Searches and limit analyses with the Fourier transform

Alex (+LBL?), Donatella, Franco,
Giuseppe, Sandro, Stefano

Outline

- Quick introduction to the method
- Example
- Task list
- Status:
  - “Fitter”
  - Samples
  - Other pieces (PID, SSKT, Semileptonic sample) in other talks (Paola, Pierlu, Sandro)

The Method

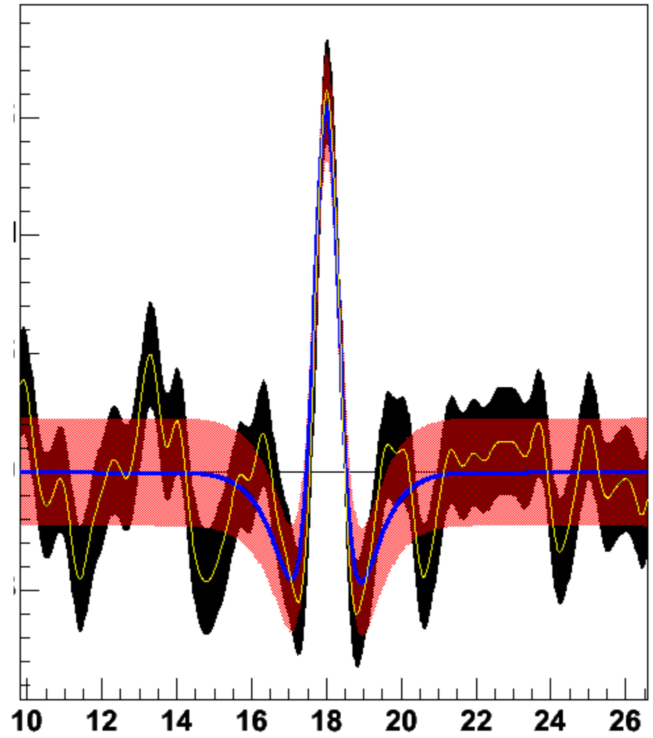
- We are looking for a periodic signal: Fourier space is the natural tool
  - Even Moser and Roussarie mention this!
  - They use it to derive the most useful properties of A-scan
  - Amplitude approach is approximately equivalent to the Fourier transform
  - Amplitude from scan ↔ Re[Fourier]
- Why not go for the real thing?
  - Computationally lighter
  - As powerful as A-scan
  - As is, no need *in principle* for measurements of D, ε etc. (however these ingredients add information and tighten the limit)

Definitions and properties

- Discrete Fourier transform definition
  - Given N measurements $\{t_j\}$ → $$g(w) = \sum_{k=1}^{N} D_k e^{-iwt_k}$$
- Properties:
  - Average:
    - If f(t) is parent distribution of $\{t_j\}$ $$\langle g(w) \rangle = N \langle D \rangle \tilde{f}(w)$$
  - Normalization:
  - Errors:
    - Real part: $$s^2(\mathrm{Re}\, g(w)) = N\left(\langle D^2 \rangle - \frac{1}{N} \langle \mathrm{Re}\, \tilde{f}(w) \rangle^2 + \frac{\langle D^2 \rangle}{\langle D \rangle^2} \langle \mathrm{Re}\, \tilde{f}(2w) \rangle \right)$$
    - NB: Errors can be calculated directly from the data!
    - $\Delta(w) \equiv g_{\mathrm{Un}Mix}(w) - g_{Mix}(w)$ behaves “as you’d expect”
    - While Δ and its uncertainty are fully data-driven, predicted Δ requires exactly the same ingredients as the amplitude scan fit

Properties of Δ...

- Re[Δ]
  a) contains all the information of the standard amplitude scan
  b) Amplitude scan properties are only approximate and mostly derived assuming (Amplitude scan)≈Re[Δ]



- Re[F] and $\sigma_{Re[F]}$ can be computed directly from data!
- b) ⇒ Sensitivity is exactly:

$$\frac{\Delta(w=\Delta m_s)}{s_{\Delta}} = \sqrt{Ne\langle D\rangle^2}\sqrt{\frac{S}{S+B}}e^{-\Delta m^2 s_{ct}^2/2}\sqrt{1+\frac{s_D^2}{\langle D^2\rangle}}$$

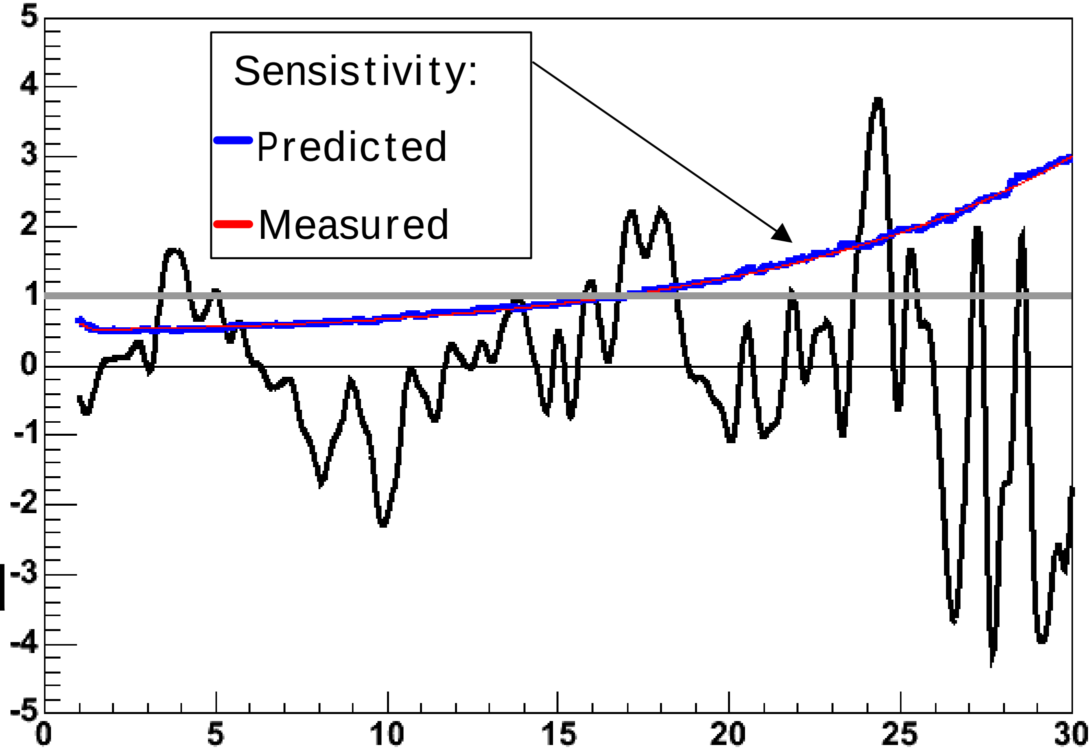
Can we reproduce the A-scan itself?

Toy Example

“A-scan” a` la fourier

$$\frac{\Delta(w)}{pred.\Delta(w;\ \Delta m_s = w)}$$

- 1000 toy events
- Δm_s=18
- S/B=2.
- εD_{signal}^2=1.6%
- εD_{back}^2=0.4%
- Background and signal parameterized according to standard analyses
- Histogrammed σ_{ct}
- Best knowledge on SF parameterization



No actual fit involved: this method allows to flexibly study systematics!

Plans for our method

- Final proof of principle:

  Process data from last round of analyses and show consistent picture with standard A-scan
- Prove viability of our method:
  - Full semileptonic and hadronic samples
  - Same taggers and datasets as latest blessed A-scans
  - Compare results to our method
  - Will be ready on time for winter conferences
- Extend:
  - 1fb^{-1}
  - All possible modes
  - State of the art taggers
  - We will have a full analysis by Summer conferences

Tasks

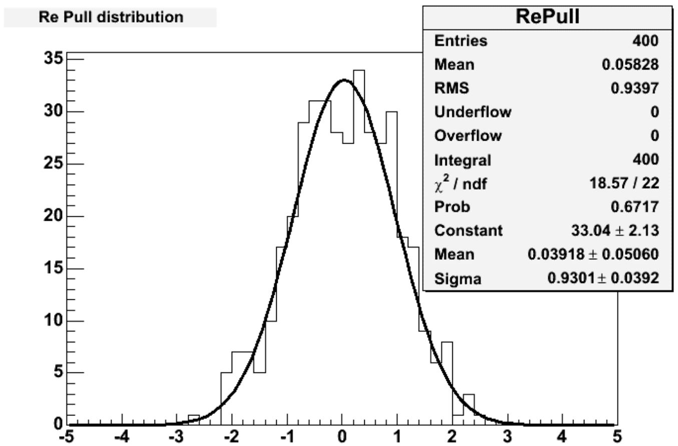
(my view, still being finalized not yet endorsed/discussed)

1) Data [Donatella, MDS, Stefano]
   - Skimming [Donatella, Marjorie]
   - MC
   - Ntuples [Johannes, Giuseppe]
2) Reco: [Alex, MDS, Stefano]
   - Optimize selections [Alex, MDS]
   - New channels (new modes, partially reconstructed) [Alex, MDS]
3) Basic tools: [Stefano, Alex, MDS, Giuseppe, Johannes]
   – PID [Stefano]
   – Vertexing (understand resolutions etc.) [Alex, MDS]
   – new taggers? (OSKT, SSKT...) [Giuseppe, Johannes]
4) Fourier "fitter" [Alex, Franco]
   - Toy MC [Alex]
   - Tool for data Analysis (from ct, sigma, D, etc. to "the plot") [Alex]
5) Semileptonic Analysis [Alex, Sandro]
   - Spring Analysis: reproduce the MIT result
   - Summer Anal.: - full 1 fb^{-1} indipendent analysis
6) Hadronic Analysis (same as 5)

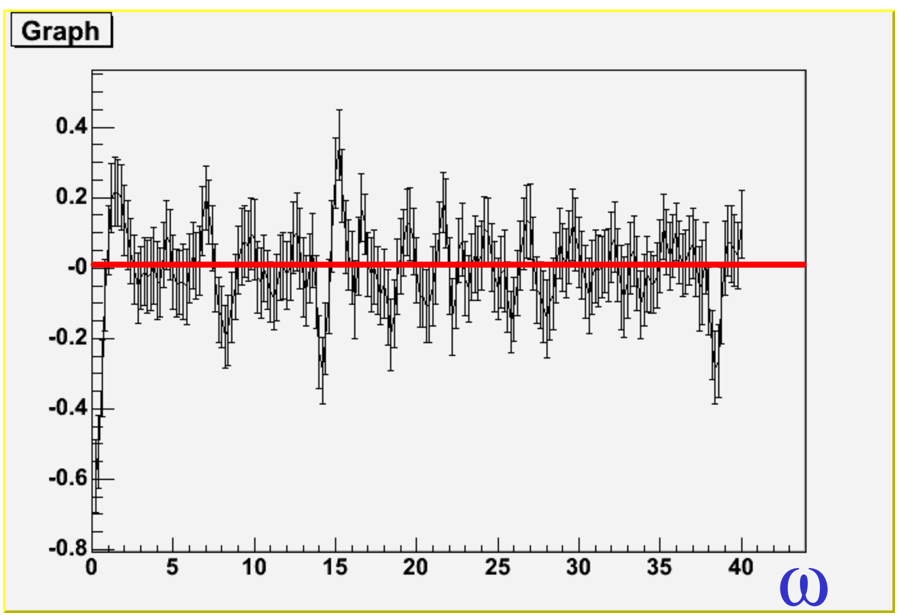
   [Alex, Amanda, Giuseppe, Hung-Chung, Stefano]
7) Combine Analyses [Alex]

Fitter Status

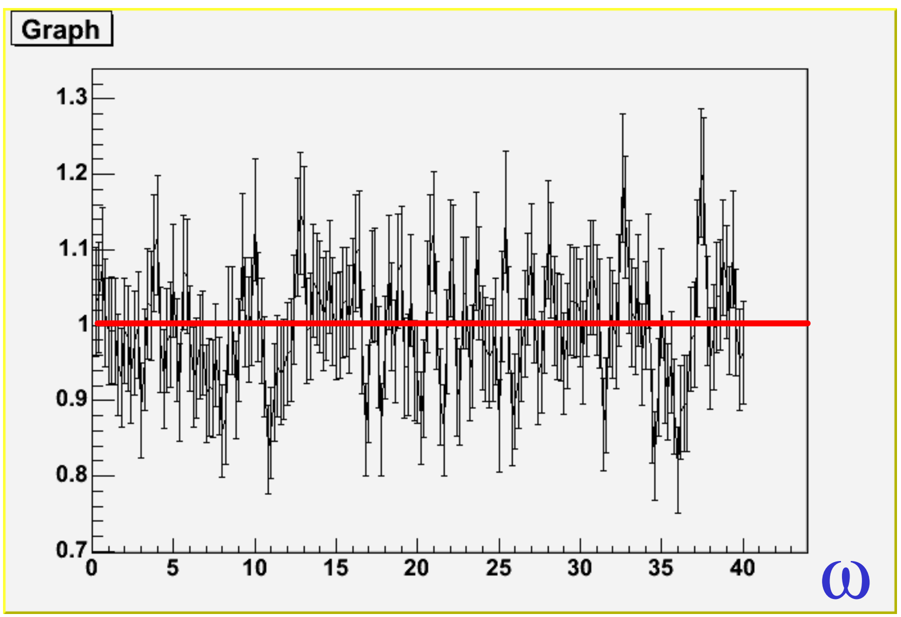
- "Fitter" fully implemented
- Provided in the same consistent framework:
    - Data processing
    - Toy MC generation
    - Bootstrap extraction
- Combination of several samples



Pulls Mean vs ω



Pulls σ vs ω



Dataset Skimming

	X→	Files size [evts] π	Files size [evts] π_{WS}	Files size [evts] 3π		Old Sample π	Old Sample π_{WS}	Old Sample 3π	New Sample π	New Sample π_{WS}	New Sample 3π	MIT Yields π	MIT Yields 3π
$B_s \to D_s X$	φπ					👍			👍	👍	👍 (90%)	551±42	158±17
	φ3π					👍	👍	👍 (99%)					
	K*K	71	62	637		-			🕘	🕘	🕘	238±42	63±11
	$K_s K$	-	-	-	2476 evts 270 MB	-							
	πππ	134	94	-		👍			🕘	🕘		108±24	
$B^0 \to D^+ X$		210 evts 25 MB				👍							
	Kππ	370	316	2038					🕘	🕘	🕘	8424±81	4611±129
$B^0 \to D^*(D^0\pi)X$	Kπ	18	-	100					🕘		🕘	1377±35	1089±43
	KK	-	-	-									
	ππ	-	-	-									
	K3π	-	-	-								1013±26	820±35
$B^+ \to D^0 X$	Kπ	92	-	-		👍			🕘			9601±84	1557±45
	KK	90	-	-		👍			🕘				
	ππ	42	-	-		👍			🕘				
	K3π	-	-	-		👍							

Main samples including new data are going to be there in ~week

Conclusions

- This is an AGGRESSIVE PLAN
- We started moving at a good pace
- We need to keep going, faster?
- We want to have
  - Preliminary results by spring (me hopes ~march)
  - independent results by the summer!
- A joint effort is the only way of getting this through!