

# UPDATES CONCERNING SC QUESTIONNAIRE

**Check document on wiki for details.  
Here, I summarize the main punchlines.**

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# SUBTOPICS

- **Open-charm production in  $p \bar{p}$**
- **$D_{(s)}$  Spectroscopy: exotics, transitions & decays**
- **$\Lambda_c/\Sigma_c/\Xi_c$  Spectroscopy: [see above]**
- **Form Factors: (semi-)leptonic decays**
- **Electroweak: (in)direct CPV, rare decays**

# GROUPS INVOLVED

- **FZJ**
  - Ds spectroscopy, D(s) production & semi-leptonic decays
  - *Elisabetta Prencipe, Lu Cao, Andreas Herten, ...*
- **GSI/FAIR**
  - Electroweak
  - ...
- **U of Giessen**
  - Ds spectroscopy, electroweak
  - *Andreas Pitka, ...*
- **KVI-CART**
  - Open-charm production & spectroscopy
  - *Alexandros Apostolou, Solmaz Vejdani, ...*
- **Mainz**
  - Electroweak, (semi-)leptonic form factors?
  - *Donghee Kang, ...*
- **U of Muenster**
  - D(s) leptonic decays
  - ...

# ADVISORS FROM THEORY

- **Nora Brambilla**
  - TUM
- **Jochen Heitger**
  - Univ. Muenster
- **Matthias Lutz**
  - GSI
- **Thomas Mannel**
  - Univ. Siegen
- **Sinead Ryan**
  - Trinity College Dublin
- **Wolfgang Schweiger**
  - Univ. Graz

# MOTIVATION

- **Links QCD dynamics and electroweak**
  - form factors, decay constants
- **Charm weak decays**
  - sensitive probes for BSM
  - long-distance effects in weak decays
- **Links to meson and baryon spectroscopy**
  - “heavy” charm quark: HQS, chiral symmetry, ...
  - potential probes to search for “exotics”

# ORIGINALITY PANDA

- **Associative production near thresholds**
  - quantum entanglement in weak sector
  - mass and width precision in spectroscopy
- **Usage of antiprotons**
  - sensitivity to D-waves in spectroscopy
  - physics in open-charm production is not understood
- **Electromagnetic decays and  $\pi^0$  transitions**
  - Photon detection, PID, vertex, ...
  - sensitive to various “new” physics aspects

# COMPETITORS

- **LHCb**
  - lots of open-charm production
  - no photon detection, no associative production
- **Belle II**
  - no associative production
- **BES III**
  - Limited energy
- **J-PARC**

**strongly depends on cross sections in  $p\bar{p}$**

# LUMINOSITY

- **open-charm production in  $p \bar{p}$** 
  - $\sim 10^7$  reconstructed pairs of open-charm hadrons
  - $S/B=1:1$  or better
- **D(s) spectroscopy**
  - mass scan ( $D_{sj}(2317)$  case: 5 nb at 5 MeV above threshold, at least 50 pb<sup>-1</sup> for  $\sim 15$  scan points
  - inclusive measurement,  $S:B=1:1$  or better
- **charm-baryon spectroscopy**
  - similar as D(s) spectroscopy
- **(semi-)leptonic decays**
  - $5 \times 10^8$  exclusive D(s)D(s) pairs
  - $\sim 10^0\%$  detection efficiency, integrated luminosities:  $\sim \text{fb}^{-1}$
- **Electroweak**
  - similar to (semi-)leptonic decays



# ROLE MODEL CHANNELS

- **Open-charm production in  $p \bar{p}$** 
  - $p + \bar{p} \rightarrow D^0 \bar{D}^{0*} \rightarrow (K \pi) + (K \pi)^* / (K \pi) + X$
  - $p + \bar{p} \rightarrow D^+ \bar{D}^- \rightarrow (K 2\pi) + (K 2\pi)^* / (K 2\pi) + X$
  - $p + \bar{p} \rightarrow D_s^+ \bar{D}_s^- \rightarrow (2K \pi) + (2K \pi)^* / (2K \pi) + X$
  - $p + \bar{p} \rightarrow \Lambda_{bc}^+ \bar{\Lambda}_{bc}^- \rightarrow (p K \pi) + (p K \pi)^* / (p K \pi) + X$
  - $p + \bar{p} \rightarrow \Lambda_{bc}^+ \bar{\Lambda}_{bc}^- \rightarrow (\Lambda \pi) + (\Lambda \pi)^* / \dots$
- **D(s) spectroscopy**
  - $D_s D_{s0}(2317), D_s D_{s1}(2460), D_s D_{s1}(2536)$
  - radiative,  $\pi, 2\pi, K$  transitions among D(s) states.
  - $D \rightarrow K \pi \pi / K K \pi$  (Dalitz)

# ROLE MODEL CHANNELS

- **charm-baryon spectroscopy**
  - $\Lambda_{bc}(2940) \Lambda_{bc} \rightarrow p D_0 + \bar{p} K^+ \pi^-$
- **(semi-)leptonic decays**
  - $D_s D_s \bar{\nu} \rightarrow (K K \pi) + \mu + \nu$
  - $D_s \rightarrow \eta/\eta' + e^+ + \nu$
- **electroweak**
  - $D_0 D_0 \bar{\nu} \rightarrow g g + (K \pi)$
  - $\Lambda_{bc} \Lambda_{bc} \bar{\nu} \rightarrow p g + (\bar{p} K \pi)$

# POTENTIAL TRIGGERS

- Focus on weakly decaying  $D(s)$  and charm baryons:
- Identification of displaced tracks
- Invariant-mass reconstruction of “tagged” hadrons

# BACKGROUND SOURCES

- Misidentification of pions as kaons
- Multiple photons and corresponding combinatorics
- $\pi^0$  production in the case of radiative decays
- Channels with similar event topologies, f.e. non-resonant contributions with the same final state

# BACKGROUND FILTERS

- Central and forward tracking
- MVD and STT for tracking and vertex reconstruction
- Combination with pellet target and tracking system
- EMC: photons are competitive probes!
- GEM to detect particles below 20 degrees
- DIRC for pion/kaon separation
- Muon detector, in particular for (semi)leptonic decays
- (Kinematically) over-redundant information
- Multi-variate analysis with combined PID information

# FIGURE OF MERIT

- **open-charm production in  $p \bar{p}$** 
  - statistical significance
- **D(s) spectroscopy**
  - statistical significance
  - mass and width precision
- **charm-baryon spectroscopy**
  - statistical significance
  - mass and width precision
- **(semi-)leptonic decays**
  - statistical significance
  - precision (stat & sys) of form factors and decay constants
- **Electroweak**
  - statistical significance
  - precision (stat & sys) CP asymmetries