectation