Focus Topic: beyond semileptonic electroweak penguins

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Outline of the presentation

- The scope of the focussed topic
- The expert team
- The tools
- State-of-the-art
- The objectives.

1. The scope of the focussed topic

- Semileptonic decays (Electroweak penguins in the SM) with tau in the final states are not measured. First evidence for neutrinos just out!
- One of the flavour physics sectors that are beyond the reach of the current experimental programme(s). Boost at the *Z* / case for luminosity at the Z.
- Occupied some space as a change of paradigm for the search of New Physics from the Flavour problem(s).
- The canonical decays with taus places ultra-demanding requirements on the vertex detector (fully solvable kinematics provided the decay vertices are known).
- We thought to place the transition $b \to s \nu \nu$ as another study in this FT to complement the knowledge of $b \to s l l$ transitions at large.

1. The scope of the focussed topic

- The targets:
  - Assess performance requirements for the vertex detector.
  - Identify the detector parameters needed to reach these performance.
- Mandate for the expert team:
  - define the methodology of the prospective study.
  - steer the steps.
  - if you wish, work on it actually.
- Outcome: get out of this study with a contributing paper to the ECFA Yellow Book.

2. The expert team

- Ex-officio: P. Goldenzweig, P. Koppenburg, D. Marzocca, S. Monteil
- Semileptonic decays $b \rightarrow s\tau^+\tau^-$ analysis: T. Miralles, S. Monteil (Clermont)
- Semileptonic decays $b \rightarrow s\nu\nu$ analysis: A. Wiederhold (Warwick), M. Kenzie (Cambridge)
- Belle II expertise on both subjects: E. Manoni (Perugia), P. Goldenzweig (KIT).
- Vertex detectors: Fabrizio Palla (Pisa), Paula Collins (CERN)
- Theory expertise: J. Kamenik (JSI), Luiz Vale Silva (IFIC)

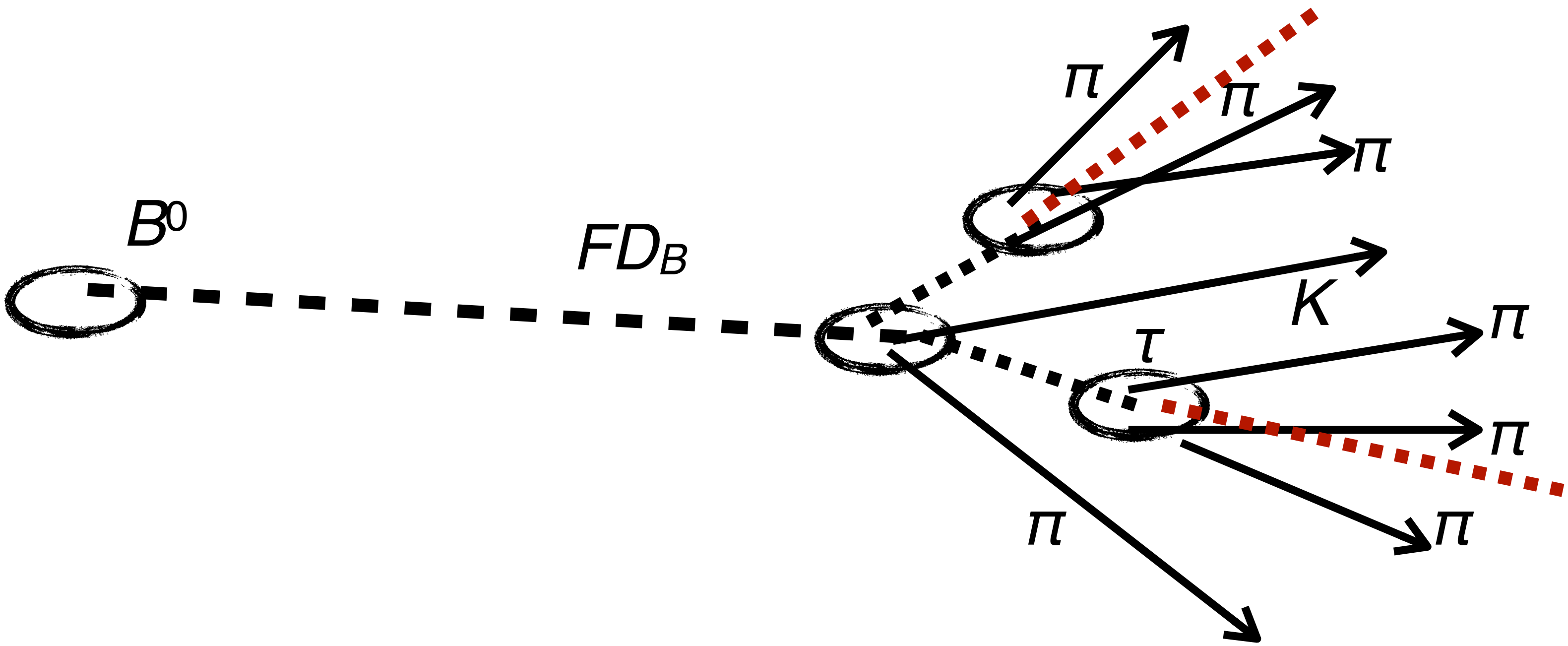
3. The tools (physics)

- $B^0 \to K^{*0}\ \tau^+\tau^-$ at Z pole can be studied as a function of:
  - the luminosity (number of Z decays).
  - the vertex performance.
- Generation of events: one needs here EvtGen:
  - most accurate description of the SM signal ph. sp., as are tau3h.
  - there are a number of backgrounds. Here again, accurate generation in order.

Decay	BF (SM/meas.)	Intermediate decay	BF_had	Additional missing particles
Signal : $B^0 \to K^* \tau\tau$	1.30×10^{-7}	$\tau \to \pi\pi\pi\nu$, $K^* \to K\pi$	9.57×10^{-11}	
Backgrounds $b \to c\bar{c}s$:				
$B^0 \to K^{*0} D_s D_s$	2.78×10^{-4}	$D_s \to \tau\nu$	5.79×10^{-10}	2ν
		$D_s \to \tau\nu, \pi\pi\pi\pi^0$	6.52×10^{-10}	ν , π^0
		$D_s \to \pi\pi\pi\pi^0$	7.35×10^{-10}	$2\pi^0$,
		$D_s \to \tau\nu, \pi\pi\pi\pi^0\pi^0$	5.47×10^{-9}	ν , $2\pi^0$
		$D_s \to \pi\pi\pi 2\pi^0$	5.17×10^{-8}	$4\pi^0$,
$B^0 \to K^{*0} D_s D_s^*$	8.78×10^{-4}	$D_s \to \tau\nu$	1.83×10^{-9}	2ν, γ/π^0
		$D_s \to \pi\pi\pi\pi^0\pi^0$	1.63×10^{-7}	$4\pi^0$, γ/π^0
Backgrounds $b \to c\tau\nu$:				
$B^0 \to K^{*0} D_s \tau\nu$	9.17×10^{-6}	$D_s \to \tau\nu$	3.59×10^{-10}	2ν
$B^0 \to K^{*0} D_s^* \tau\nu$	2.03×10^{-5}	$D_s \to \pi\pi\pi\pi^0\pi^0$	7.51×10^{-9}	ν, γ, $2\pi^0$

4. The state-of-the-art (3-prongs tau decays)

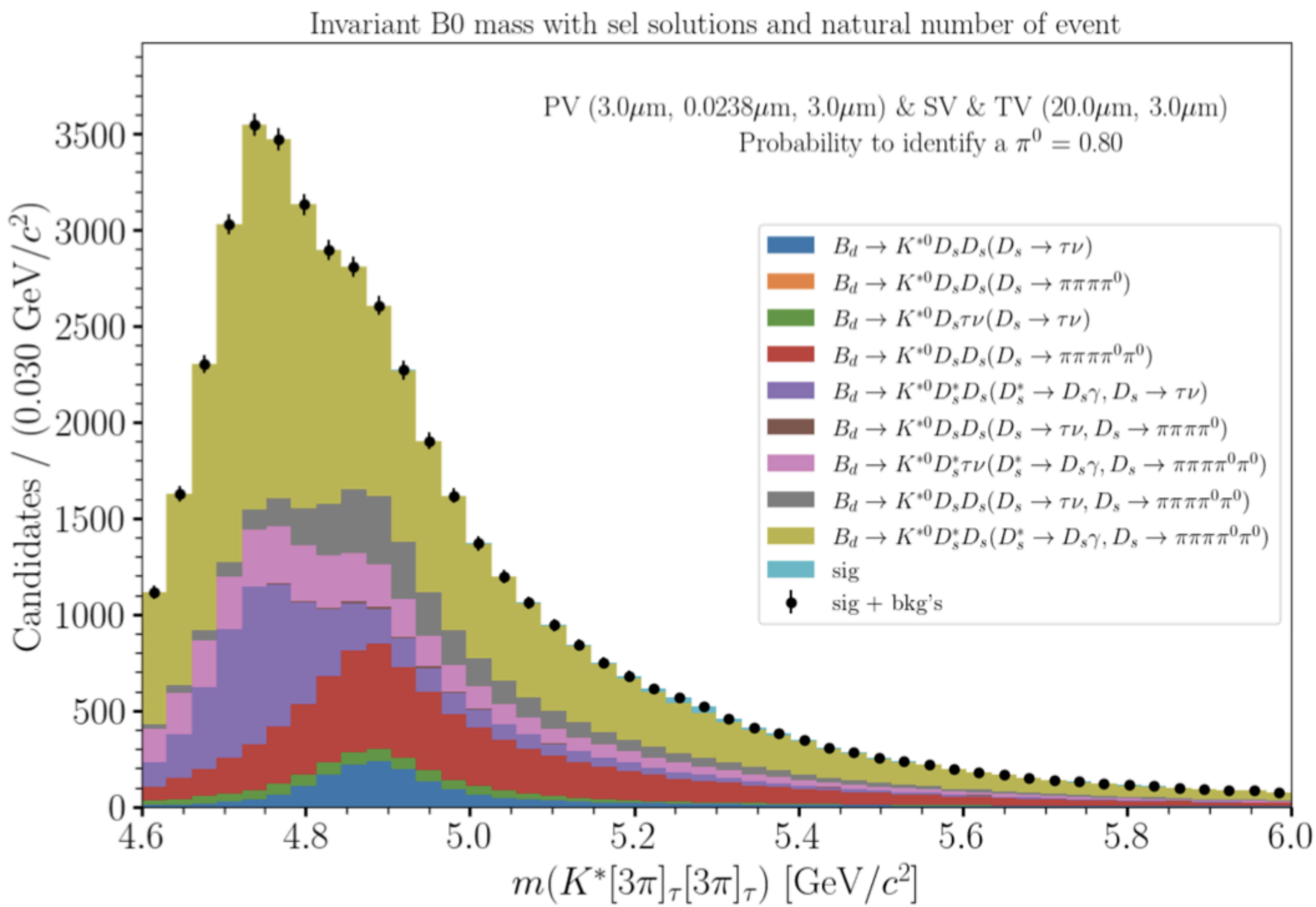
- $B^0 \to K^{*0}\ \tau^+\tau^-$: some vertices indeed.



- Six momentum components to be searched for:
  - B^0 momentum direction from $K\pi$ fixes 2 d.o.f.
  - τ momenta direction fixes 4 d.o.f.
  - Mass of the τ provides 2 additional constraints
  - Since both tau legs provide quadratic equations, one ends up w/ 4 solutions.
  - Yet, the system is over-constrained and in principle fully solvable.

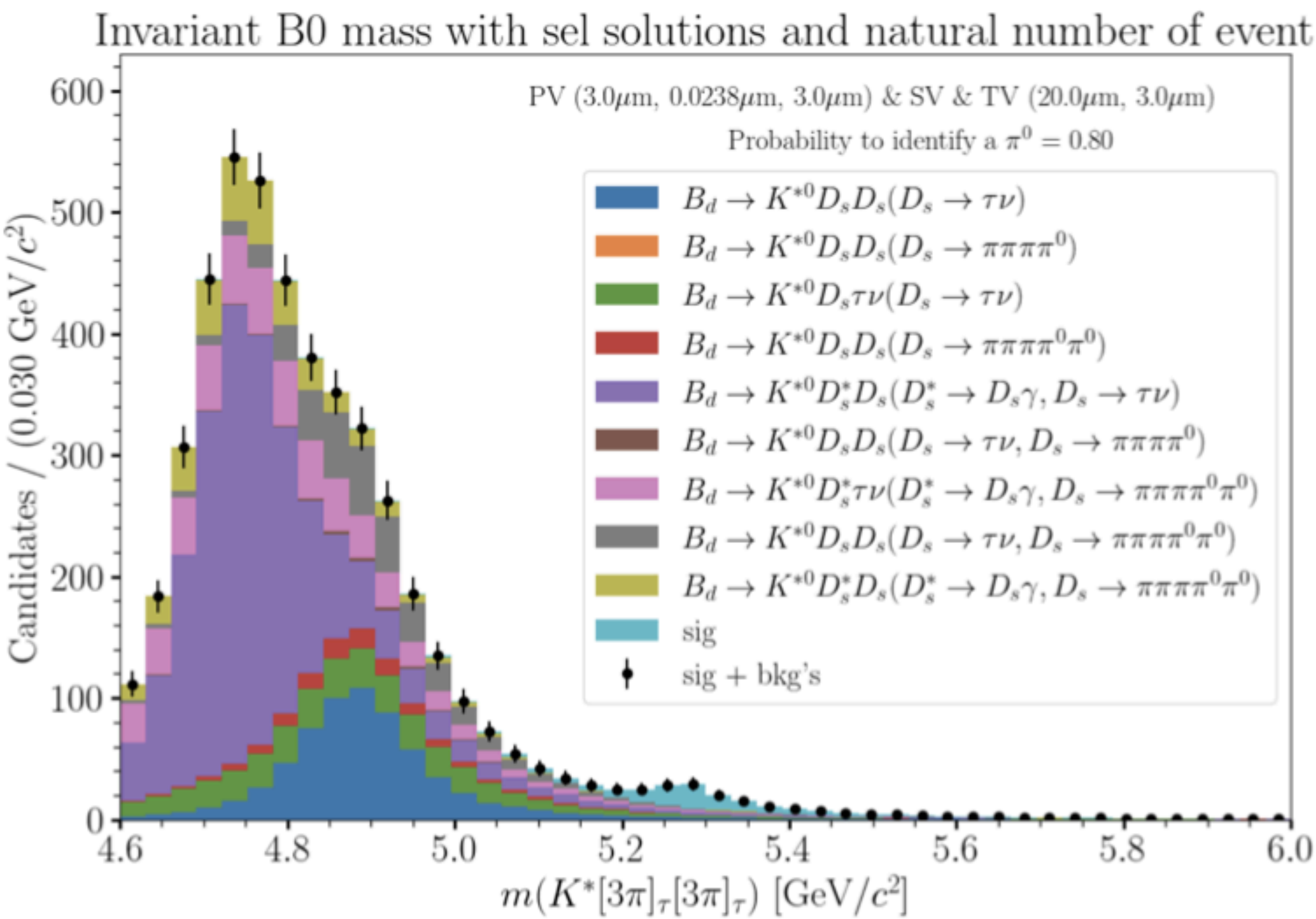
4. The state-of-the-art (3-prongs tau decays)

- $B^0 \rightarrow K^{*0}\ \tau^+\tau^-$: life is complicated at first, even w/ an excellent calorimeter and 5 10^{12} Z



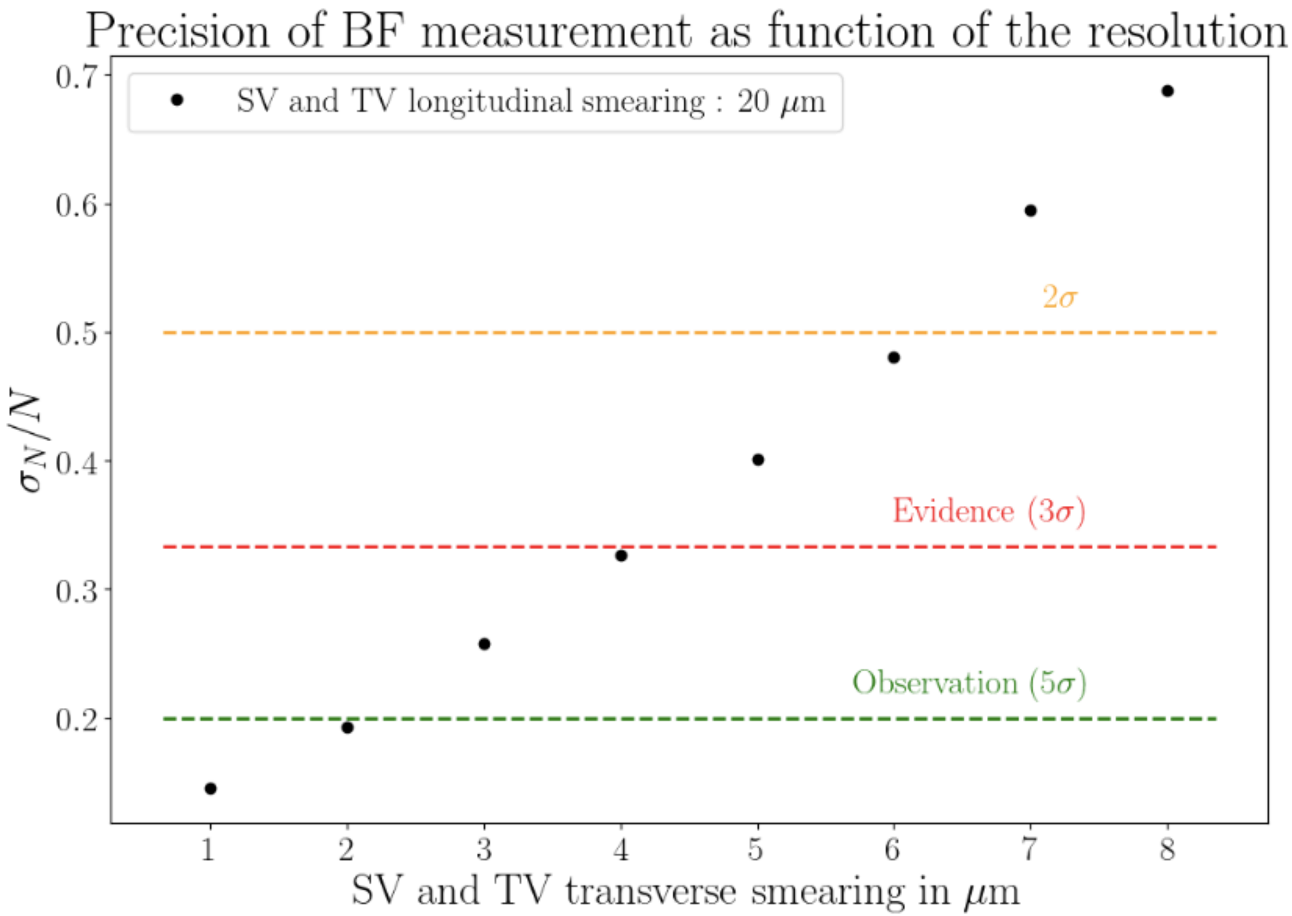
4. The state-of-the-art (3-prongs tau decays)

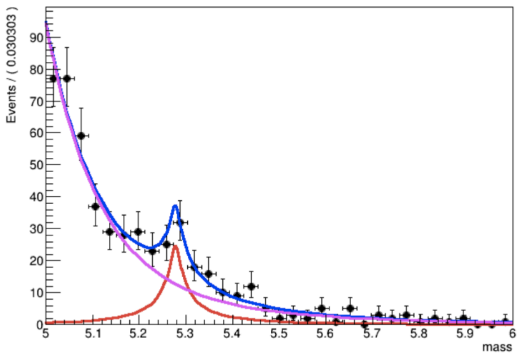
- $B^0 \to K^{*0}\ \tau^+\tau^-$: then issue a selection, based on rec. method:



4. The state-of-the-art (3-prongs tau decays)

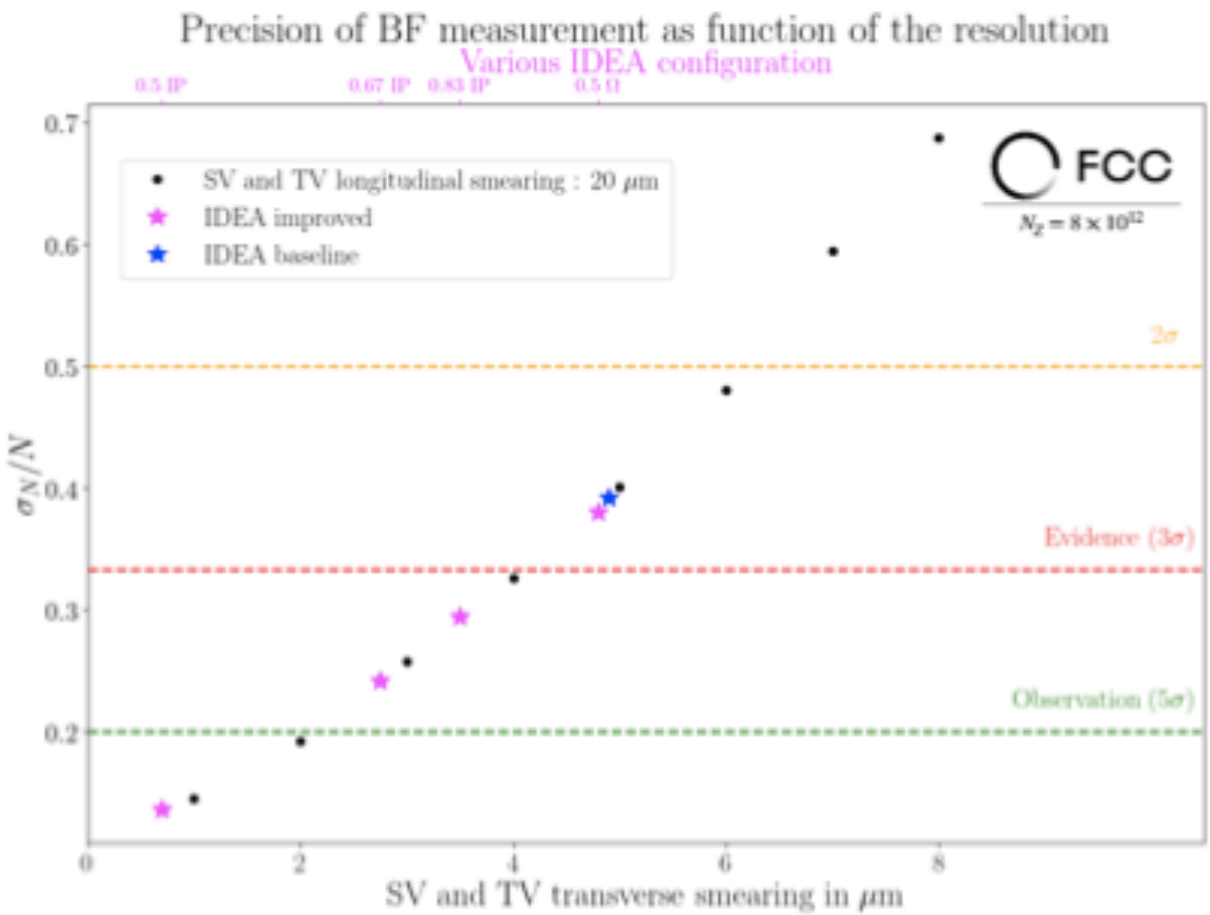
- $B^0 \to K^{*0}\ \tau^+\tau^-$: How is the branching fraction precision evolving with the vertexing resolution? Emulation of an arbitrarily good detector.





4. The state-of-the-art (3-prongs tau decays)

- $B^0 \rightarrow K^{*0}\ \tau^+\tau^-$: Checking how much to improve a vertex detector design? The IDEA example @ FCC-ee.



5. The possible questions / objectives (to drive our discussion)

- Preparing the ground: (physics studies)

  - $B^0 \rightarrow K^{*0}\ \tau^+\tau^-$:
    - detector: constraints on vertex detectors.
    - physics: adding up leptonic final states, less handles but more statistics.

  - $B^0 \rightarrow K^{*0}\nu\nu$:
    - Belle II just issued a hint of the decay (large BF).
    - address the perspectives at Tera-Z (a paper to be out very soon)
    - should we do more?
    - detector constraints? Calorimetry?

  - Compare in both cases with Belle II anticipated precisions.

  - Address the phenomenological interest of the precisions at hand?

5. Some conclusions from the first Expert Team meeting

- Physics analyses: already advanced. Papers out shortly. Assess comparisons with the anticipated exp. landscape at EW/H/t factory.

- Phenomenology: discussion on the scope to be held at the next ET meeting.

- Detector studies: several suggestions brought by Fabrizio:

  - Highly demanded requirements acknowledged.
  - Distance to IP, Bending of the detector, the pitch, material budget discussed, etc…
  - Bottleneck clearly identified: low momenta final state tracks can only be resolved better with less material (multiple coulombian scattering).
  - Short term: complete fast simulation studies. for different detector design concepts. Change of parameters (design agnostic) to assess the target performance.
  - Next: actual geometries / detector concepts in full simulation studies.