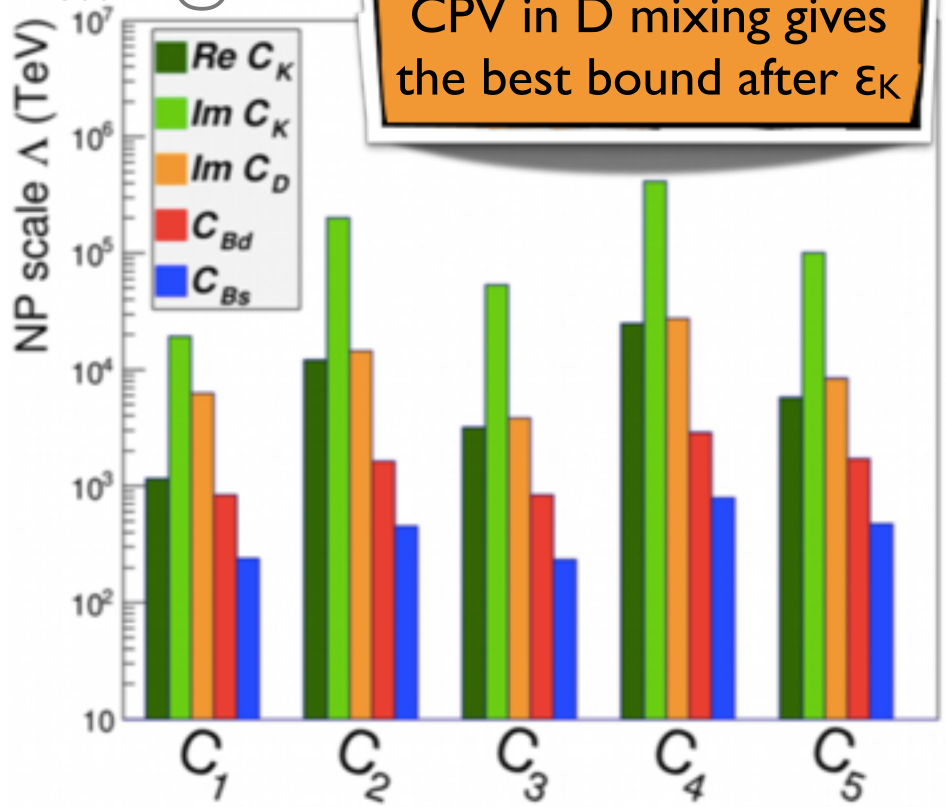
Recent CHARM Physics Activities

L.Silvestrini@B2TiP



CPV in D mixing gives the best bound after ε_K

Giulia Casarosa

INFN - Sezione di Pisa

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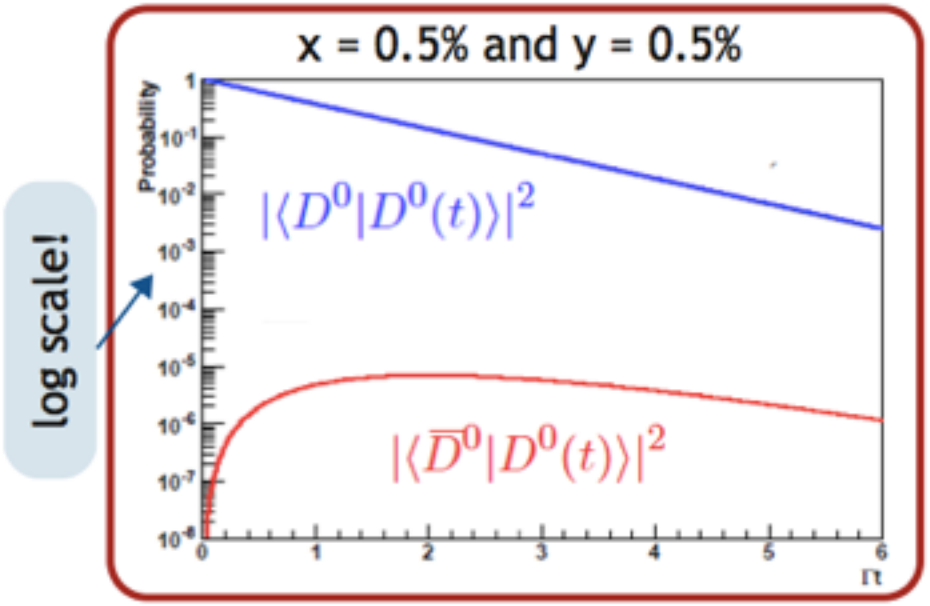
Outline

- ➡ Introduction on Time Dependent Analysis
- ➡ Analysis Demonstration: $D^{*+} \to D^0 \pi^+$; $D^0 \to K_S \pi^+ \pi^-$
  - dataset, selection and classification of the background events
  - Dalitz Plot distribution, Proper Time and its Error
- ➡ Studies on the D Proper Time Resolution
  - $D^{*+} \to D^0 \pi^+$; $D^0 \to h^+ h^-$ case
  - $e^+e^- \to D\ X$ case
- ➡ Conclusions

Time-Dependent Charm Analyses

- Time-Dependent Analysis are sensitive to Mixing and Indirect CP Violation → most sensitive to New Physics
- D^0 mixing is <u>very</u> slow
- Time–Dependent (TD) mixing analysis must be sensitive to effects of the order of 10^{-3} (x,y, y') to 10^{-5} (x'^{2}).
- The sensitivity to Indirect CP Violation parameters is suppressed by the mixing parameters:

Time Evolution of a $D^0(t=0)$:



Wrong Sign Kπ, allowing for direct CPV:

$$x'^{\pm} = |q/p|^{\pm 1}(x' \cos\phi \pm y' \sin\phi)$$

$$y'^{\pm} = |q/p|^{\pm 1}(y' \cos\phi \mp x' \sin\phi)$$

$$\phi = \arg(q/p)$$

Lifetime Ratio Analysis, $D^0 \to K\pi$ VS $D^0 \to hh$

$$y_{CP} = y\cos\phi - \tfrac{1}{2}A_M x \sin\phi$$
$$A_\Gamma = \tfrac{1}{2}A_M y \cos\phi - x\sin\phi$$

$$A_M = \frac{|q/p|^2 - |p/q|^2}{|q/p|^2 - |p/q|^2}$$

Time-Dependent Dalitz Plot Analysis $D^0 \to K_S\pi\pi$

$$|\mathcal{A}|^2 \propto |A_f|^2 e^{-\Gamma t}\left[\frac{1+|\lambda_f|^2}{2}\cosh(y_D\Gamma t) + \frac{1-|\lambda_f|^2}{2}\cos(x_D\Gamma t) - Re\lambda_f \sinh(y_D\Gamma t) + Im\lambda_f \sin(x_D\Gamma t)\right]$$

$$\lambda_f = \frac{q}{p}\frac{\bar{A}_f}{A_f}$$

Improving the precision on the mixing parameters increases the sensitivity to the CPV parameters

Charm Golden Channel:
allows the direct measurement
of the CPV & mixing parameters

$D^{*+} \to D^0\pi^+$; $D^0 \to K_S\pi^+\pi^-$
Analysis Demonstration

this study was presented at the 20th *B2GM* in February 2015

$D^0 \to K_S \pi^+ \pi^-$ Reconstruction

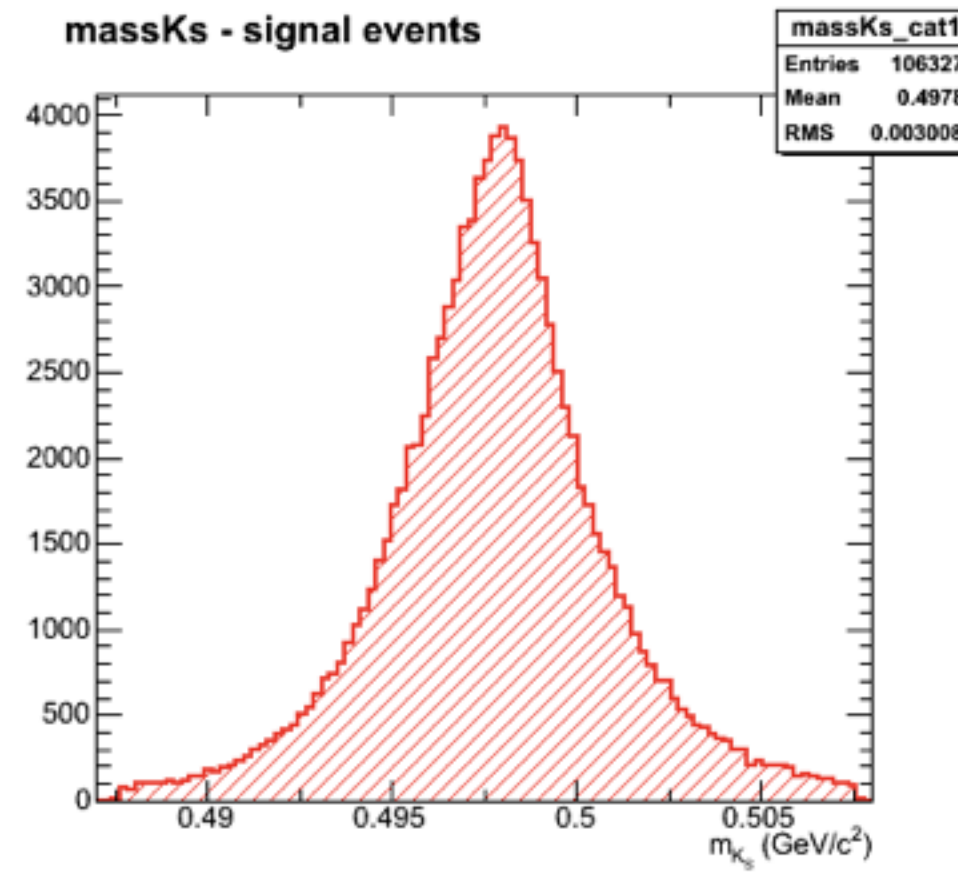
dataset:
$100 fb^{-1}$ MC4.5
build-2014-10-18

- $\pi^\pm$, D^0 daughters candidates
  - std loose list (piid > 0.1 and chiProb > 0.001)
  - p_t > 0.1 GeV/c *well-measured tracks*
  - ~~# hits in L1 & L2 > 2~~ *not available!* *well-measured tracks*

    now available

- K_S candidates
  - std K_S list + 10 MeV/c^2 wide mass window

    now we have "good" K_S list (neural network)



- D^0 candidates
  - pre-fit cuts: p^* > 2 GeV/c & 100 MeV/c^2 wide mass window
  - vertex fit, with mass constraint (RAVE), $P(\chi^2) > 10^{-4}$
  - post-fit cuts: 40 MeV/c^2 wide mass window & p^* > 2.4 GeV/c

to reject D from B decays

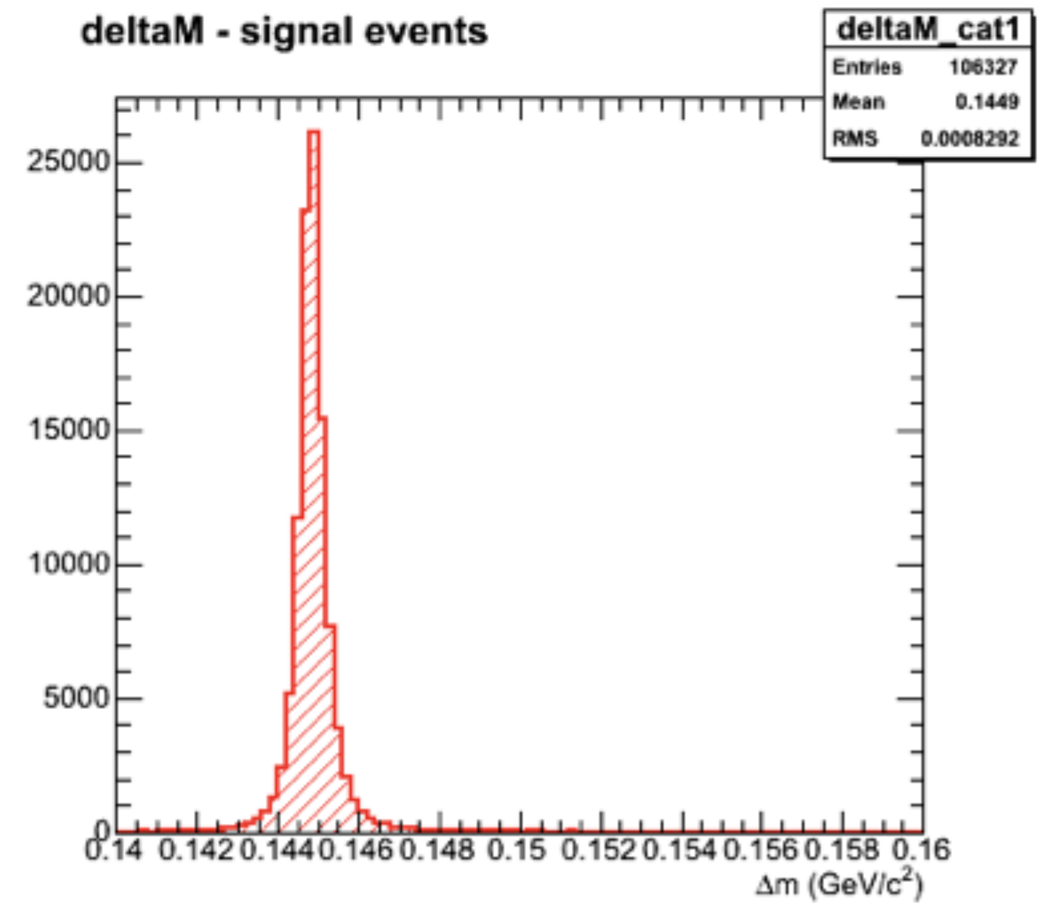
$D^{*+} \to D^0\pi^+$ Reconstruction

➡ soft π^+ candidates

- p_t > 0.1 GeV/c *well-measured track*
- p*< 500 MeV/c *kinematic limit*
- ~~# hits in CDC > 0~~ *well-measured track* ~~not available!~~ now available

➡ D* candidates, 3 lists ↔ 3 different fit constraints

- pre-fit cuts: 0 < Q (MeV) < 30
- vertex fit, $P(\chi^2) > 10^{-4}$
  1. RAVE, no constraint
  2. RAVE, D* constrained to originate in the beam spot, use π_s *best Δm resolution* ← used
  3. RAVE, D* constrained to originate in the beam spot, use π_s and D^0
- post-fit cuts: 0 < Q (MeV) < 20



something going on? Δm resolution from fit 3. is worse than from fit 1. and 2.

there was (is?) something wrong with the CopyList python function (still under investigation)

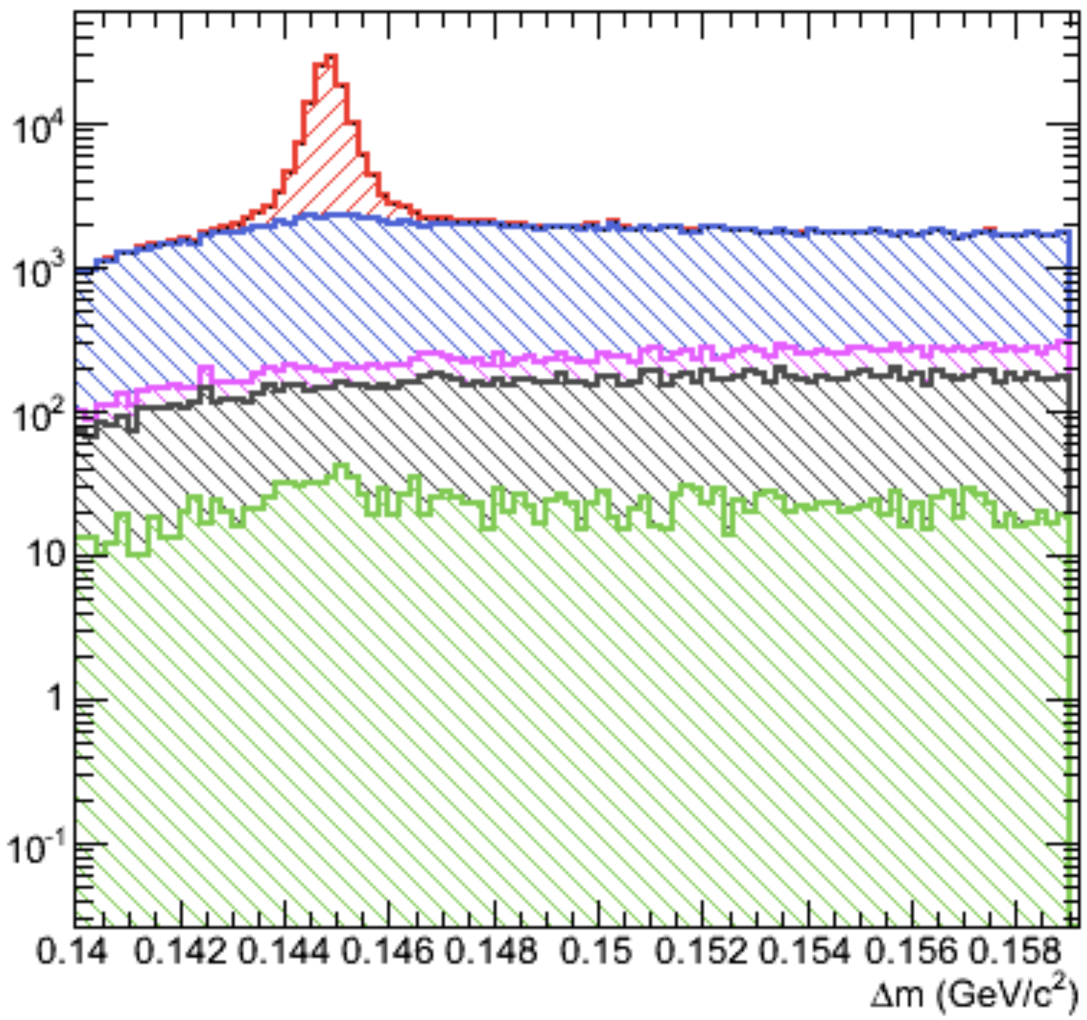
Signal & Background Classification

		definition(*)	*D^0 mass peaking*	*Δm peaking*
D^0 ☆ π_s ☆ D^{*+}	*cat1*	*correct D^0, correct π_s correct D^{*+}*	*yes*	*yes*
D^0 ☆ π_s ☆ D^{*+}	*cat2*	*correct D^0, mis-rec. π_s mis-rec. D^{*+}*	*yes*	*no*
D^0 ☆ π_s ☆ D^{*+}	*cat3*	*mis-rec. D^0, correct π_s mis-rec. D^{*+}*	*no*	*~yes*
D^0 ☆ π_s ☆ D^{*+}	*cat4*	*mis-rec. D^0, mis-rec. π_s mis-rec. D^{*+}*	*no*	*no*
D^0 ☆ π_s ☆ D^{*+}	*cat5*	*correct D^0, correct π_s mis-rec. D^{*+}*	*yes*	*~yes*

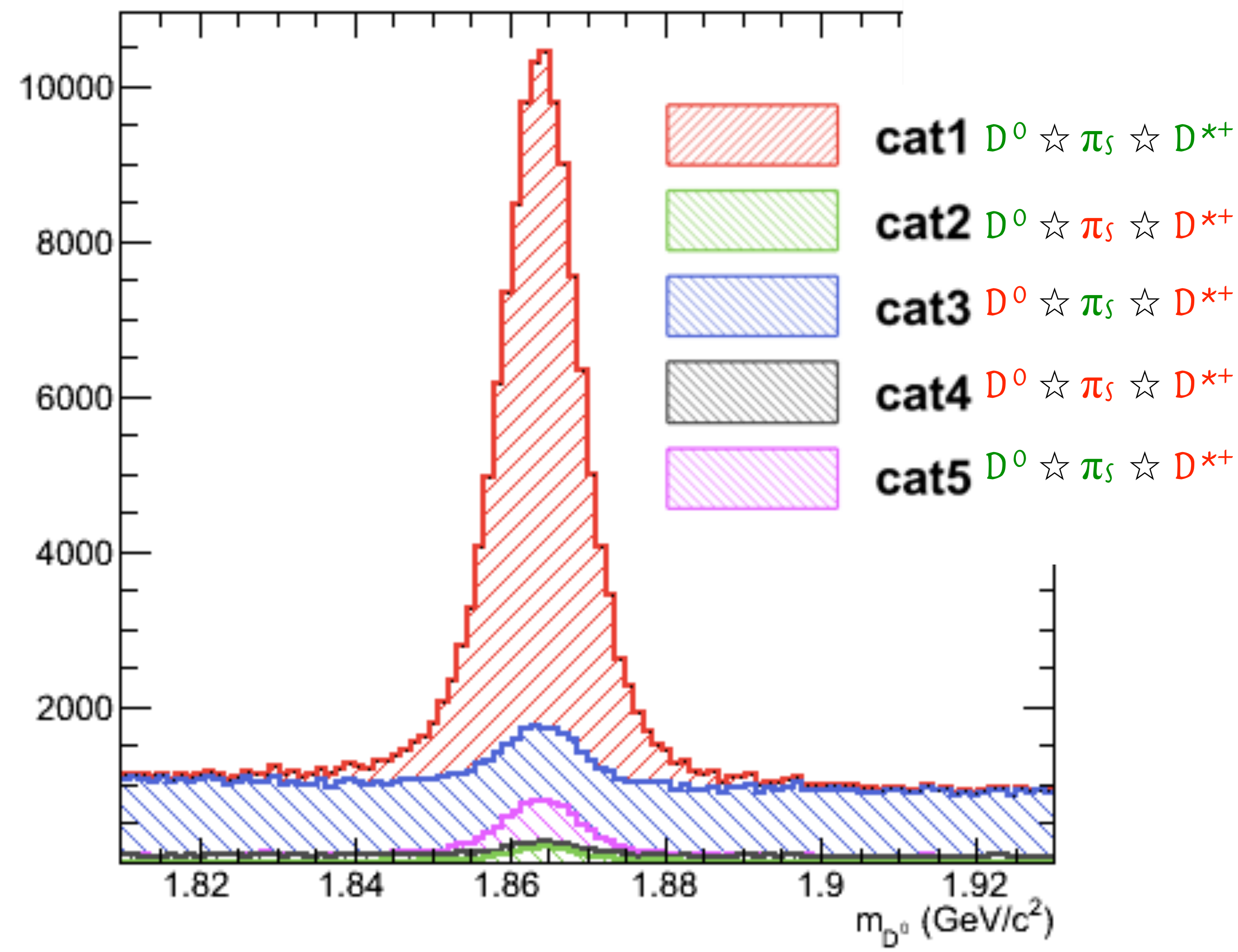
(*) mis-rec. = mis-reconstructed, correct = correctly reconstructed

Selected Events

Δm distribution - all events



m_D distribution - all events



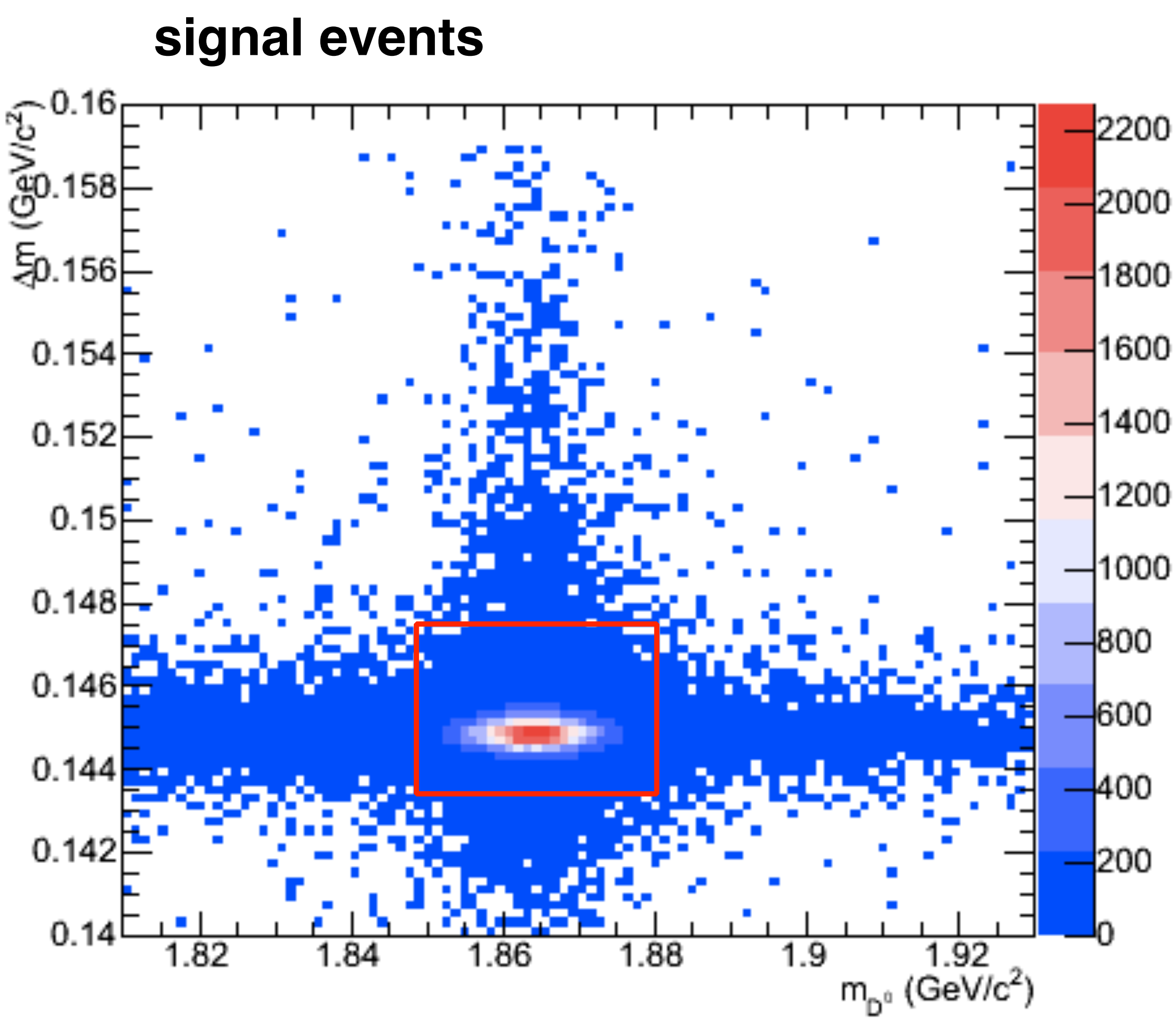
- 106k signal events in the *large* (m_D, Δm) region
- resolution of m_D and Δm are a bit worse than *BABAR*
  - m_D distribution has an RMS 20% larger than *BABAR*, 10.1 VS 8.2 MeV/c^2
  - Δm distribution has an RMS 40% larger than *BABAR*, 830 VS 502 keV/c^2

caveat:
in the *BABAR* analysis an *optimised* selection was applied

Signal Region Definition

➡ We define a signal region in the m(D^0), Δm plane

- 82k signal events



signal region:

15 MeV/c^2 in m_D
2 MeV/c^2 wide in Δm

+

K_S flight distance significance:

FDE/FD > 10

cut available only at flat ntuple level

+

K_S angle between flight length and momentum:
$\cos\theta_K > 0.99$

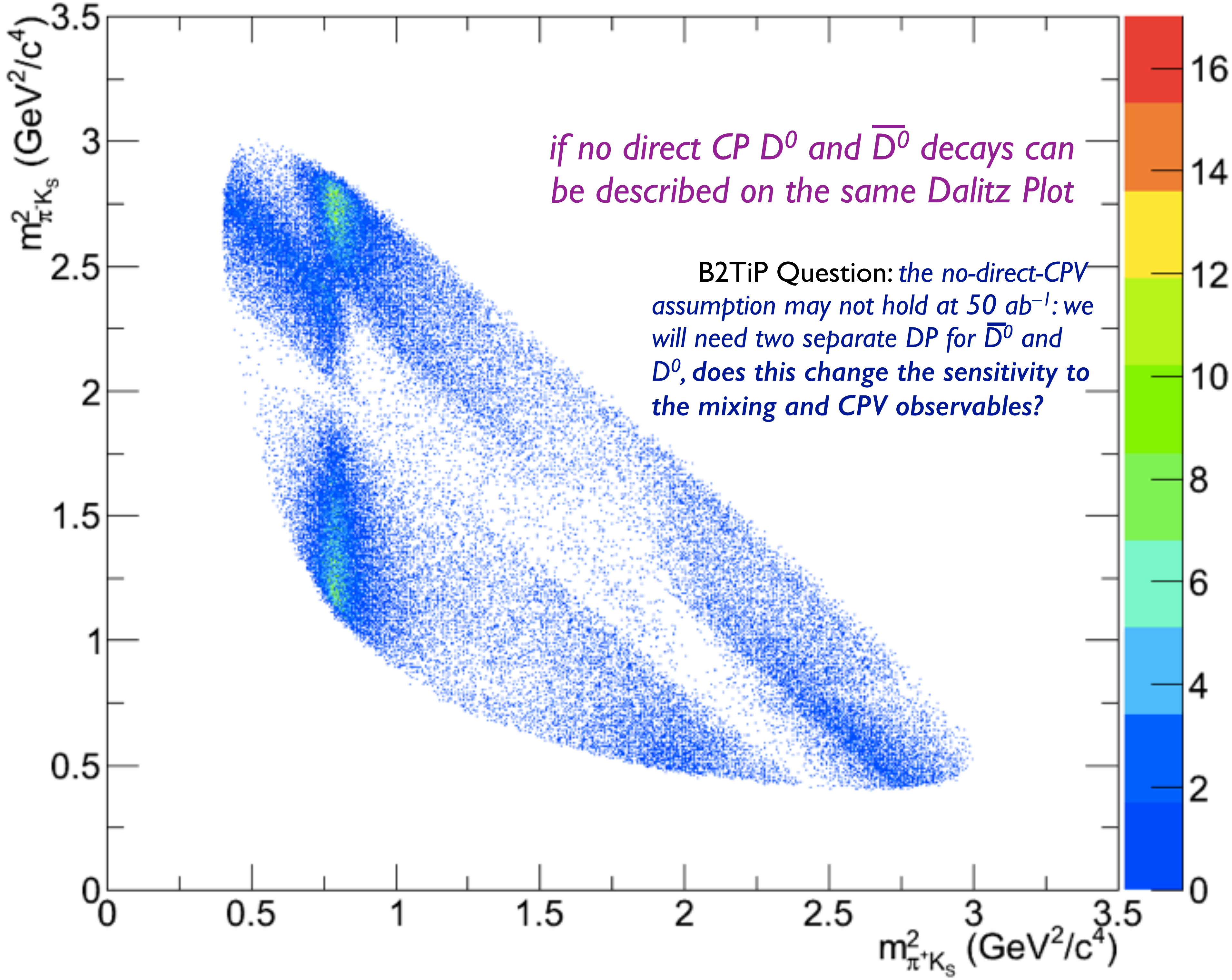
not applied! no time to implement it

now available

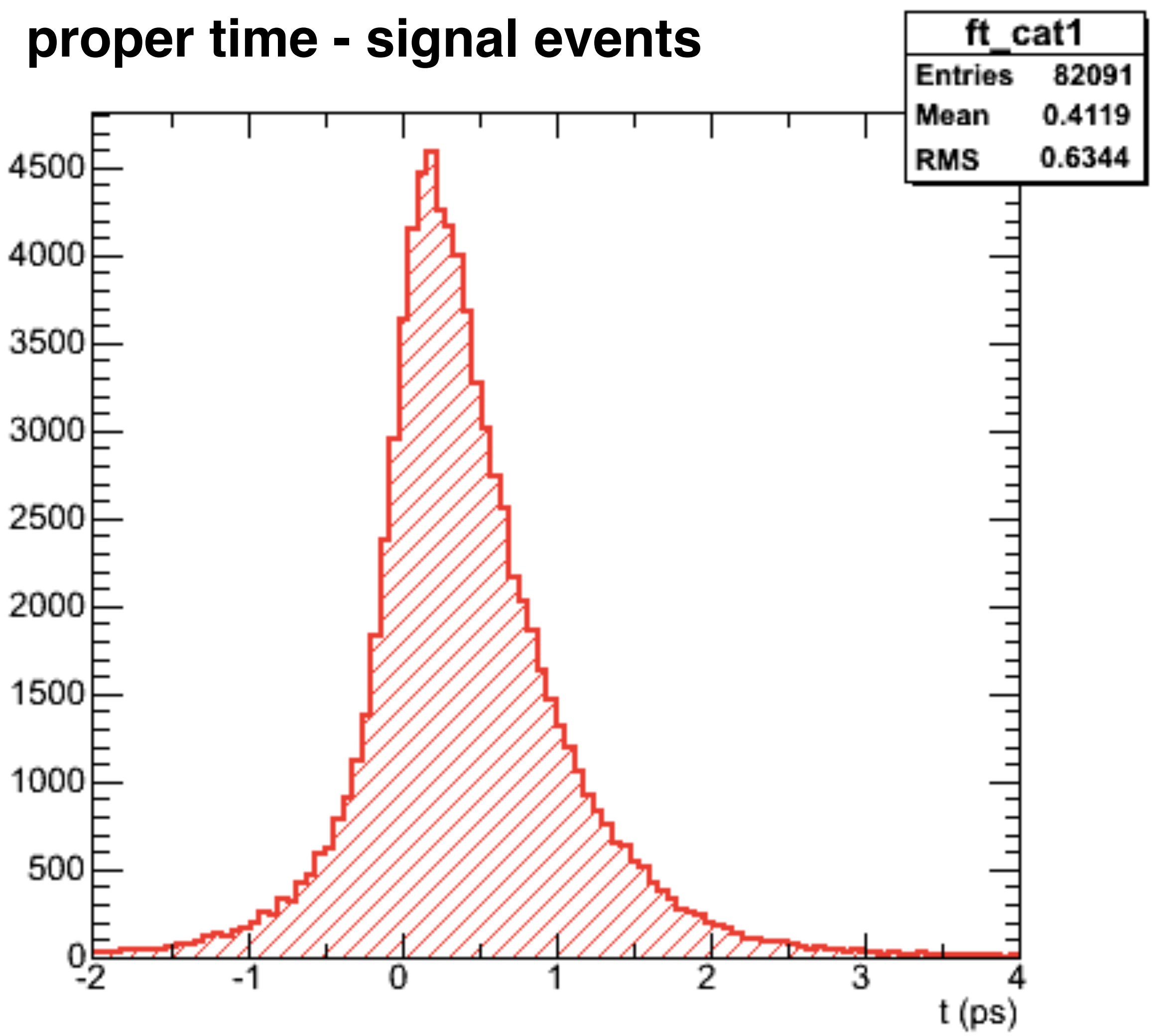
% events in the signal box	cat1	cat2	cat3	cat4	cat5
	92.7%	0.5%	5.5%	0.3%	1%

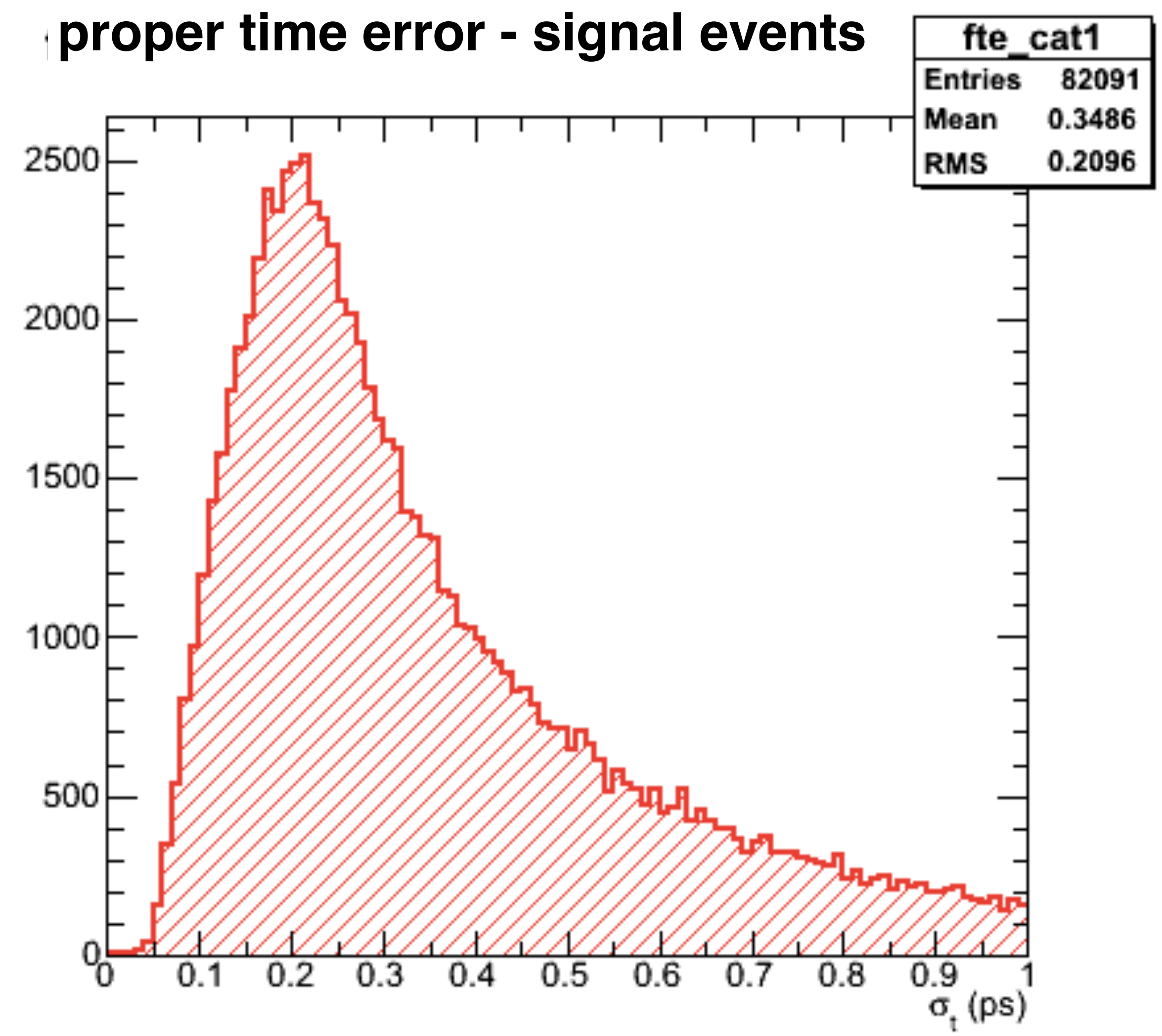
next plots are for signal region events only.

Dalitz Plot Distribution for Signal Events



D^0 Proper Time and its Error





- the observed performance is compatible with a 4-layer SVD-only tracking
  - known low-efficiency for the pixel hits in the VXD pattern recognition → understood
- the expected performance should be a factor 2 better than *BABAR*:
  - *BelleII* innermost layer is a factor 2 nearer the IP than the *BABAR* SVT
  - reduced center-of-mass-boost effect is negligible in charm events

$cc \to D^{*-}\Omega\pi^0 D^{*+}$

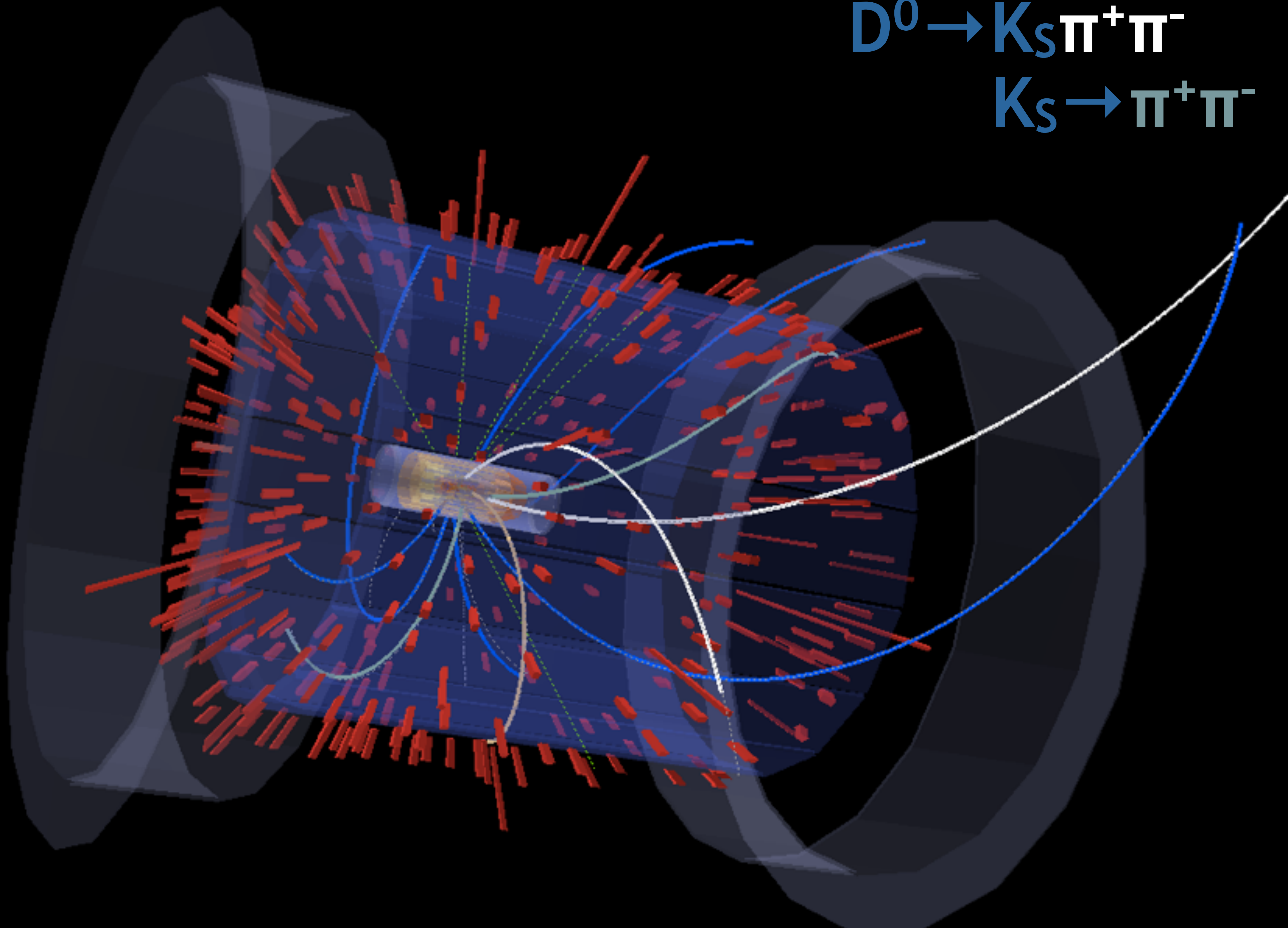
build-2014-10-18

- D^{*-} signal
- $\pi^0 \to \gamma\gamma$
- $\Omega \to \pi^+\pi^-\pi^0$
  - $\pi^0 \to \gamma\gamma$
- $D^{*+} \to D^0\pi^+$
  - $D^0 \to \pi^+K^-\eta$
    - $\eta \to \pi^+\pi^-\gamma$

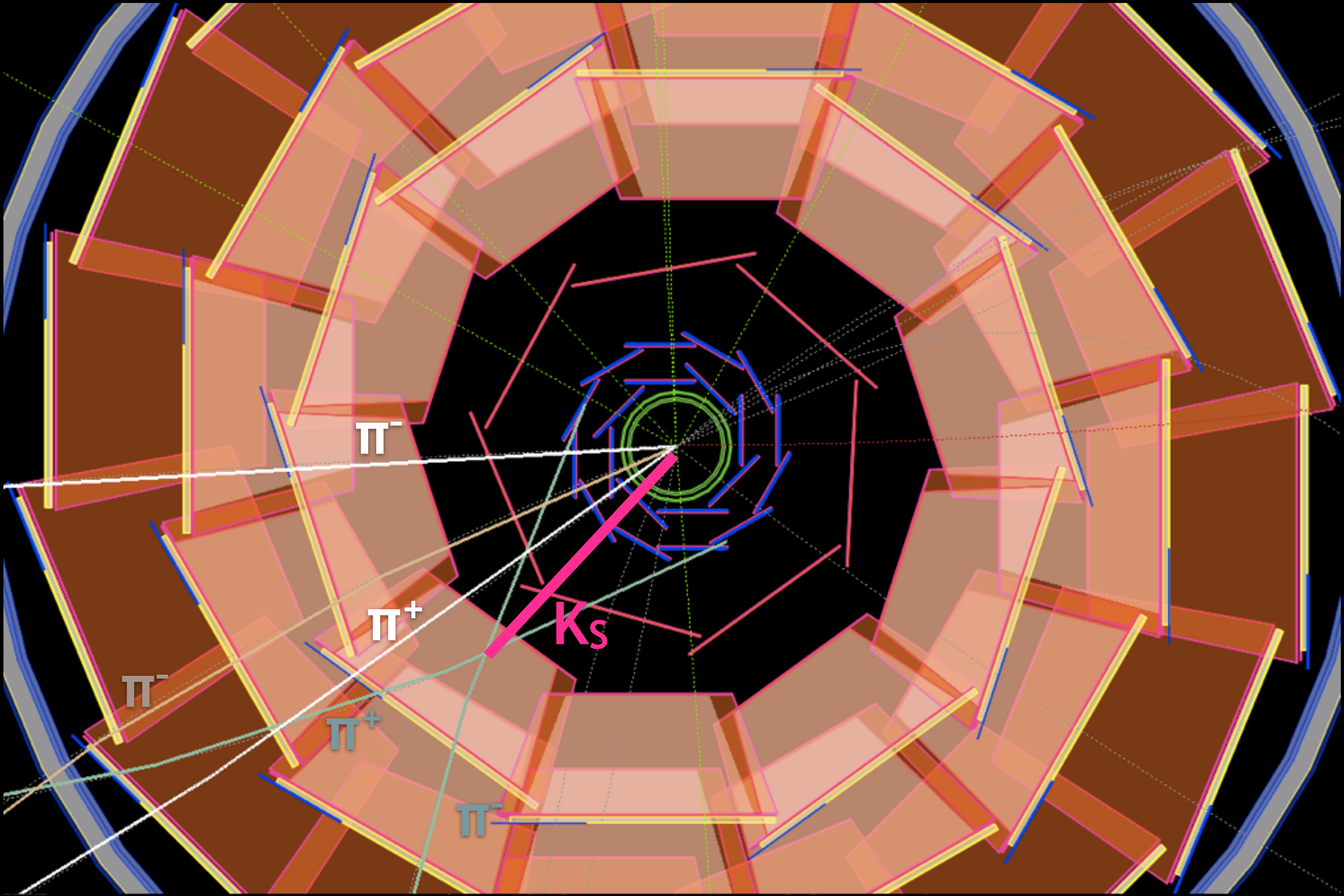
$D^{*-} \to \overline{D}^0\pi^-$

$\overline{D}^0 \to K_S\pi^+\pi^-$

$K_S \to \pi^+\pi^-$



NOTE: the figure does not include ECL timing or energy threshold requirements


π⁻
π⁺
Ks
π⁻
π⁺
π⁻

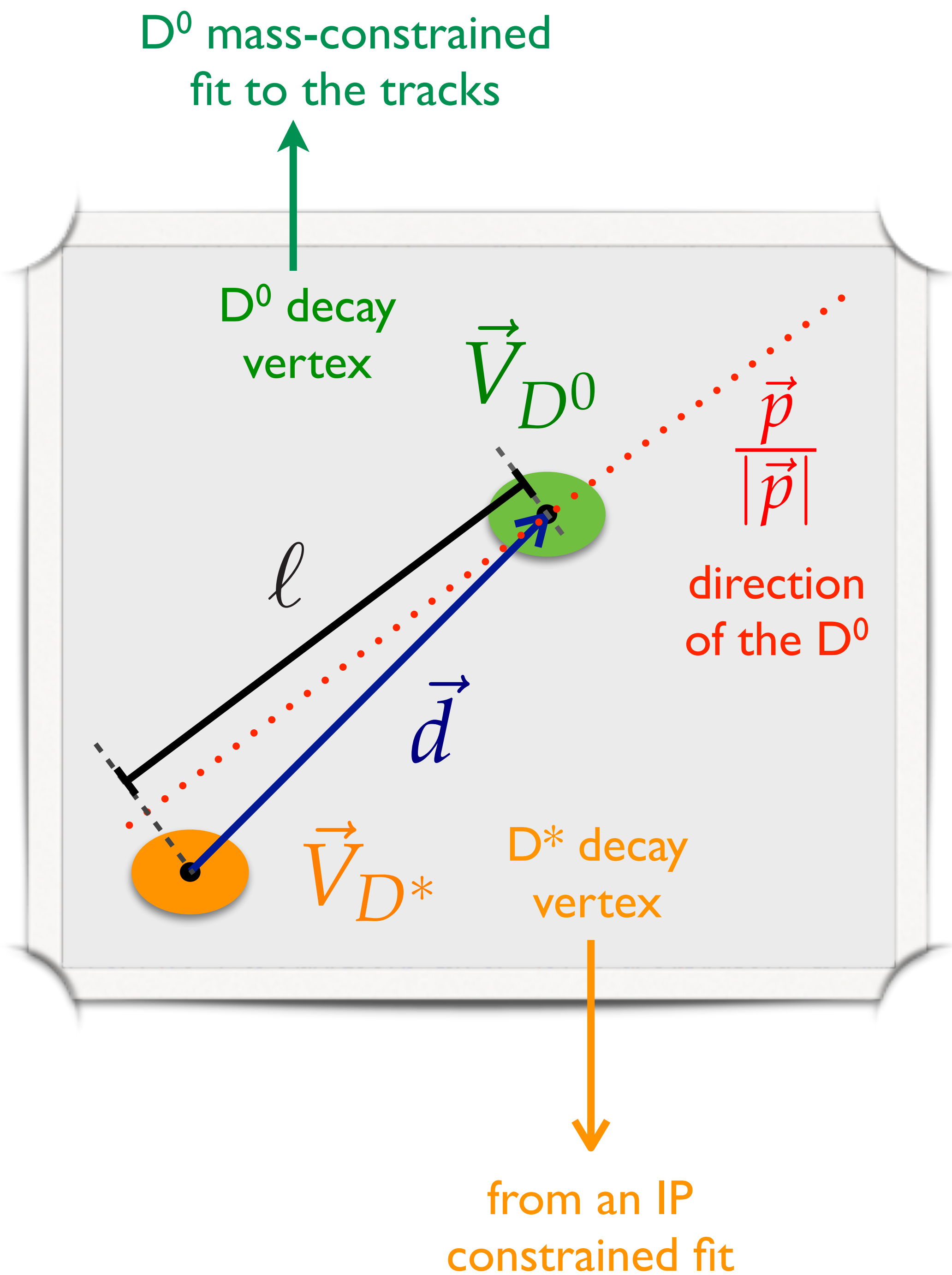
D Proper Time Resolution Study

this study was presented at the 2nd *B2TiP Workshop* in April 2015

Motivations

- Time-dependent analysis are at the core of the charm physics program, in particular for mixing and CPV measurements
  - $D^{*+} \to D^0 \pi^+$, $D^0 \to K_S \pi^+\pi^-$, mixing & CPV on the Dalitz Plot
  - $D^{*+} \to D^0 \pi^+$, $D^0 \to K\pi$, K^+K^-, $\pi^+\pi^-$, mixing & CPV
- An accurate estimation of the D^0 proper time resolution is fundamental for the correct estimation of the precision that *Belle II* can reach on x,y |q/p| and ϕ.
- SuperKEKB and *Belle II* present differences w.r.t *BABAR* and Belle that will affect tracking and vertexing for charm events:
  - *new 6-layer silicon detector:* the innermost layer is 1.4 cm from the IP (vs ~3cm of *BABAR*) → improved resolutions on impact parameters
  - *squeezed beams at the IP*: size of the beam-spot is 2 orders of magnitude smaller w.r.t. *BABAR* → improved constraint for the decay chain vertex fitting
  - *reduced center-of-mass boost of the machine*: it does not affect charm physics as it does for B physics since charm quarks are lighter and therefore more boosted

The D^0 Proper Time Measurement



In order to measure the D^0 proper time we need the positions of the production and decay vertices of the D^0 and a measurement of the D^0 momentum.

➡ The D^0 flight distance time ℓ is:

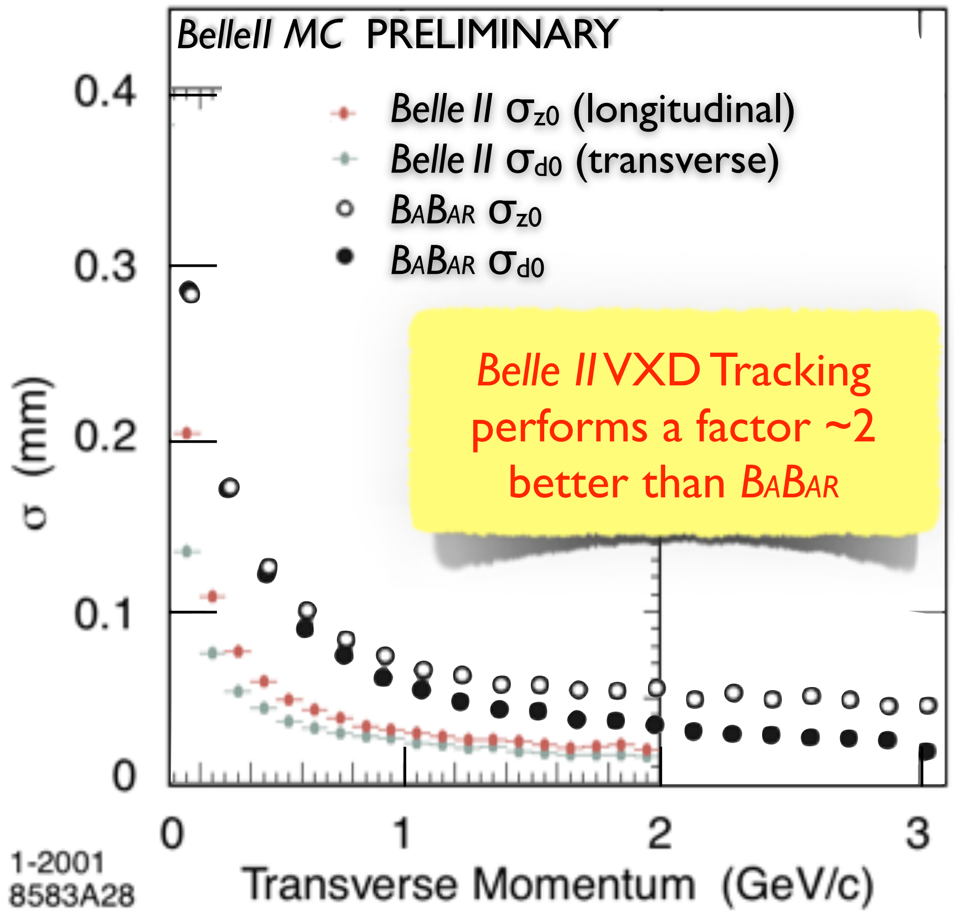
$$\ell = \frac{\vec{d}\cdot\vec{p}}{|\vec{p}|} \qquad \vec{d} = \vec{V}_{D^0} - \vec{V}_{D^*}$$

the direction of the D^0 is much better determined with the measurement of the momentum

➡ The D^0 proper time t is:

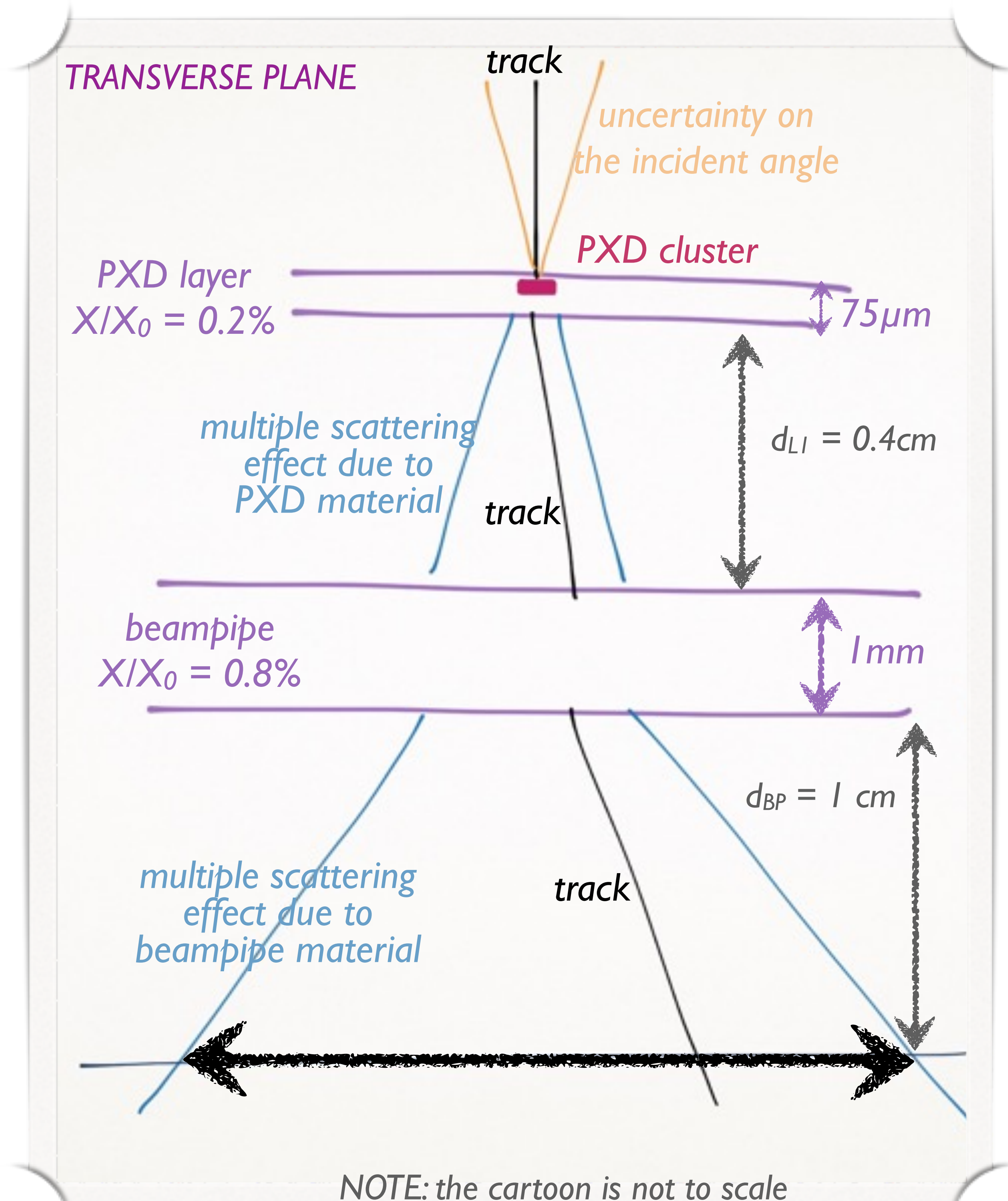
$$t = \frac{\ell}{\beta\gamma c} = \frac{\ell}{c}\frac{m_D}{|\vec{p}|}$$

BelleII Tracking in Silicon



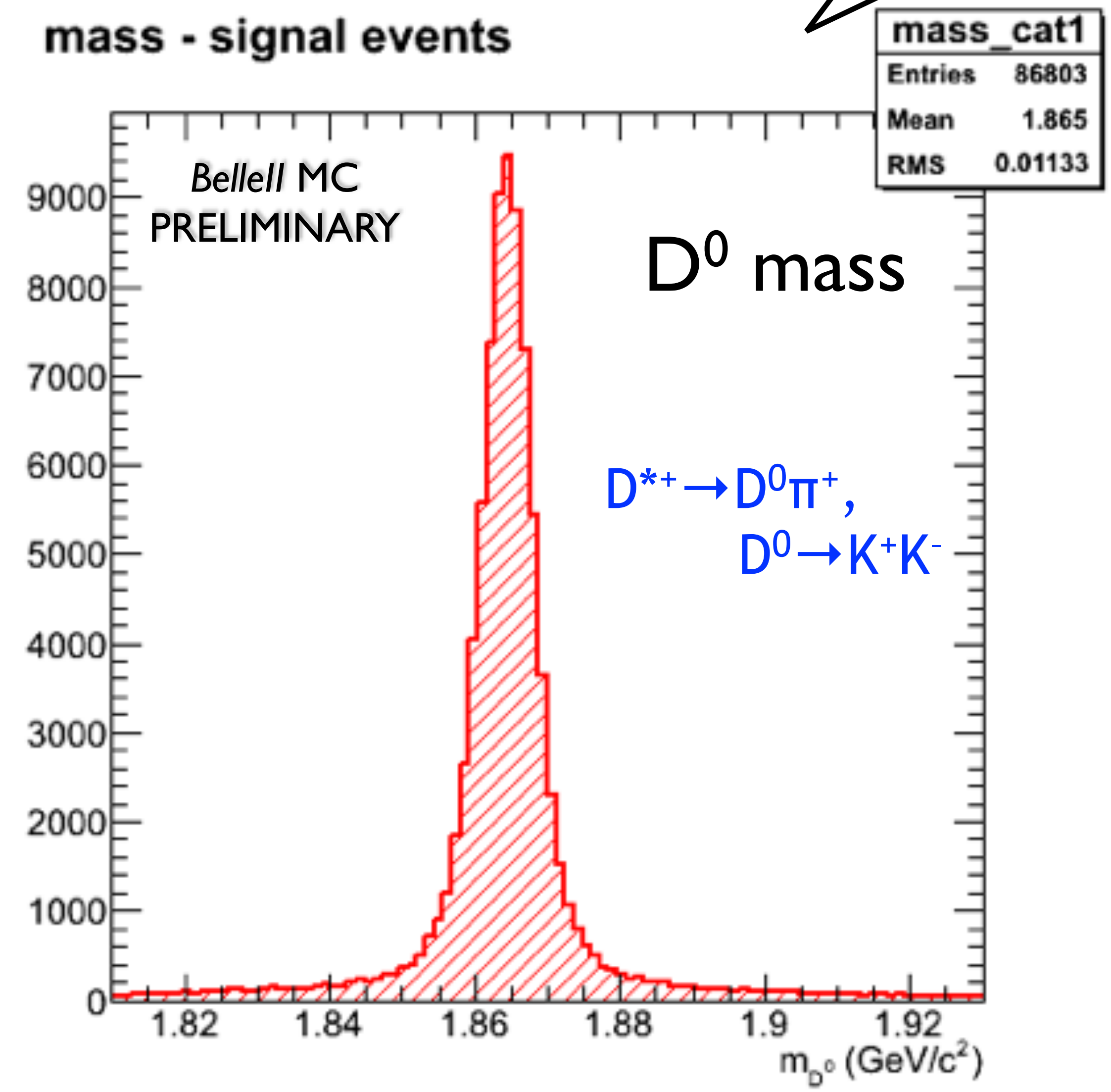
naively, the uncertainty on the longitudinal impact parameter (z_0) is due to:

- hit position
  $\sigma_{hit} \simeq$ pixel pitch/$\sqrt{12}$ = 75μm/$\sqrt{12}$ ≃ 20μm
- multiple scattering from material
  $\sigma_{MS} \simeq d\,\theta_{MS} \propto d_{L1}\sqrt{X/X_0}$
  σ_{MS} (layer1) = 32μm (for a 1GeV pion)



$D^0 \rightarrow K^+K^-$ Reconstruction

dataset:
300k signal events
build-2015-03-01



➡ $K^\pm$, D^0 daughters candidates

- std loose list
- p_t > 0.1 GeV/c
- # hits in L1 || L2 > 0

well-measured tracks

➡ D^0 candidates

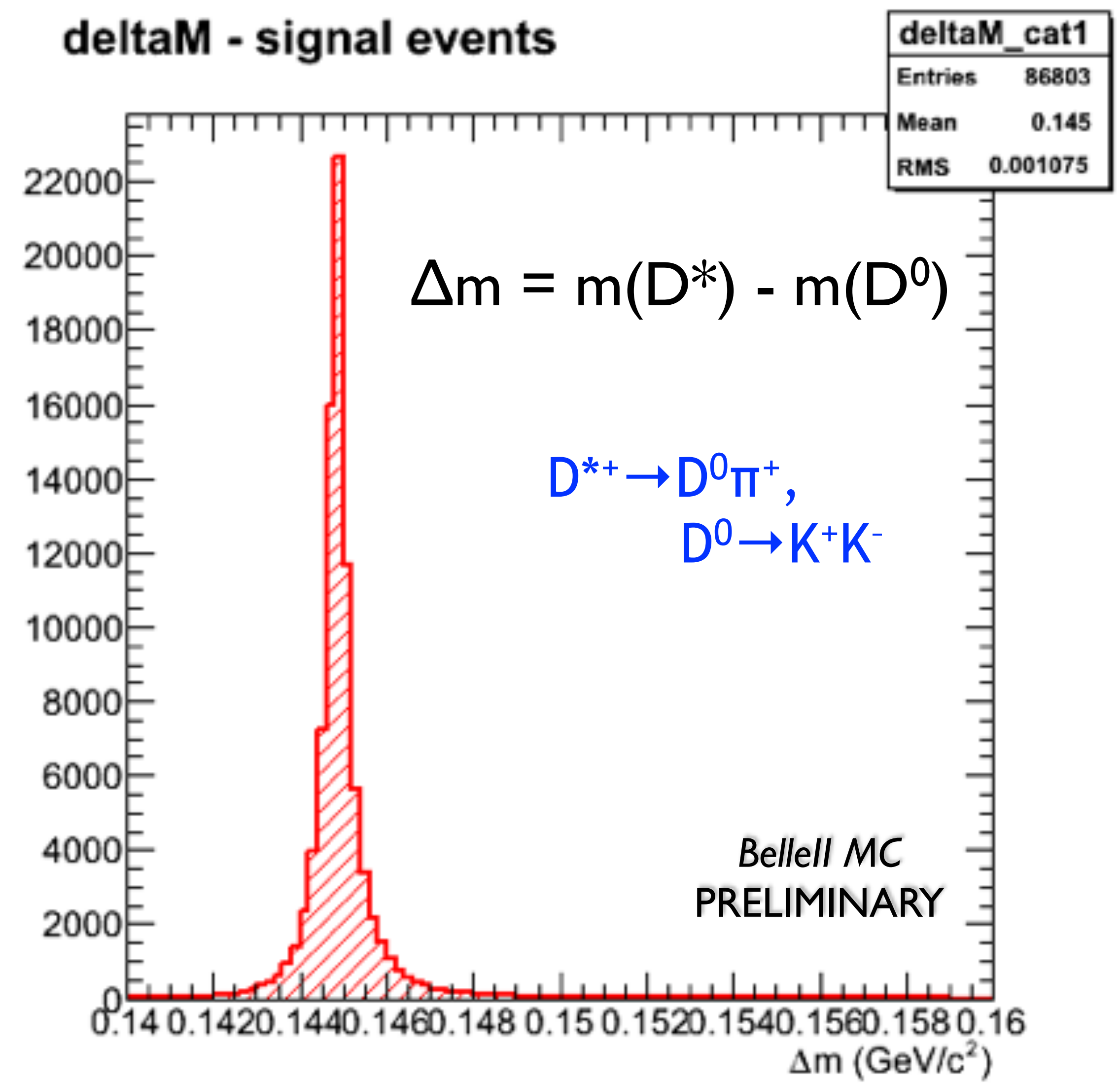
- pre-fit cuts: p* > 2 GeV/c & 100 MeV/c^2 wide mass window
- vertex fit, with *mass constraint* (RAVE), $P(\chi^2) > 10^{-4}$
- post-fit cuts: 40 MeV/c^2 wide mass window & p* > 2.4 GeV/c

to reject D from B decays

$D^{*+} \rightarrow D^0\pi^+$ Reconstruction

➡ soft π^+ candidates

- $p_t > 0.1$ GeV/c *well-measured track*
- $p^* < 500$ MeV/c *kinematic limit*

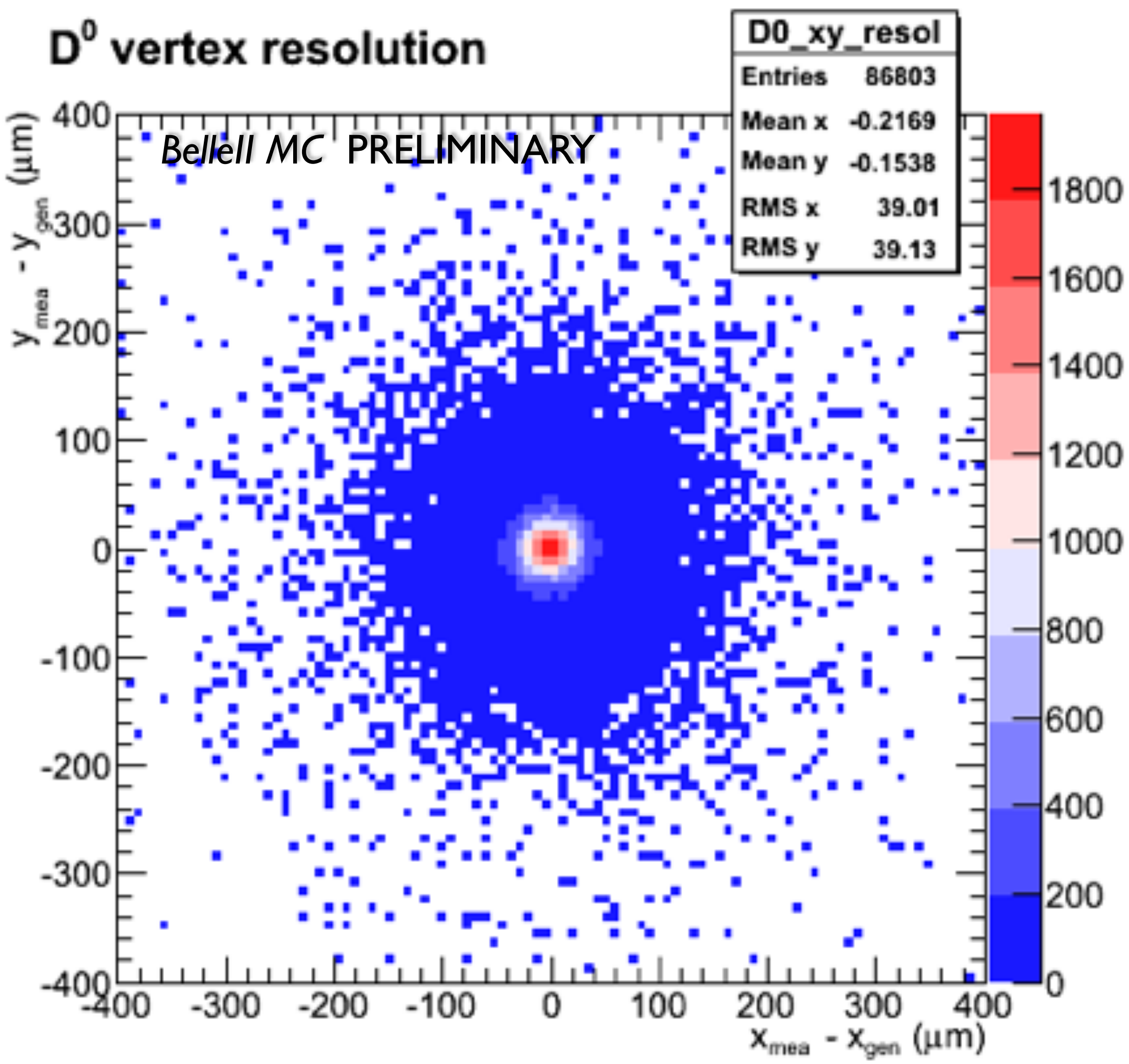


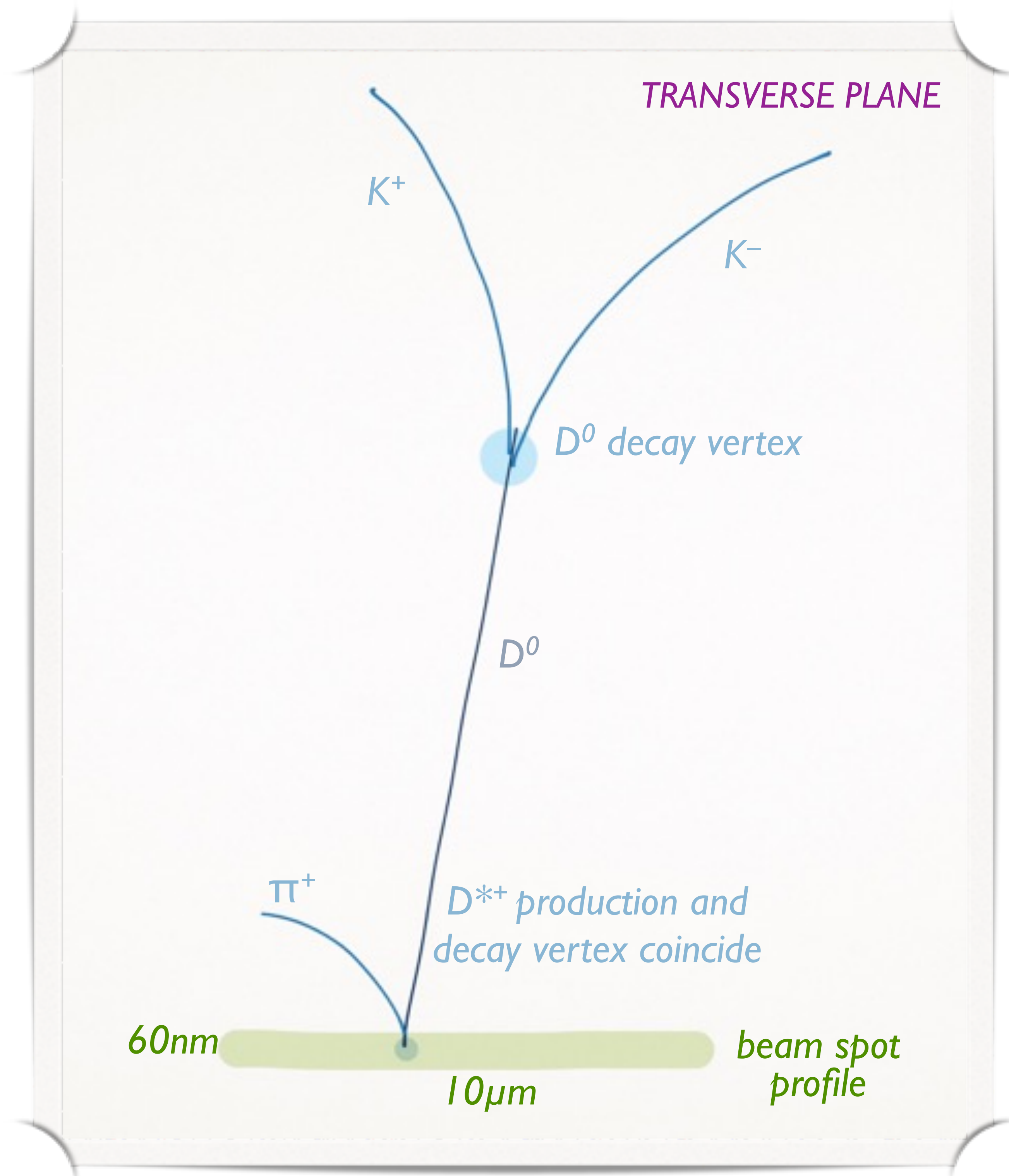
➡ D* candidates

- pre-fit cuts: $0 < Q$ (MeV) < 30
- vertex fit with the D* constrained to originate in the beam spot, $P(\chi^2) > 10^{-4}$
- post-fit cuts: $0 < Q$ (MeV) < 20

D^0 Decay Vertex Reconstruction

- Consider the decay chain:
  - $D^{*+} \to D^0\pi^+$, $D^0 \to K^+K^-$
- D^0 *mass–constrained* vertex fit yields:
  - a resolution of ~40μm in the transverse directions and also in the longitudinal one

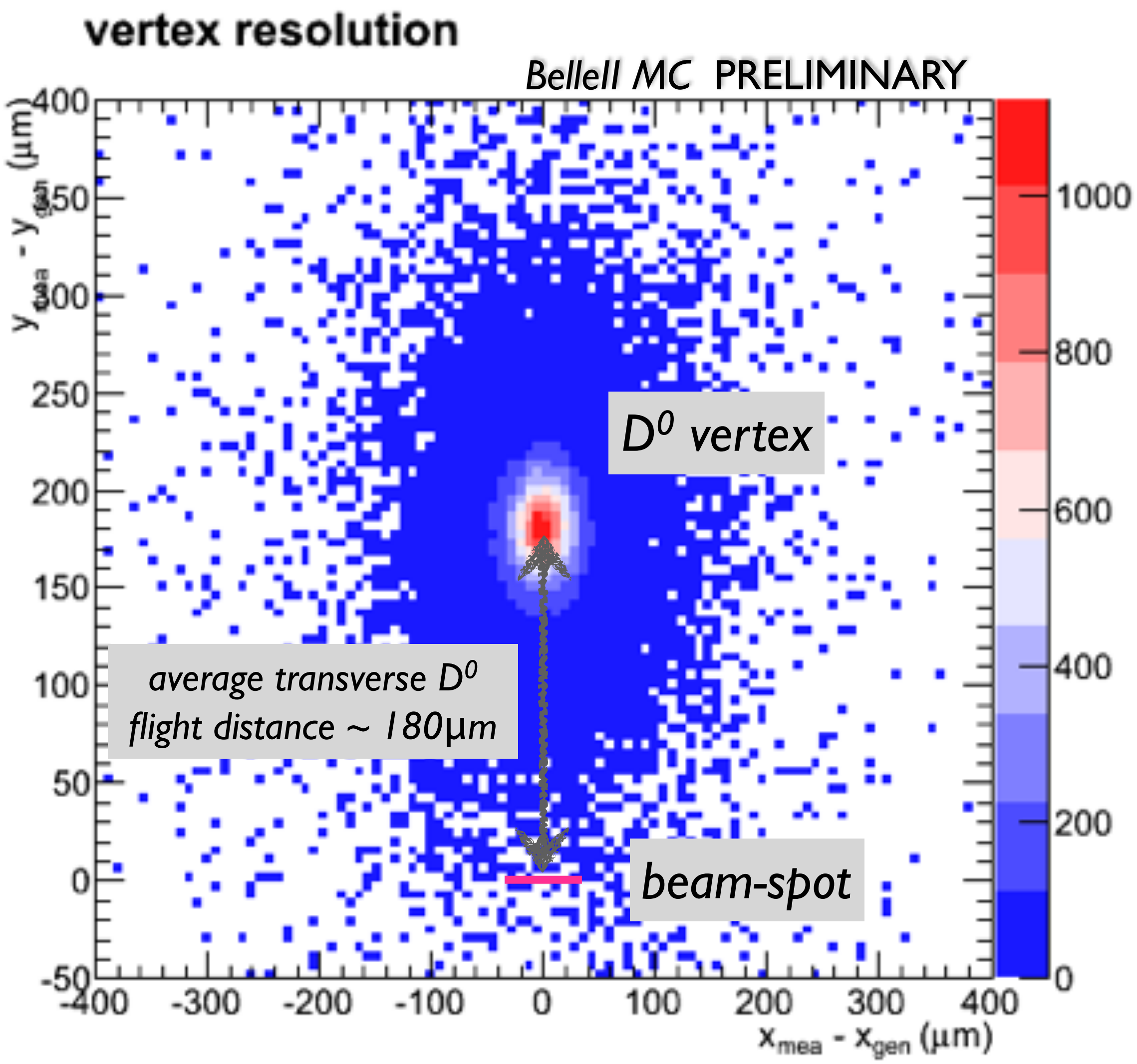


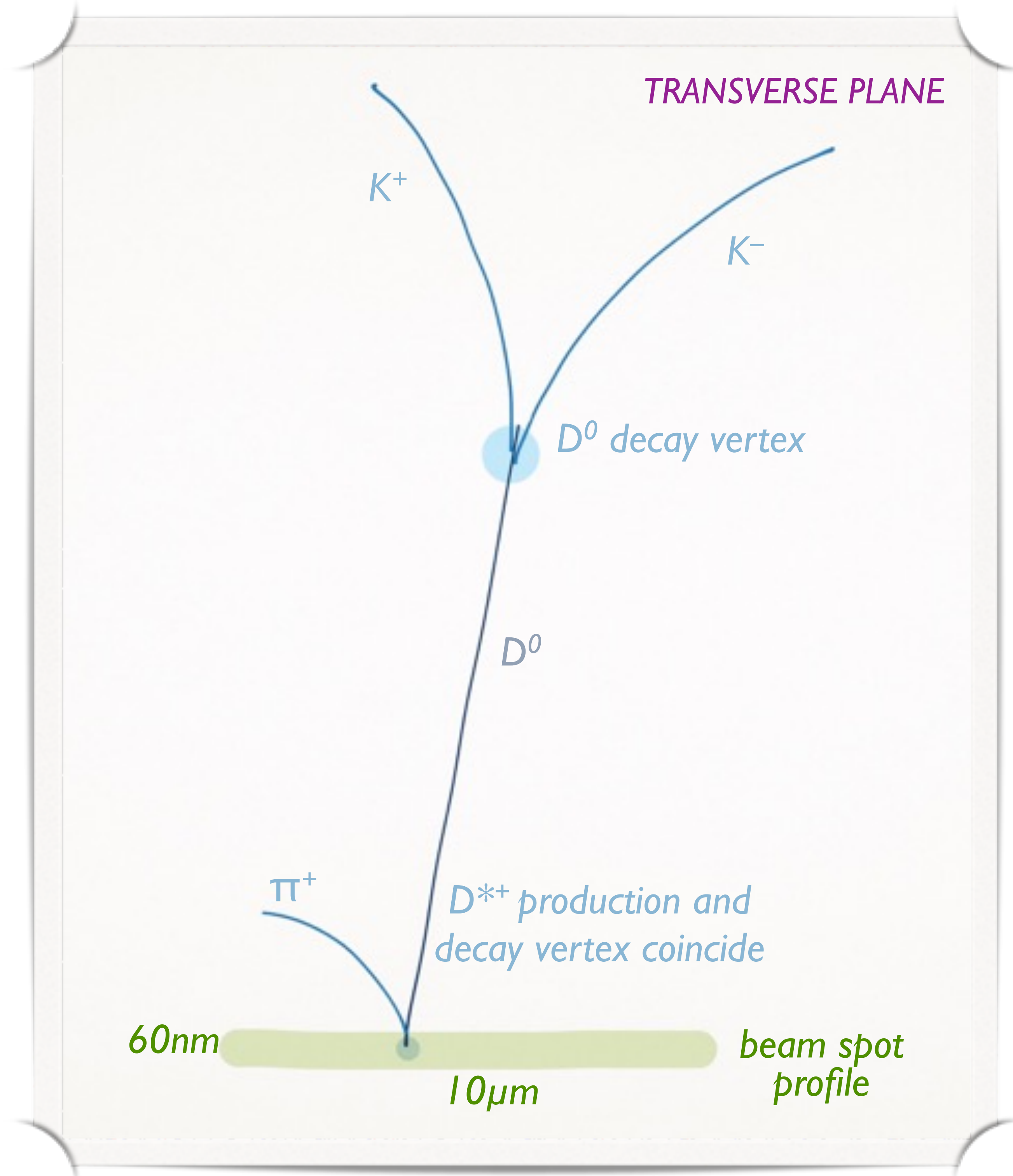


NOTE: the cartoon is not to scale

D^0 Production Vertex Reconstruction

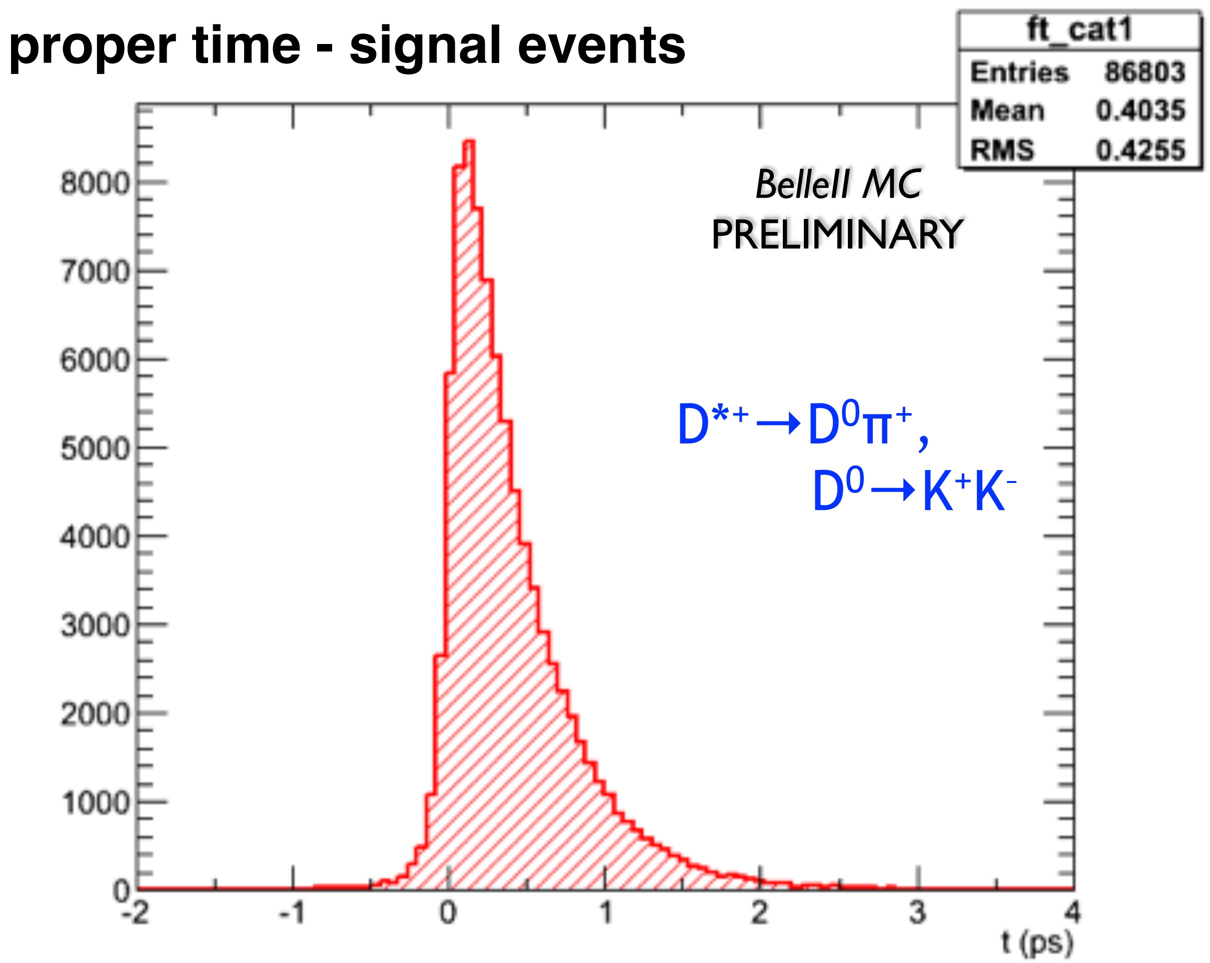
- ➡ $D^{*+} \to D^0\pi^+$ is a strong decay, D^0 production vertex is inside the beam-spot → beam-spot constrained fit (or IP constrained fit)
  - beam-spot transverse dimensions:
    - *Belle II:* 60nm x 20μm
    - *BaBar*: 6μm x 110 μm

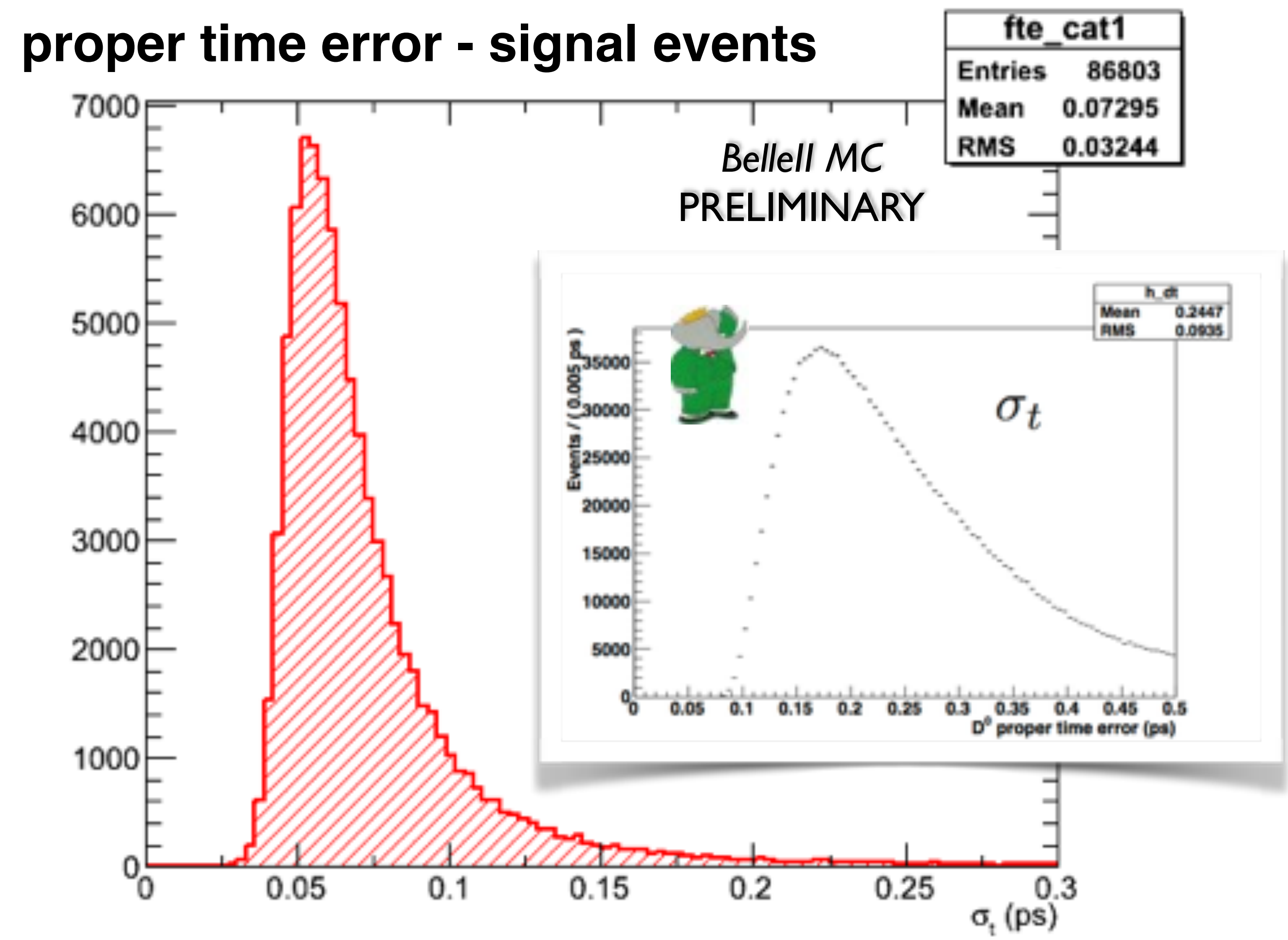




NOTE: the cartoon is not to scale

Proper Time t & Proper Time Error σ_t

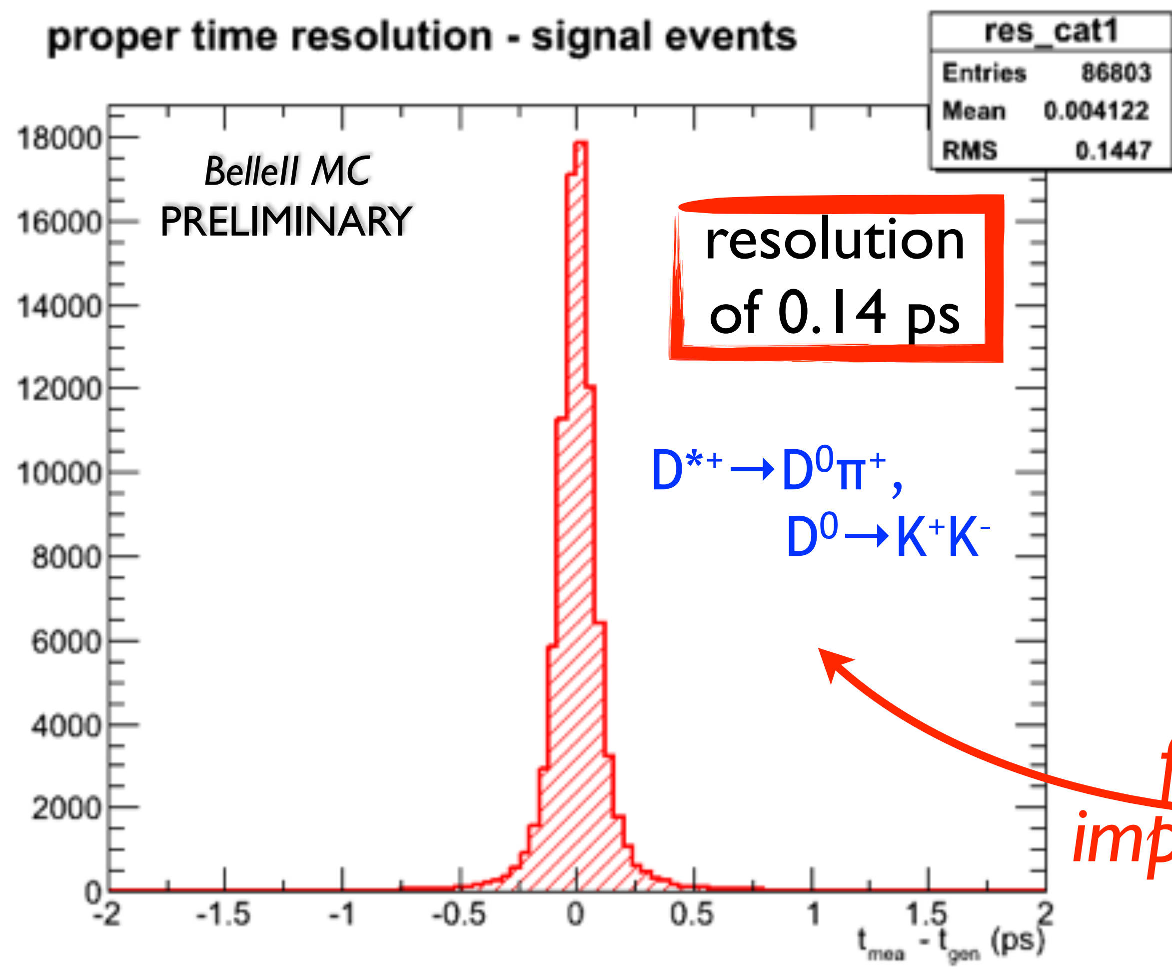


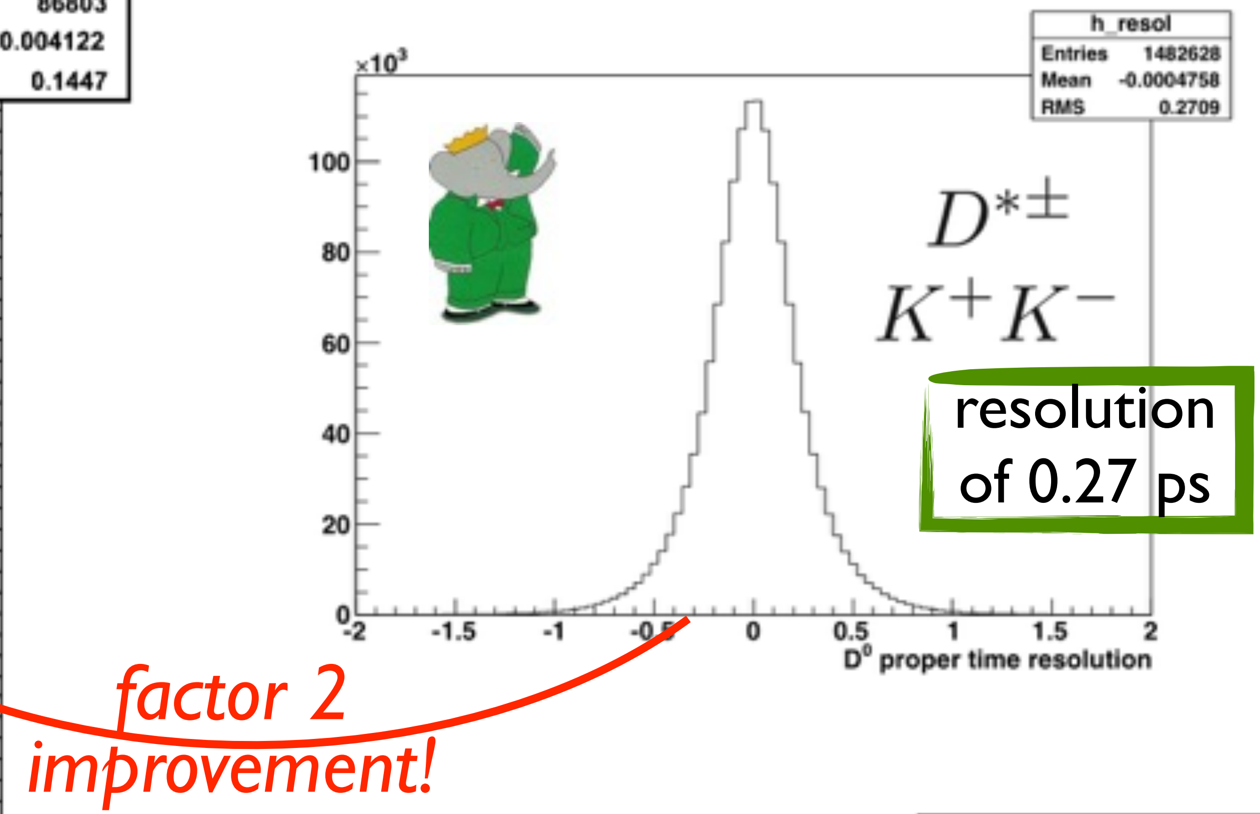


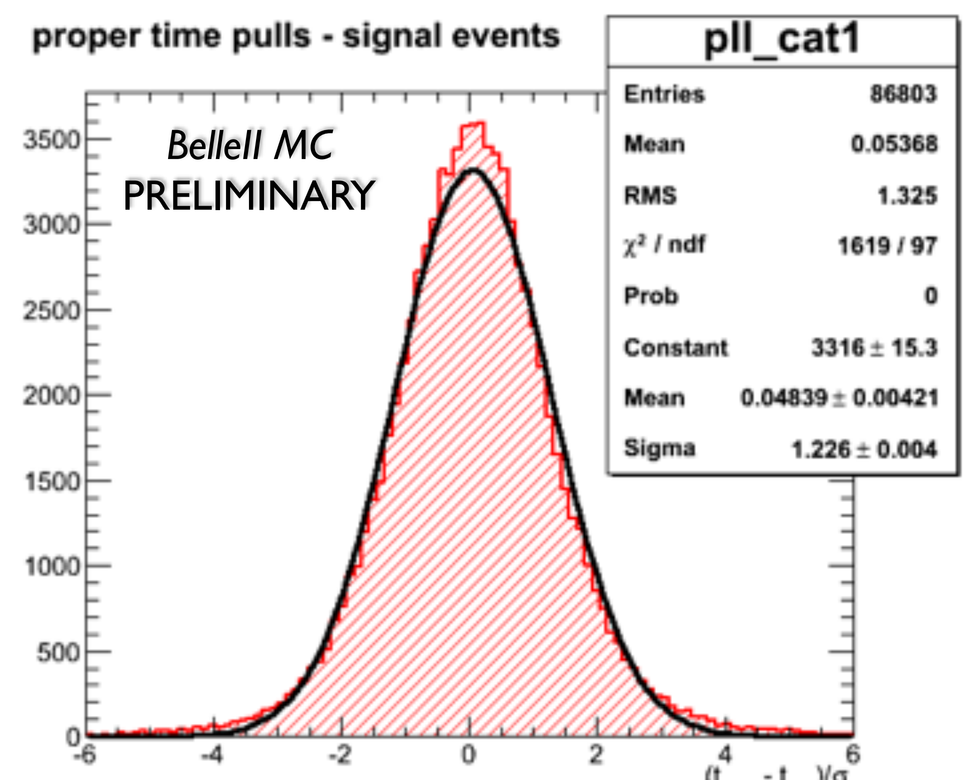
- improvement in the computation of σ_t w.r.t. *BABAR* (plot in the box)
  - average σ_t = 0.07 ps VS 0.25 ps for *BABAR*
  - RMS σ_t = 0.03 ps VS 0.09 ps for *BABAR*
- factor 3 improvement in the D^0 proper time significance, t/σ_t
  - average of 6.2 (with RMS of 6.6) VS average of ~2 in *BABAR*

NOTE: no signal region definition, take also events from tails of m_D and Δm

Proper Time Resolution

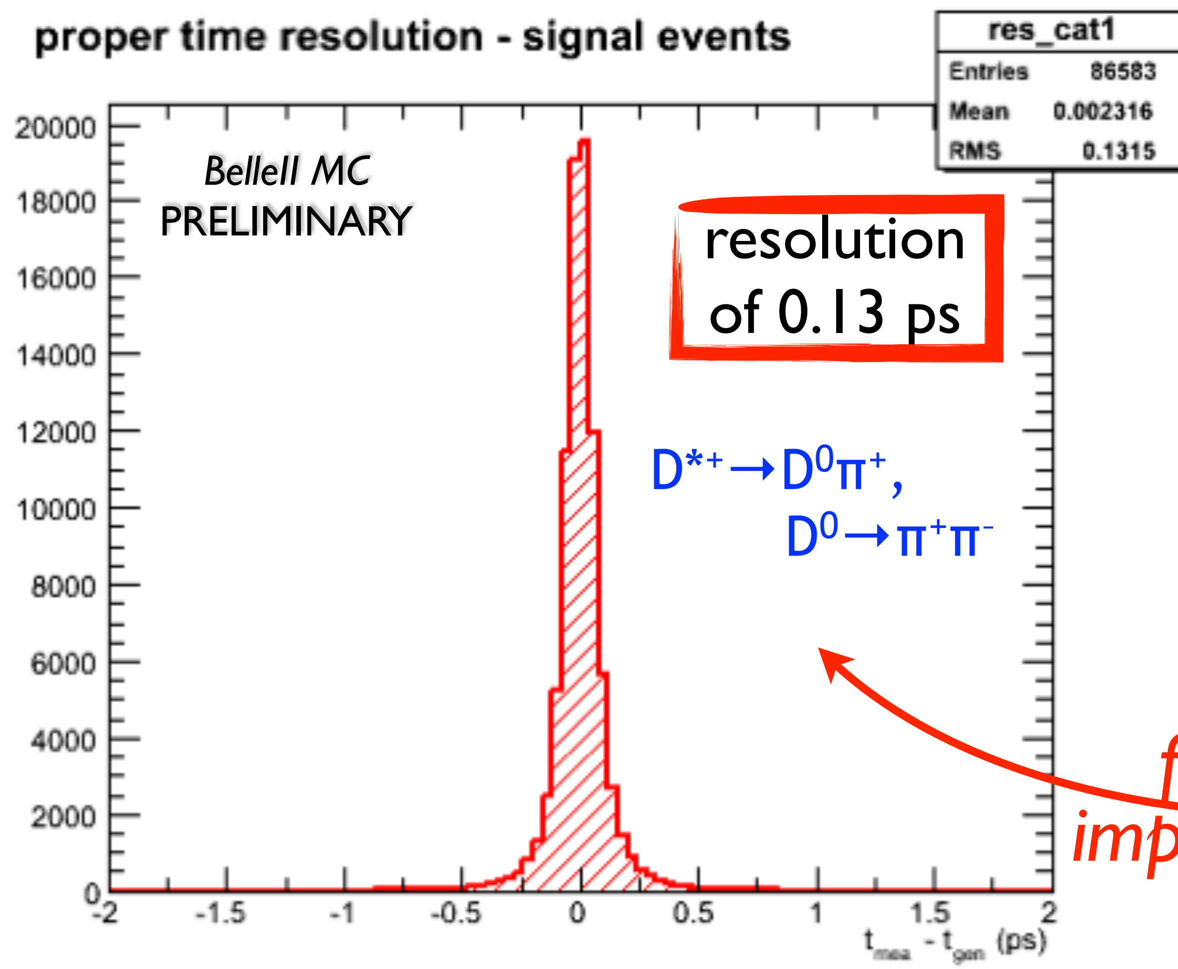


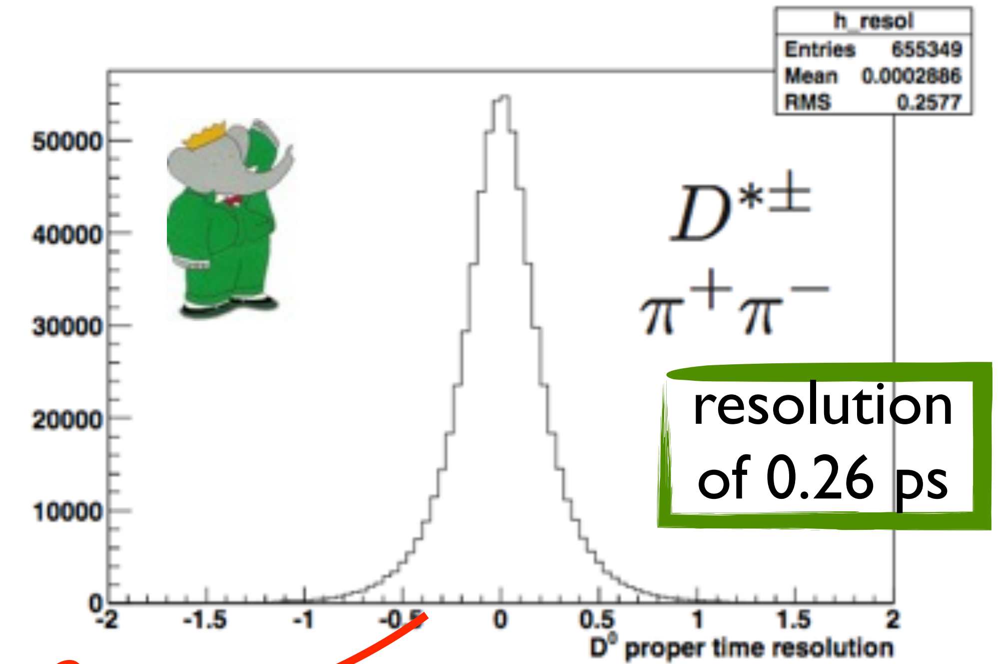




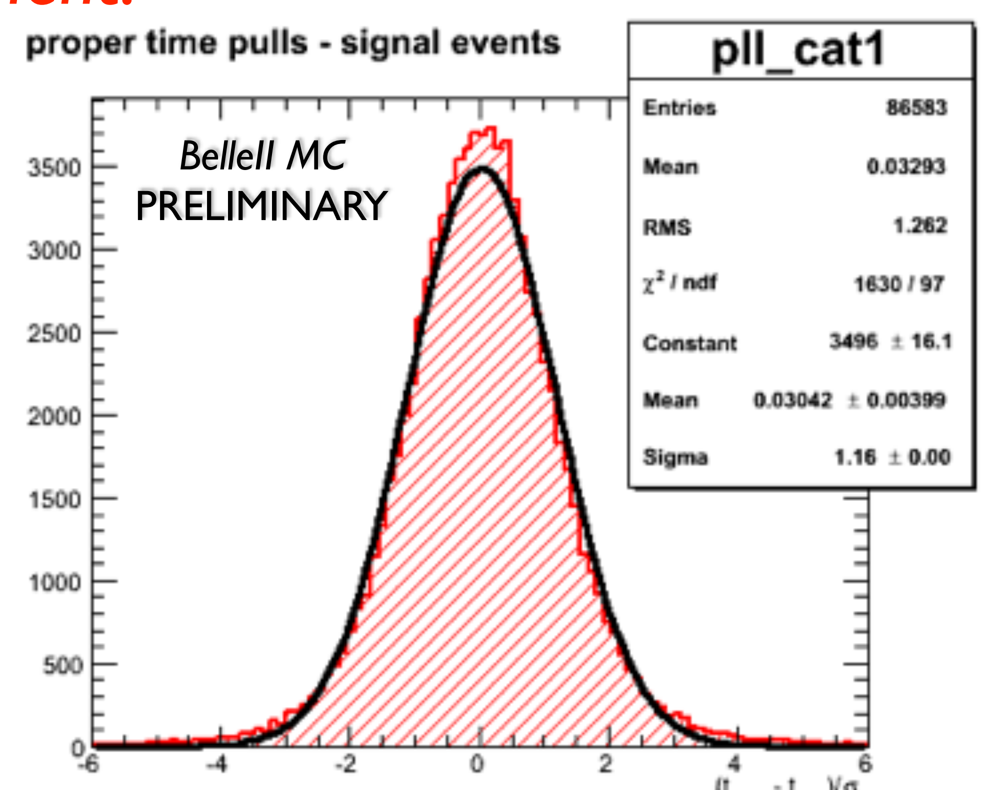
- **D^0 proper time resolution = 0.14 ps**
- factor 2 improvement w.r.t *BaBar* and Belle
- pulls distribution is OK:
  - error correctly estimated within 23%
  - bias of 5% of the error

Proper Time Resolution ($D^0 \to \pi\pi$)





factor 2 improvement!



- **D^0 proper time resolution = 0.13 ps**
- factor 2 improvement w.r.t *BABAR* and Belle
- pulls distribution is OK:
  - error correctly estimated within 13%
  - bias of 3% of the error

Impact on the Mixing Parameters Measurement

- A correct estimation of the errors on the mixing parameters should take into account the improved resolution in the proper time measurement
- ToyMC study, using the **Wrong Sign Kπ** mixing analysis (statistical-dominated measurement)
  - 3.5k signal events & S/B = 2.2, background lifetime = $\tau(D^0)$ (from 400 fb^{-1} Belle paper)
  - *proper time resolution = 0.14 ps (from BelleII simulations)*

error on	Belle measured	Belle scaled (Staric, KEKFF)	*Belle II simulation* (*Schwartz, ToyMC*) PRELIMINARY		
	1 ab^{-1}	50 ab^{-1}	5 ab^{-1}	20 ab^{-1}	50 ab^{-1}
x'^2 (10^{-5})	22	3	7.5	3.7	2.3
y'(%)	0.34	0.04	0.111	0.056	0.035
|q/p|	0.6	0.06	-	-	-
ϕ	25°	2.3°	-	-	-

$$\sigma_{BelleII} = \sqrt{(\sigma^2_{stat} + \sigma^2_{sys})\frac{\mathcal{L}_{Belle}}{50\ \mathrm{ab}^{-1}} + \sigma^2_{\mathrm{ired}}}$$

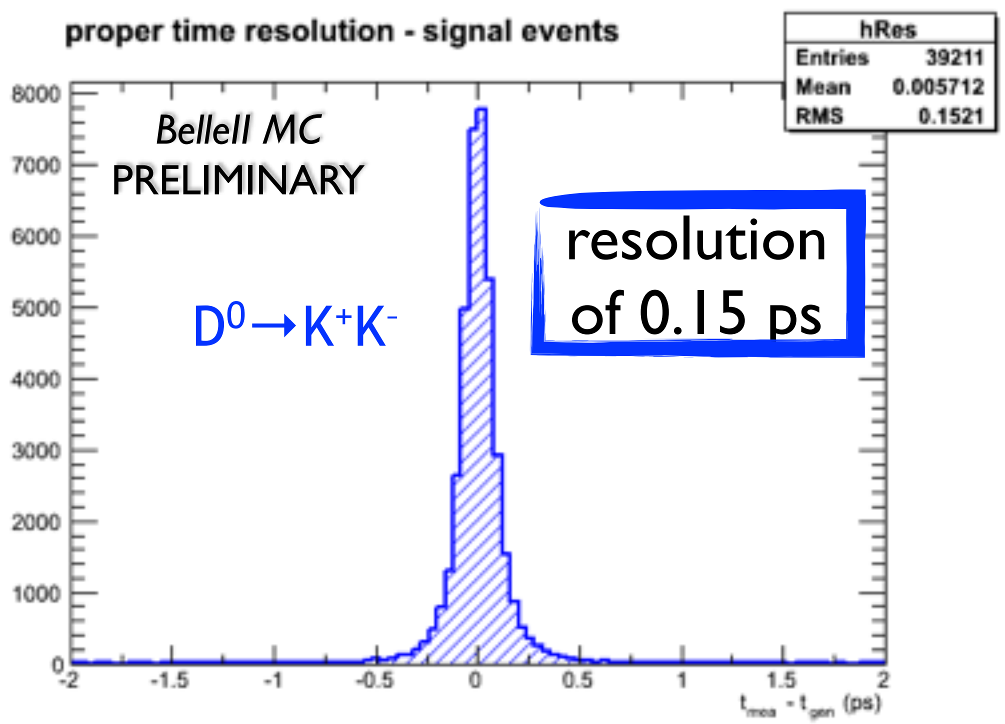
10-20% improvement

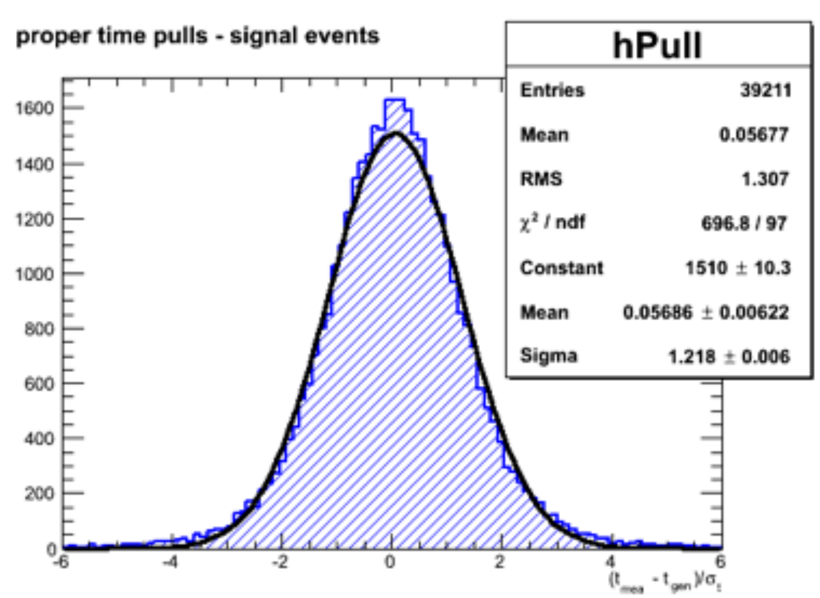
ToyMC with improved t resolution (stat. only)

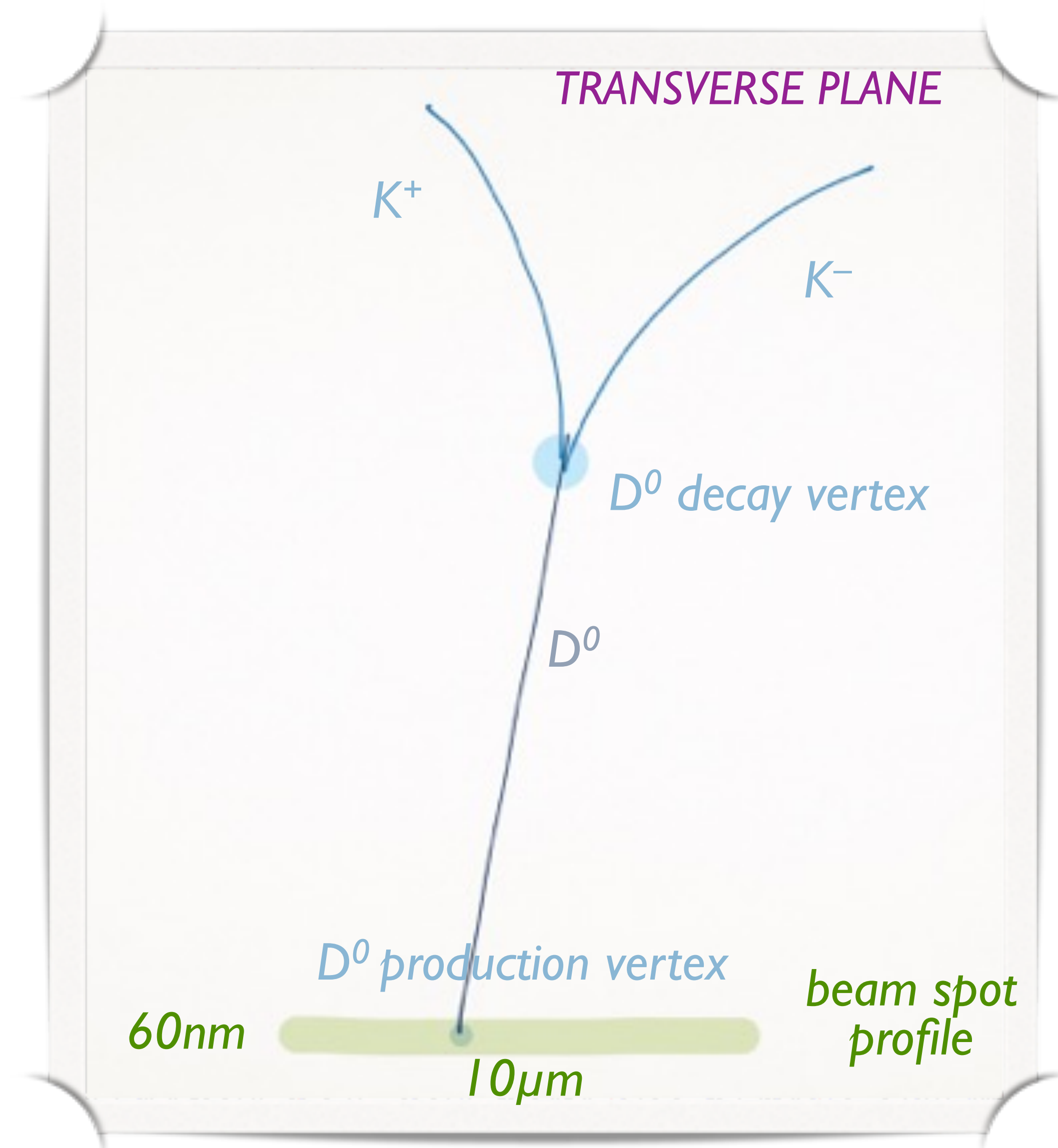
favourably compare to LHCb results @ $3fb^{-1}$
$\sigma(x'^2) = 5.5\ 10^{-5}$, $\sigma(y') = 0.5\%$

t Resolution for $e^+e^- \to D\,X$ Events

- We can measure the proper time of D^0 coming directly from the hadronization of the charm quark with comparable precision.
- We can't tag their flavour at production in the standard way ($D^* \to D^0\pi$)







NOTE: the cartoon is not to scale

Some Ideas for Possible CHARM Studies

- Follow up on the $D^{*+} \to D^0 \pi$; $D^0 \to K_S \pi\pi$ analysis
  - improved tracking + improved K_S selection
  - missing: update of the momentum of the daughter after the fit
- Direct CPV in channels with neutrals in the final state
- study CP asymmetries in bins of proper time
- What can we do with a sample of untagged D^0, $D^+_{(s)}$ with a precise measurement of their proper time?
- Leptonic & Semileptonic Decays
  - CPV is not the only window on NP
- How well can we select a flavour-tagged sample of D^0 from B decays?
  - need the TreeFitter, can't be done now
- $D \to VV$, VS 4-body Dalitz Plot (e.g. $\rho\rho$, K K*)
  - missing:update of the momentum of the daughter after the fit

Conclusions

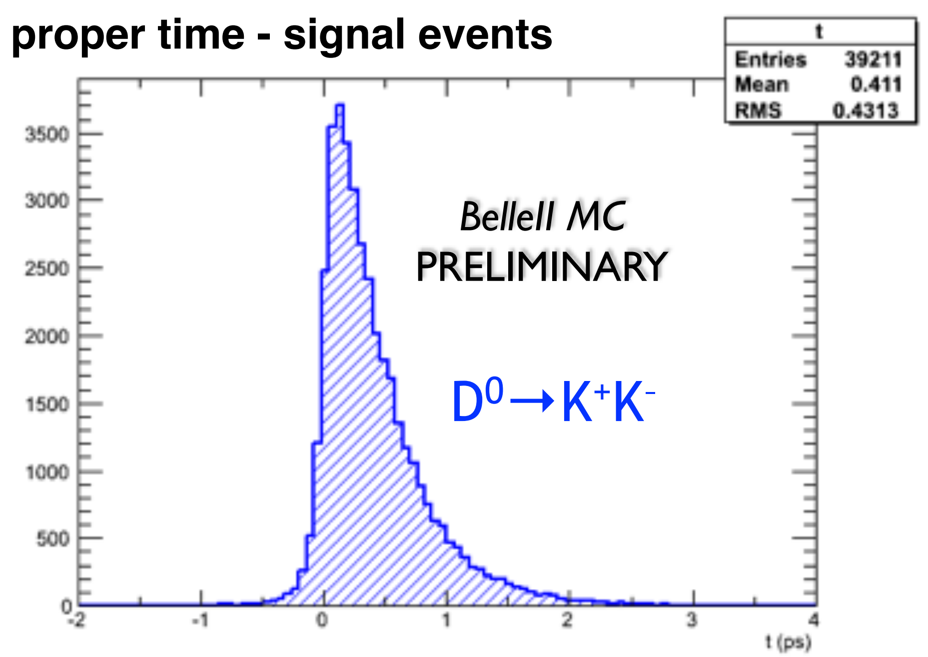
- ➡ I have shown the recent activity in the charm WG
  - basic analysis tools needed to perform time-dependent analysis are in place and are working
  - there are some missing tools, important not only for charm analysis
  - first update of golden observables with a *Belle II* simulation study was presented
- ➡ Many opportunities and things to explore in charm at *Belle II:*
  - unprecedented precision of the determination of the D production vertex may open the possibility of a new class of measurements at *Belle II*
  - there are new ideas, things not done at Belle/*BABAR* interesting for or feasibility studies
  - a lot of room for new ideas on analysis already done at B-Factory to reduce the systematic error and increase the precision at 50 ab^{-1}
- ➡ the Charm WG lacks of **people**, currently only 3 people (1 active) are involved
  - it is impossible to write down a reliable program with milestones if no manpower is available
  - the activities turn on before B2GM / B2TiP and turn off right after (prone to errors, things that could have been done if-only-I-had-thought-about-this-before…)
  - it is impossible to cover the wide charm program (mixing, CPV, rare decays, leptonic and semileptonic decays, 4-body DP)

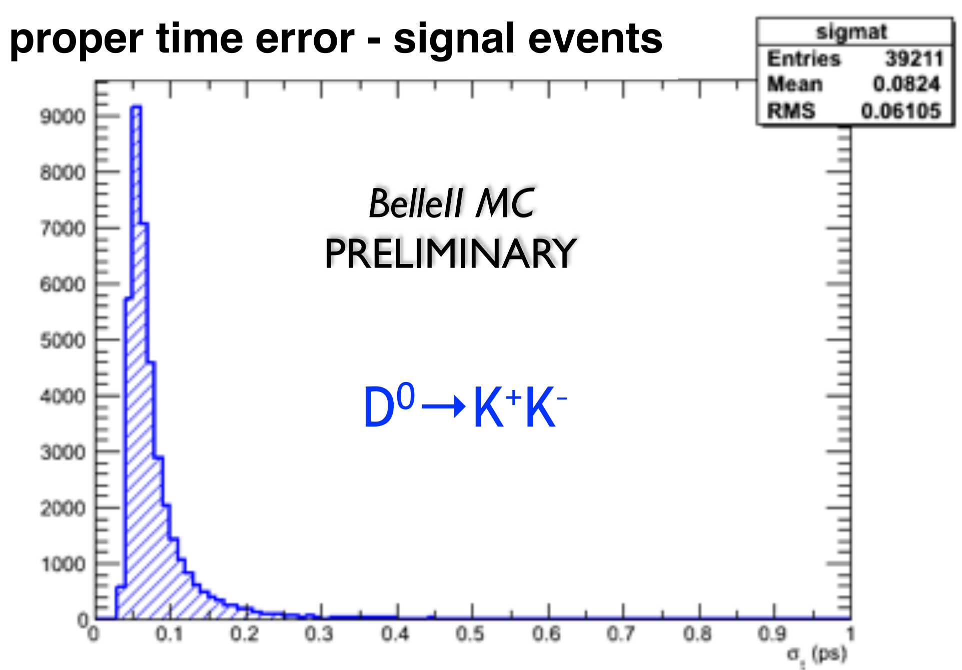
Thank You!

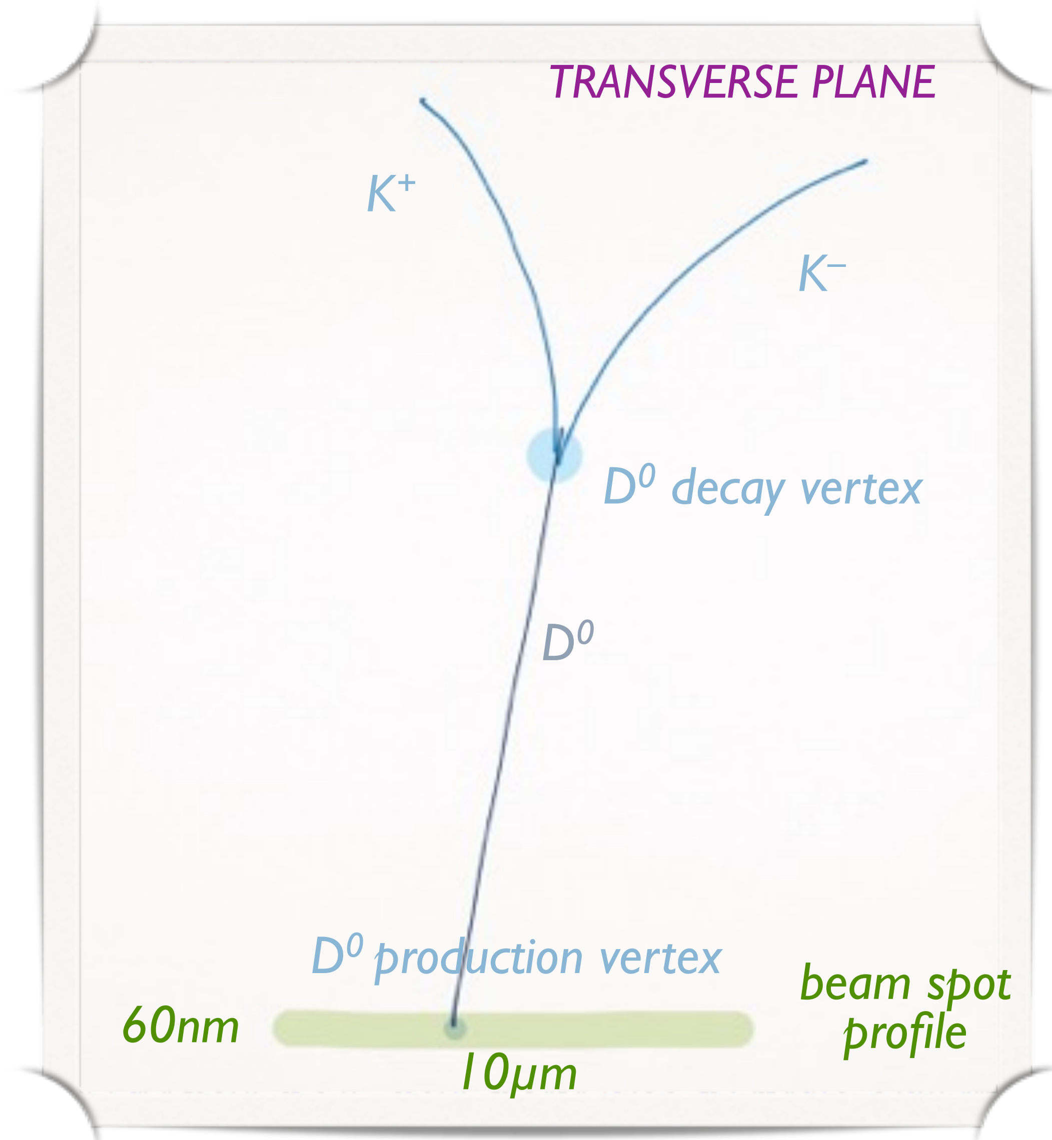
backup slides

What about untagged D^0?

➡ With such a good performance of tracking and vertexing, can we fit the D^0 that come directly from the hadronization of a charm quark?







NOTE: the cartoon is not to scale

Untagged Asymmetries

Petrov@BEACH2014

Other observables: untagged asymmetries?

A.A.P., PRD69, 111901(R), 2004

★ Look for CPV signals that are
- first order in CPV parameters
- do not require flavor tagging (for D^0)

★ Consider the final states that can be reached by both D^0 and $\overline{D^0}$, but are not CP eigenstates ($\pi\rho$, KK^*, $K\pi$, $K\rho$, ...)

$$A^U_{CP}(f) = \frac{\Sigma_f - \Sigma_{\bar{f}}}{\Sigma_f + \Sigma_{\bar{f}}} \quad \text{where} \quad \Sigma_f = \Gamma(D^0 \to f) + \Gamma(\overline{D}^0 \to f)$$

★ For a CF/DCS final state $K\pi$, the time-integrated asymmetry is simple

$$A^U_{CP}\left(K^+\pi^-\right) = -y \sin\delta_{K\pi} \sin\phi \sqrt{R_{K\pi}}$$

($<10^{-4}$ for NP)

★ For a SCS final state $\rho\pi$, neglecting direct CPV contribution,

$$A^U_{CP}\left(\rho^+\pi^-\right) = -y \sin\delta_{\rho\pi} \sin\phi \sqrt{R_{\rho\pi}}$$

($<10^{-2}$ for NP)

Note: a "theory-free" relation!

Time-Dependent Dalitz Plot Analysis $D^0 \to K_S \pi^+ \pi^-$

- *Assuming no direct CPV* the mixing and CPV parameters (x,y,|q/p|,arg(q/p)) are accessible through a time-dependent analysis of the Dalitz plot distribution for D^0 and $\overline{D}^0$
  - currently the no direct CPV assumption is cross-checked with a separate fit to the DP of D^0 and $\overline{D}^0$

this assumption may not hold at 50ab^{-1}: we will need two separate DP for D^0 and $\overline{D^0}$, does this change the sensitivity to the mixing and CPV observables?

Analysis	Observable	Uncertainty	
		Now ($\sim$1 ab^{-1})	$\mathcal{L} = 50$ ab^{-1}
$K^0_S\pi^+\pi^-$	x (%)	0.19	0.08
	y (%)	0.15	0.05
	$\lvert q/p \rvert$	0.16	0.06
	ϕ	11°	4°

~ factor 3 better

limited by systematics

- Dominant irreducible systematics limiting the precision at 50ab^{-1} are due to the use of a *model* to describe the DP distribution

to fully exploit the power of 50ab^{-1} we will need to use a model-independent approach: need to balance the deterioration of the statistical error and the reduction of the systematic one

- No systematics/correction applied for the presence of the K_S in the final state

probably not relevant at 1ab^{-1}, need to think at the effects we will be sensitive to at 50ab^{-1}

Indirect CPV in two-body decays

- **Wrong-sign $D^0 \to K^+\pi^-$ analysis** will provide measurement of mixing parameters (rotated by the strong phase δ) and of the indirect CPV parameters.
- **Lifetime Ratio $D^0 \to K^-\pi^+$,K^-K^+,$\pi^-\pi^+$ analysis** will provide measurement of the mixing parameter y_{CP} and the CPV parameter A_Γ for both the fina states.

No limitations foreseen due to irreducible systematics
The current hypothesis of no direct CPV can be realised with no harm for the analysis technique, nor the theoretical interpretation of the results

Analysis	Observable	Uncertainty	
		Now (~ 1 ab^{-1})	$\mathcal{L} = 50$ ab^{-1}
$\pi^+\pi^-$, K^+K^-	y_{CP} (%)	0.22	0.04
	A_Γ (%)	0.20	0.03
$K^+\pi^-$	x'^2 (%)	0.022	0.003
	y' (%)	0.34	0.04
	$\|q/p\|$	0.6	0.06
	ϕ	25°	2.3°

~ factor 6 better

comparable contributions from statistical and systematic errors

~ factor 8-10 better

systematics free measurement

Charm Working Group - Theory Focus

- CP violation in $D-\bar{D}$ mixing:
  talks from Luca Silvestrini, Alex Kagan
  - employ a parametrization that is appropriate for the level of precision expected in the Belle II / LHCb upgrade era
  - improve upper bound estimate for SM CP violation (CPV), to more clearly delineate the window for New Physics in mixing CPV at Belle II

- Flavor $SU(3)$ analysis of direct CPV and rates in $D \to PP$ and $D \to VP$ decays:
  talks on PP: Martin Jung, Uli Nierste, Ayan Paul; on VP: Dean Robinson
  - can the presence of New Physics be inferred in direct CPV measurements using SM $SU(3)$ relations
  - quantifying $SU(3)$ violation in $D \to PP$, VP decays with increasing experimental precision can improve upper bound estimates of SM $D-\bar{D}$ mixing CPV

- Relatively clean observables for New Physics in Semileptonic and leptonic D decays:
  talks from Svetlana Fajfer, Alexey Petrov
  - lattice input: talk from Andreas Kronfeld

The "Real SM" Approximation and Beyond

- D mixing is described by:
  - Dispersive $D \to \bar{D}$ amplitude M_{12}
    - SM: long-distance dominated, not calculable
    - NP: short distance, calculable w. lattice
  - Absorptive $D \to \bar{D}$ amplitude Γ_{12}
    - SM: long-distance, not calculable
    - NP: negligible
  - Observables: $|M_{12}|$, $|\Gamma_{12}|$, $\Phi_{12}=\arg(\Gamma_{12}/M_{12})$

- The corresponding results on fundamental parameters are

  $|M_{12}| = (4 \pm 2)/fs$, $|\Gamma_{12}| = (14 \pm 1)/fs$
  and $\Phi_{12} = (2 \pm 3)°$

- Given present experimental errors, it is perfectly adequate to assume that SM contributions to both M_{12} and Γ_{12} are real
- all decay amplitudes relevant for the mixing analysis can also be taken real
- NP could generate a nonvanishing phase for M_{12}

$$\phi = \arg(q/p) = \arg(y + i\delta x) - \phi_{\Gamma 12}$$

$\phi_{\Gamma 12} = \arg \Gamma_{12}$

Relax the assumption of real Γ_{12}, universal phase $\phi_{\Gamma 12}$

Belle II and LHCb upgrade will considerably improve the sensitivity to CPV in charm mixing

How large can $\phi_{\Gamma 12}$ be in the SM?

Can we extract $\phi_{\Gamma 12}$ from experimental data?

Can We Estimate $\phi_{\Gamma_{12}}$ in the SM?

$\phi_{\Gamma 12} \sim \mathrm{Im}\, \lambda_s \lambda_b / y\, \Gamma_3/\Gamma \sim 5\, 10^{-3}\, \Gamma_3/\Gamma$

↓

$\phi_{\Gamma 12} \sim 5$ mrad (0.3°)

leaving plenty of room for NP

Γ_3 changes Uspin by one unit,
↑ generated by SCS decay amplitudes

use exp data on BR's and DCPV to perform SU(3) analysis and estimate Γ_3

↓

more data, in particular for PV SCS decays, would allow for a better estimate of $\phi_{\Gamma 12}$

ϕ_{M12} might be estimated via dispersion rel.

Belle II/LHCb upgrade will probe ϕ_{M12} and $\phi_{\Gamma 12}$ at the level of 1°, while an "extreme" flavour experiment might reach the 0.1° level

New physics in (semi)leptonic D decays

S.Fajfer

Motivation

- Important to know CKM matrix elements V_{cs} and V_{cd};
- High precision results for the decay constants, or form- factors required!
- In $B \to D^{(*)}\tau\nu_\tau$ observed disagreement of experimental and SM prediction.

Can current precision on charm meson decay constants/form factors enables to search for New Physics in charm?

Most convenient and general approach:
Effective Lagrangian to describe NP in $c \to sl\nu_l$ transition

$$\mathcal{L}_{eff} = -\frac{4G_F}{\sqrt{2}} V_{cs} \sum_{\ell=e,\mu,\tau} \sum_i c_i^{(\ell)} \mathcal{O}_i^{(\ell)} + \mathrm{H.c.}$$

$$\mathcal{O}_{SM}^{(\ell)} = (\bar{s}\gamma_\mu P_L c)(\bar{\nu}_\ell \gamma^\mu P_L \ell) \qquad c_{SM}^{(\ell)} = 1$$

Simplest proposal for NP

$$\mathcal{O}_{L(R)}^{(\ell)} = (\bar{s} P_{L(R)} c)(\bar{\nu}_\ell P_R \ell)$$

scalar/pseudoscalar operators

$$\mathcal{O}_{V,R}^{(\ell)} = (\bar{s}\gamma_\mu P_R c)(\bar{\nu}_\ell \gamma^\mu P_L \ell)$$

What are the most appropriate observables?

- NP in branching ratios; $D \to K^* l\nu_l$
- NP in forward-backward asymmetry; $D \to K l\nu_l$
- NP in transversal muon polarization;
- Right-handed current $D \to V\ell\nu$

- In order to get tight constraints on NP one needs:

a) Lattice calculations of form factors in $D \to P$ and $D \to V$;
b) High precision experimental studies of all observables.