CHARM PHYSICS WG

ACTIVITIES & OPPORTUNITIES

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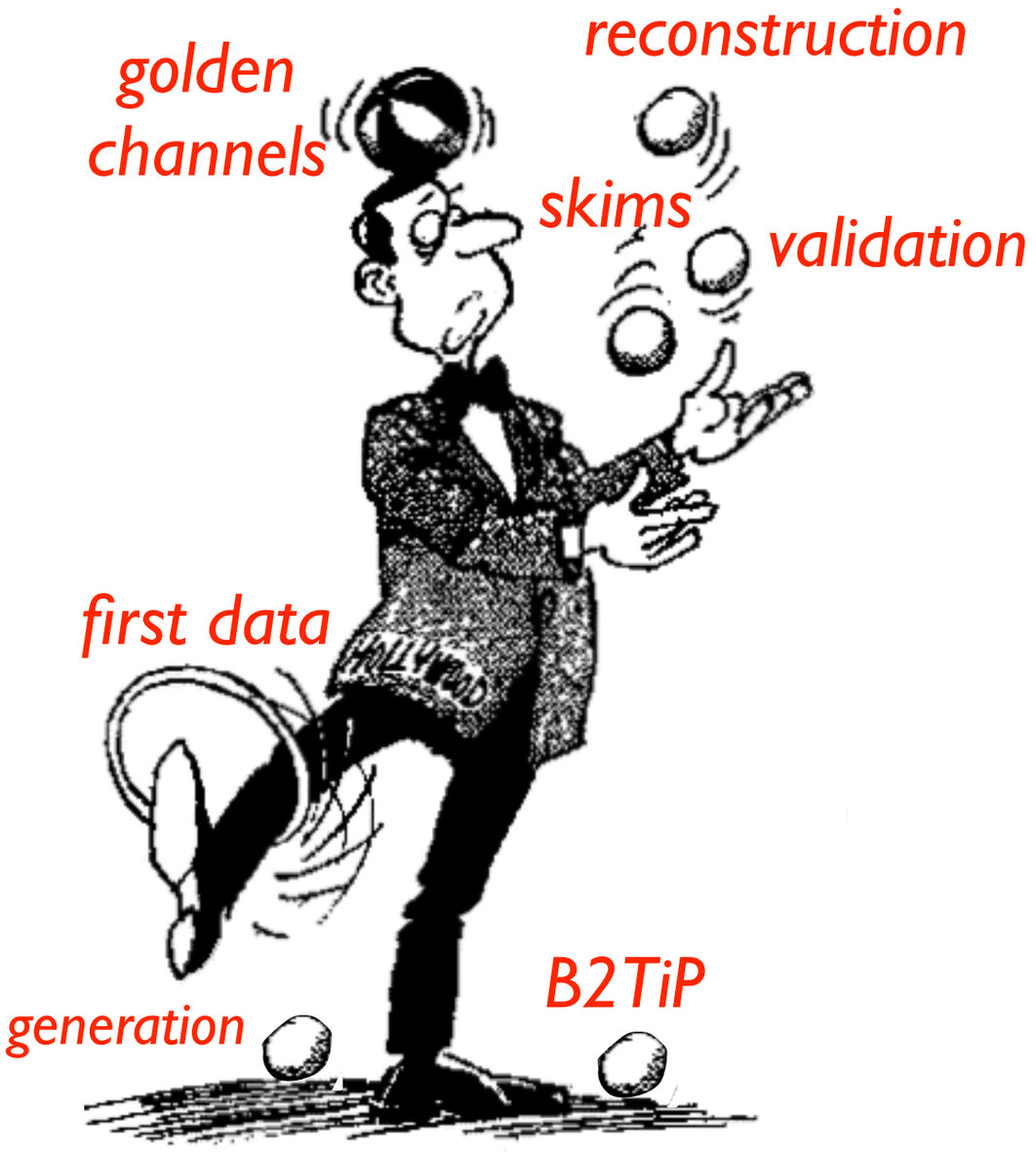
Alexander von Humboldt Stiftung/Foundation

CHARM co-convener:

Roy Briere (CMU)

7th BelleII Italian Collaboration Meeting ~ May, 4th 2017

Overview of the Current Activities



- ➡ *charm generation, skims & validation*
- ➡ *physics of the B2TiP*
  - *reconstruction performances*
  - *reconstruction techniques*
  - *golden channels*
- ➡ *what can we do with PHASE II data*

group members: R. Briere, G.C., A. Schwartz, J. Bennett, D. Last(student), G. De Pietro(?) , T. Nanut(LHCb) , J.Yelton.

Generator Tuning & Skims

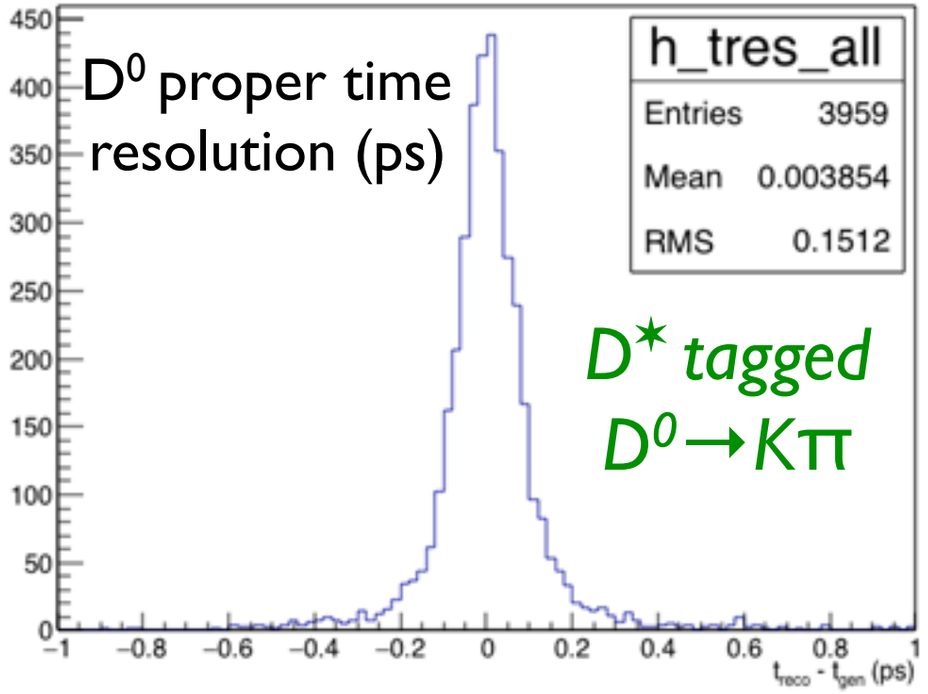
WG DUTIES & maintenance

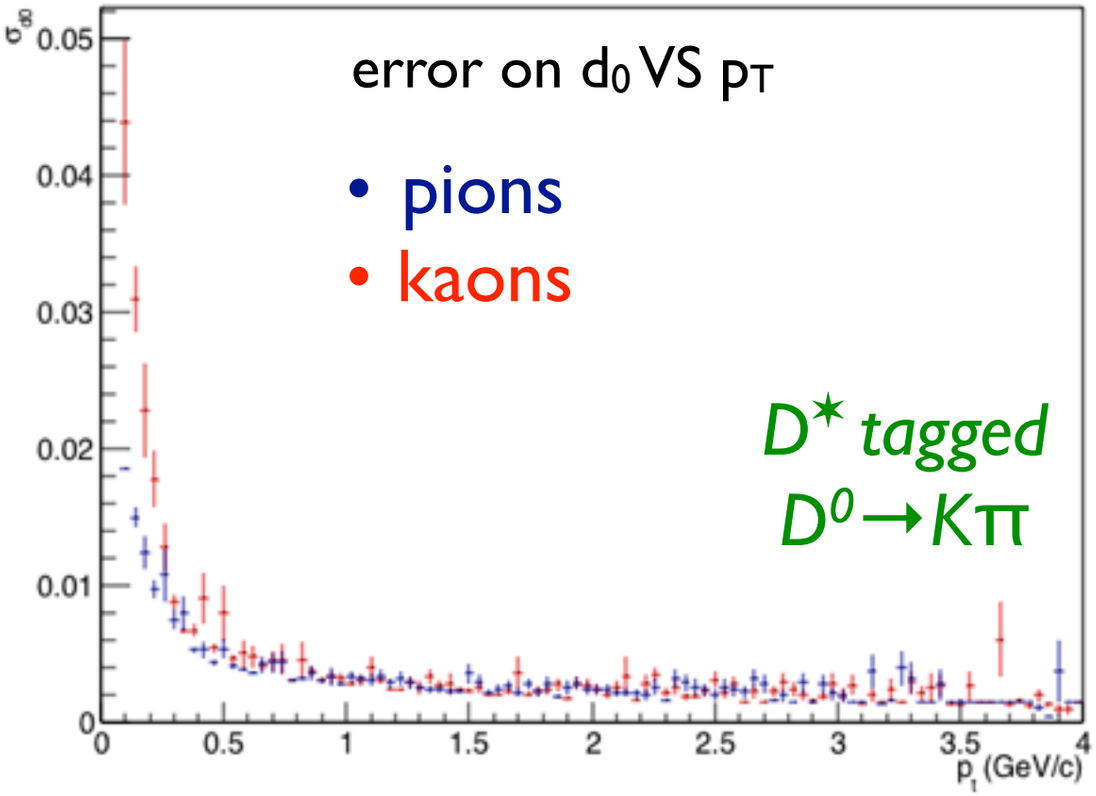
- New set of **Pythia parameters** for continuum charm generation, needed after Pythia upgrade.
  - a bug caused a big loss of D^* production
  - David Last, CMU bachelor student
  - details will be shown at the next Charm Meeting, 9th May (see Charm Confluence Page)
- **Skims** become important for MC 8: "all events" not available, only skimmed samples
  - no one working specifically on this, no one working on a specific signal channel…
  - I put together skims for a few channels of interest. They are probably OK to start, but more time should be dedicated to skim preparation
    - No real optimisation of the skims:
      - cut on center-of-mass momentum of the D
      - PID of particle lists
    - No skims available for feasibility studies, e.g. on D reconstruction
      - no skims for ROE-tagging method

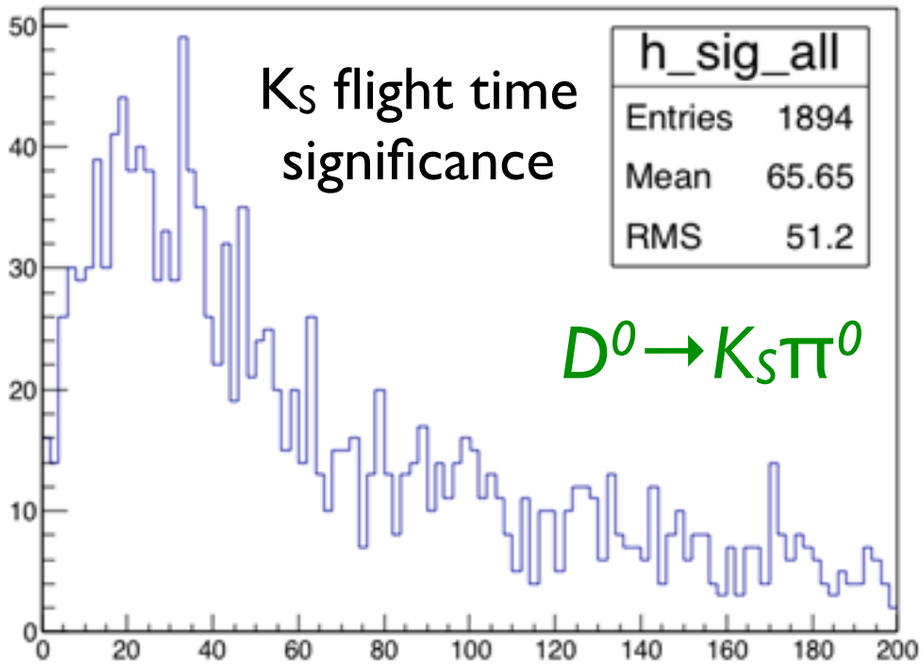
Charm Validation

WG DUTIES & maintenance

- Set of plots produced automatically in the validation framework
- Allows to monitor observables that are important for charm reconstruction/analyses
- First set of plots are provided (waiting for approval of branch merging)
  - missing efficiency plots
  - missing purity plots (w bkg)







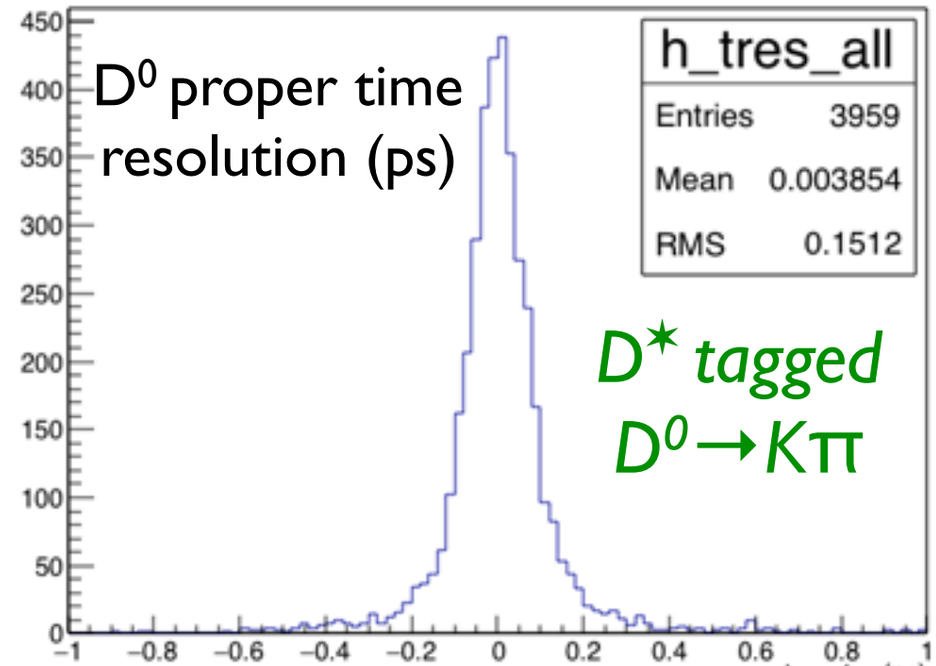
Charm B2TiP Chapter

Contents PAGE

- Despite the limited number of people of the WG, we were able present results based on simulations or ToyMC in each experimental section.
- Predictions are kept conservative

Improved Proper Time Reconstruction

- Proper time resolution for $D^\star$ tagged and prompt D is a factor 2 better than BaBar
- Impact on time-dep measurements of mixing and CPV evaluated with ToyMC on:
  - $D^0 \to K\pi$
  - $D^0 \to K\pi\pi$ (no bkg included)



WHAT'S NEXT?

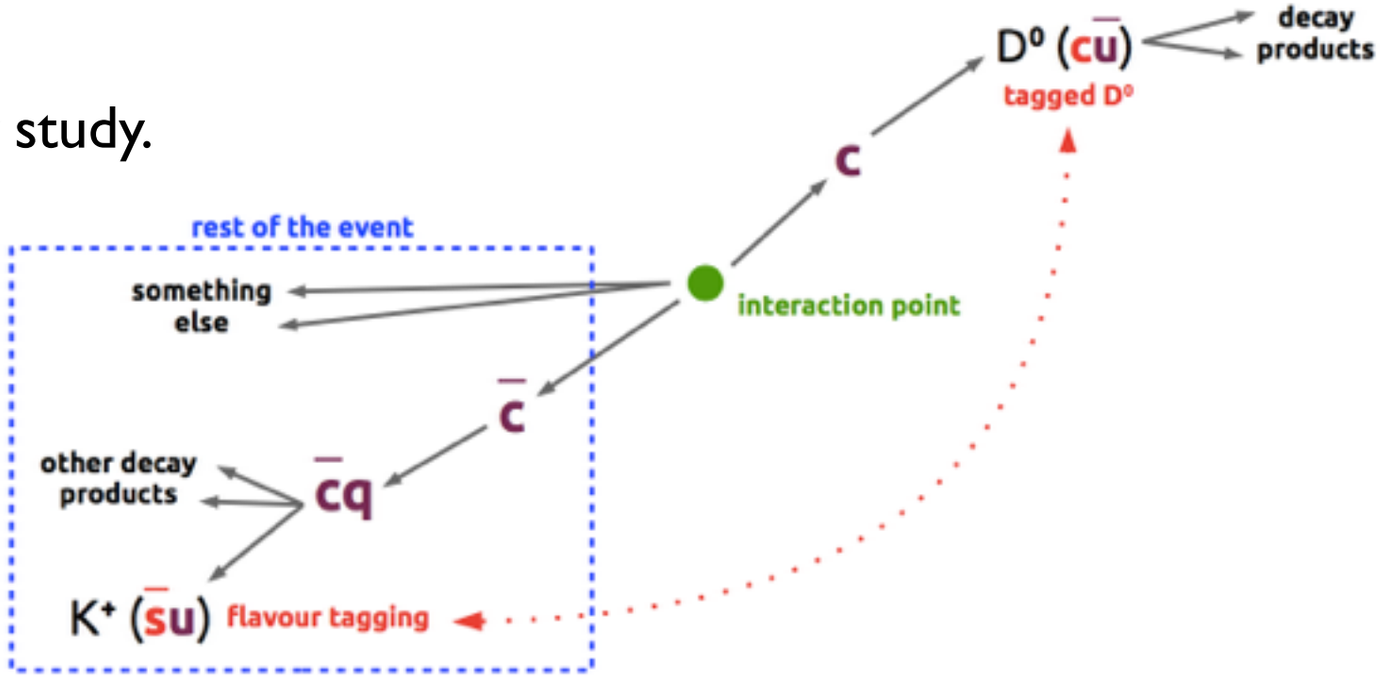
1. can the improved flight distance measurement be used in the selection criteria to reject combinatorial background?
2. Perform the analysis on a generic MC sample + signal MC sample and confirm the sensitivity obtained with Toys
   - optimize the skim
   - optimize the reconstruction (vertexing, PID lists) and the selection
   - study the difference (efficiency, proper time reconstruction) between $D^\star$ tagged and ROE tagged D^0 mesons

targeting PHASE III

ROE Flavour Tagging Method

ROE = Rest Of Event

- Giacomo has completed the *feasibility* study.
  - 35% equivalent luminosity increase, useful in A_{CP} analyses
- Promising results, need to be confirmed with a beginning-to-end A_{CP} analysis

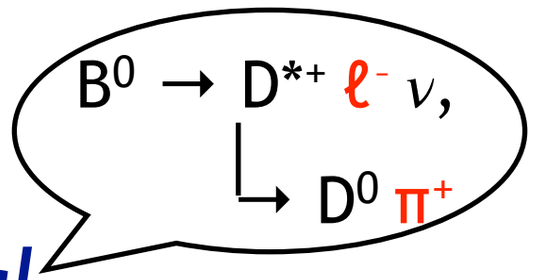


What's Next?

1. Implement the module & corresponding analysis tool to allow the analysts to apply the method. Update documentation.
2. Define the procedure to establish the cuts in the multivariate analyses (xxx% efficiency, hhh% purity, …)
3. Do we need dedicated skims?
4. Apply the method on generic MC samples, end/or A_{CP} signal MC samples
   - what is the background from Y(4S) events? and from uds continuum?
   - what is the "real" gain in precision on A_{CP} measurements? Take into account differences in background composition and resolution.

targeting Phase III

B → Charm Events



background

- ➡ reject D from B decays in order to have an unbiased measurement of the D flight length (the B is not reconstructed)
- ➡ apply a cut on the D CMS momentum
  - great reduction of B bkg ~10^{-5}
  - non negligible impact on signal: $\varepsilon = 70\%$

signal

- ➡ Partial reconstruction B → D decays provides an additional sample of flavour-tagged D^0
  - a D^0 is in the sample, can be reconstructed in any final state (e.g. invisible, rare/forbidden decays)
  - expect 13 D^0 every 100 obtained with the D^* method

WHAT'S NEXT?

1. Can we find other selection criteria, (base on multivariate analysis), with a softer impact on signal events?
   - Giacomo has performed a preliminary study, he achieved promising results

WHAT'S NEXT?

1. Need a basf2 module to implement the reconstruction.
   - I have started the implementation of a module that has the basic features and allows the reconstruction

Time-Integrated CP Violation

➡ $D^0 \to K_S K_S$:

- SM A_{CP} up to 1%, could give first evidence of CP in charm
- precision ~0.2% at 50 ab^{-1} (scaled from a Belle analysis)
- important for the optimization of the K_S reconstruction

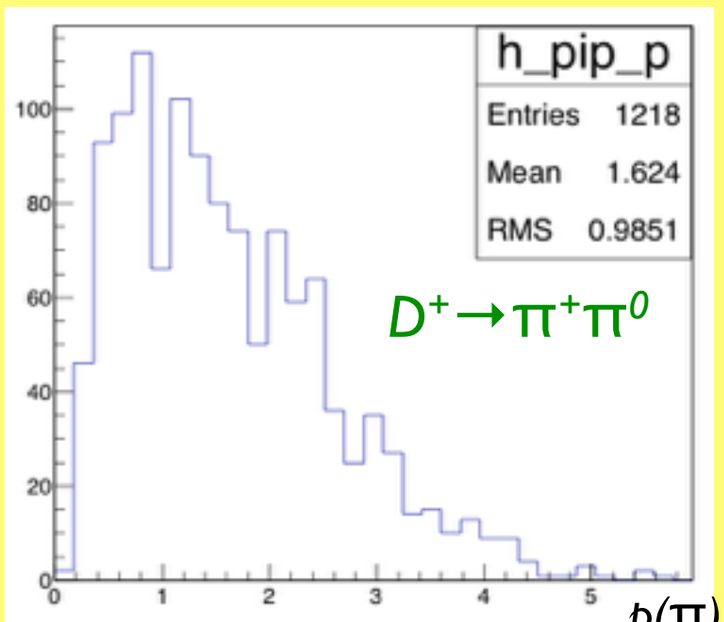
➡ $D^+ \to \pi^+\pi^0$:

- SM A_{CP} = 0, search for NP with straightforward interpretation of the results
- precision ~0.2-4% at 50 ab^{-1} (scaled from a not-published BaBar analysis)
- important for the optimisation of the π^0 reconstruction

What's Next?

1. Final state particles are suitable for *Phase II* reconstruction
   - K_S and π^+ are well reconstructed in the CDC
   - π^0 do not need VXD
2. Beginning-to-end A_{CP} analysis
   - with *Phase II* geometry and then *Phase III*
   - will automatically reserve you the right to perform the analysis in *Phase III!*

targeting Phase II



Other Possibilities

➡ Leptonic & Semileptonic Decays

- J. Bennett started the semileptonic reconstruction with promising results
- lack of time due to his responsibilities in BelleII + this project is a very long-term one → this project is on hold

➡ Radiative Decays

- T. Nanut (Ljubljana) performed some feasibility studies connected to her Belle analysis ($D \to V\gamma$) but she left BelleII

➡ Baryon Search

- Recent interest of J. Yelton (UFl) & students

  "My plan would be to reconstruct as many charmed baryon modes as possible"

- this is just the starting point, the next natural step would be to search for CP violation in baryon decays

Conclusions

- ➡ Activities are growing, the WG size is not.
  - we need the WG to grow to meet its duties to the collaboration
- ➡ No clear channel suitable for publication in PHASE II – as many other WGs –
  - other interesting things to do with PHASE II data: boost for PHASE III analyses
- ➡ Clear set of interesting channels for PHASE III
  - first evidence of CPV in charm
  - new reconstruction and flavour-tagging techniques
- ➡ Phase III is not far…it looks like, but it's not. We need to get there prepared.

"No experience necessary. We'll train you!"

[Charm Confluence Page] [mailing list subscription]

study the efficiency and purity of this reconstruction technique

Charm from B Decays

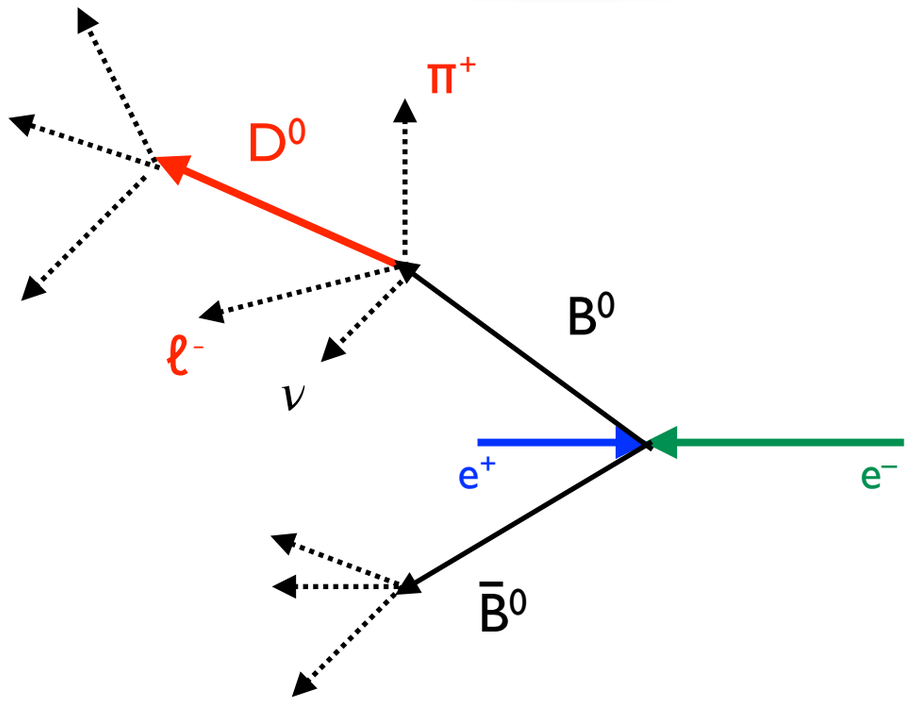
$$B^0 \rightarrow D^{*+}\, \ell^-\, \nu,$$
$$\hookrightarrow D^0\, \pi^+$$

Partial Reconstruction of the B assuming…

- ➡ B^0 is at rest in the center-of-mass of the Y(4S) (p=380MeV/c)
- ➡ D^0 produced at rest in the center-of-mass of the D^{*+}, therefore:
  - $p(D^{*+}) = \alpha + \beta\, p(\pi_s)$
  - D^{*+} and π_s have the same direction

…allows to compute the M_ν^2 peaking at 0 for signal.

- increase statistics providing independent D^0 samples
- the D^0 is *not* reconstructed in a particular channel!
  - $D^0 \rightarrow$ invisible searches
  - rare decays, …



Estimate from *BABAR* (200fb^{-1}onPeak + 22 fb^{-1} offPeak):
[M.Rotondo, F.Simonetto]

tag	# signal	purity
e	2150	52%
μ	1740	55%

1 ab^{-1}
6M
4.8M

10M/ab tagged D^0

VS

~ 80M/ab from D^{*+} tagging
(depends on the final state)

Time-Integrated CP Violation

Mode	$\mathcal{L}$ (fb^{-1})	A_{CP} (%)	Belle II 50 ab^{-1}
$D^0 \to K^+K^-$	976	$-0.32 \pm 0.21 \pm 0.09$	± 0.03
$D^0 \to \pi^+\pi^-$	976	$+0.55 \pm 0.36 \pm 0.09$	± 0.05
$D^0 \to \pi^0\pi^0$	966	$-0.03 \pm 0.64 \pm 0.10$	± 0.09
$D^0 \to K^0_S\pi^0$	966	$-0.21 \pm 0.16 \pm 0.07$	± 0.03
$D^0 \to K^0_S\eta$	791	$+0.54 \pm 0.51 \pm 0.16$	± 0.07
$D^0 \to K^0_S\eta'$	791	$+0.98 \pm 0.67 \pm 0.14$	± 0.09
$D^0 \to \pi^+\pi^-\pi^0$	532	$+0.43 \pm 1.30$	± 0.13
$D^0 \to K^+\pi^-\pi^0$	281	-0.60 ± 5.30	± 0.40
$D^0 \to K^+\pi^-\pi^+\pi^-$	281	-1.80 ± 4.40	± 0.33
$D^+ \to \phi\pi^+$	955	$+0.51 \pm 0.28 \pm 0.05$	± 0.04
$D^+ \to \eta\pi^+$	791	$+1.74 \pm 1.13 \pm 0.19$	± 0.14
$D^+ \to \eta'\pi^+$	791	$-0.12 \pm 1.12 \pm 0.17$	± 0.14
$D^+ \to K^0_S\pi^+$	977	$-0.36 \pm 0.09 \pm 0.07$	± 0.03
$D^+ \to K^0_S K^+$	977	$-0.25 \pm 0.28 \pm 0.14$	± 0.05
$D^+_s \to K^0_S\pi^+$	673	$+5.45 \pm 2.50 \pm 0.33$	± 0.29
$D^+_s \to K^0_S K^+$	673	$+0.12 \pm 0.36 \pm 0.22$	± 0.05

Estimation of Mixing Parameters

Alan Schwartz

- ToyMC study triggered from the x2 improvement in the t resolution of D^0 with respect to Belle/*BABAR*
- Use the Golden Channel WS $D^0 \to K^-\pi^+$, flavour tagged with D^{*+} decays, measures x'^2 and y'

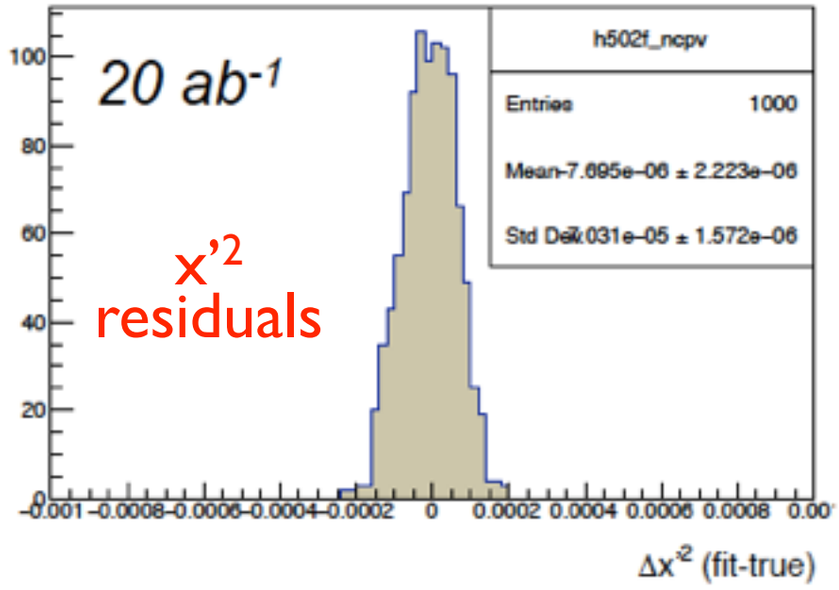
$$x' = x\cos\delta + y\sin\delta,\quad y' = y\cos\delta - x\sin\delta$$

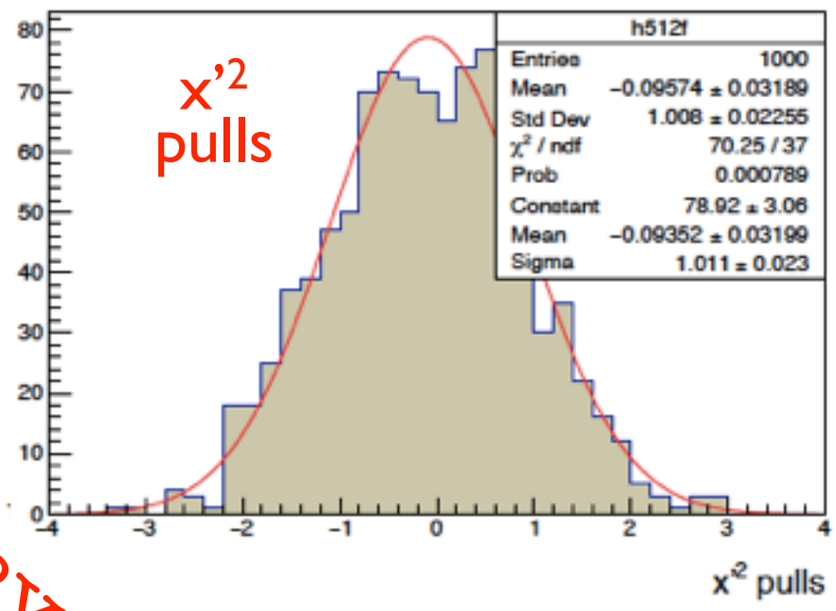
Toy MC study #1 (ROOT): no CPV

- *generate $D^0 \to K^+\pi^-$ decays with mixing*
- *smear decay times according to resolution (σ = 0.14 ps)*
- *fit decay time distribution for mixing parameters R_D, x'^2, y'*
- *statistics: 43863 (5 ab^{-1}) 175450 (20 ab^{-1}) 438630 (50 ab^{-1})*
- *generate ensembles of 1000 experiments*
- *use same PDF for D^0 and D^0bar:*

$$\frac{dN(D^0 \to f)}{dt} \propto e^{-\overline{\Gamma}t}\left\{R_D + \sqrt{R_D}\,y'(\overline{\Gamma}t) + \frac{(x'^2 + y'^2)}{4}(\overline{\Gamma}t)^2\right\}$$

convolved with a Gaussian resolution function





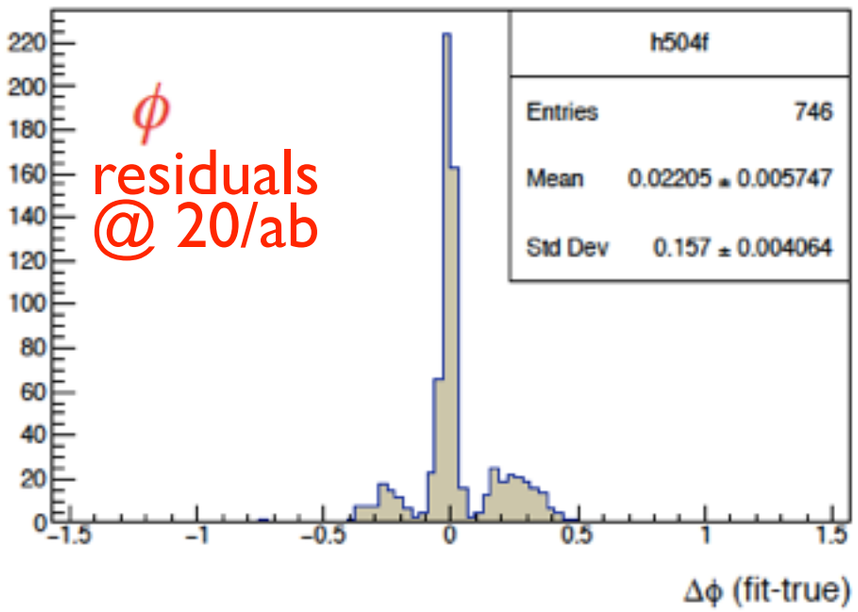
PRELIMINARY

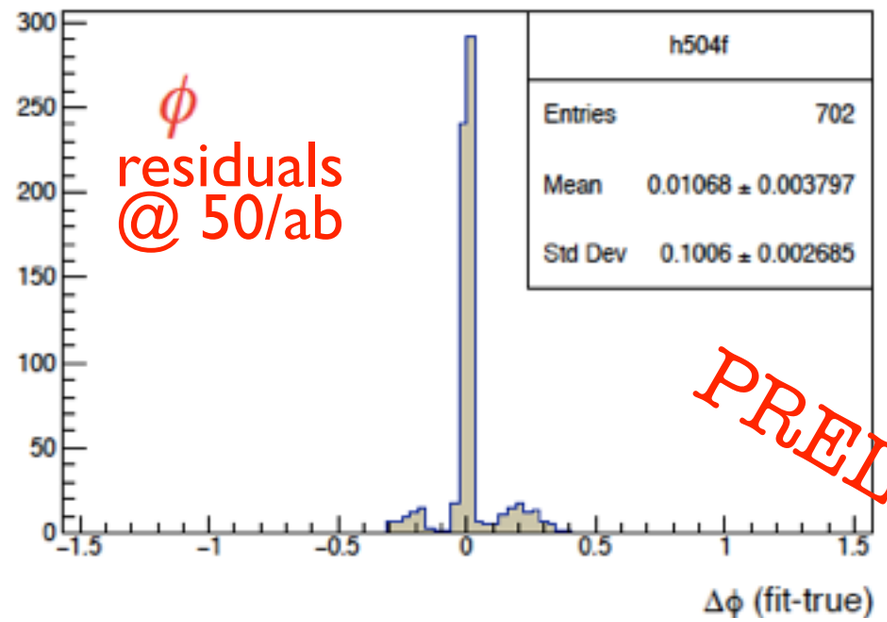
fromToyMC	5 ab^{-1}	20 ab^{-1}	50 ab^{-1}
x'^2 (x 10^{-5})	14.4	7.0	4.4
y' (%)	0.156	0.075	0.047

Estimation of Mixing & CPV Parameters

Alan Schwartz

- Pulls and residuals not as good as in the mixing-only measurement
- the fit is anyway comfortable in finding the minimum, average of minos errors agrees with the RMS of the residual distribution
- ambiguity in the definition of ϕ: $(x', y', \phi) \rightarrow (-x', -y', \phi+\pi)$





PRELIMINARY

fromToyMC	5 ab^{-1}	20 ab^{-1}	50 ab^{-1}
x' (%)	0.37	0.23	0.15
y' (%)	0.26	0.17	0.10
$\|q/p\|$	0.197	0.089	0.051
ϕ (degrees)	15.5	9.2	5.7

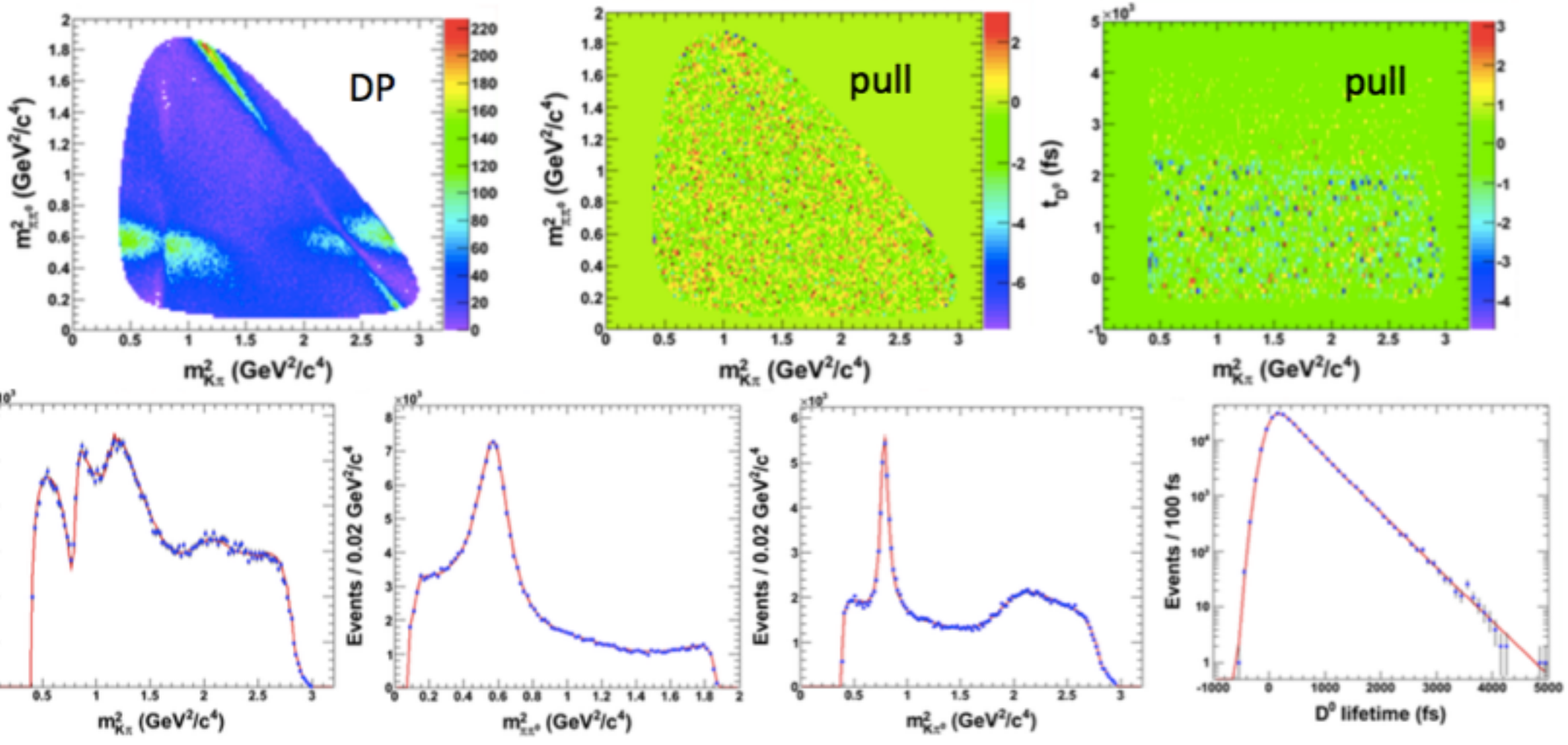
Mixing Parameters from $D^0 \to K^-\pi^+\pi^0$

Longke Li

PRELIMINARY

projection of one smear sample(225K)

with DCS res. and mixing parameters floated
with CF res. fixed; with tau(D^0) and time-resolution function fixed



For 225,000 signals of WS sample, we estimate its time-dep. Dalitz fitting error is 0.060% for x, and 0.049% for y under (delta=10° R=13.8) fixed.