UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

SMARTHEP kick-off meeting

24 Nov 2021 - Online

ESR11 project:

RTA for Dark Photons search in LHCb and smart vehicles

Main supervisor:
Stephanie Hansmann-Menzemer (UHEI)

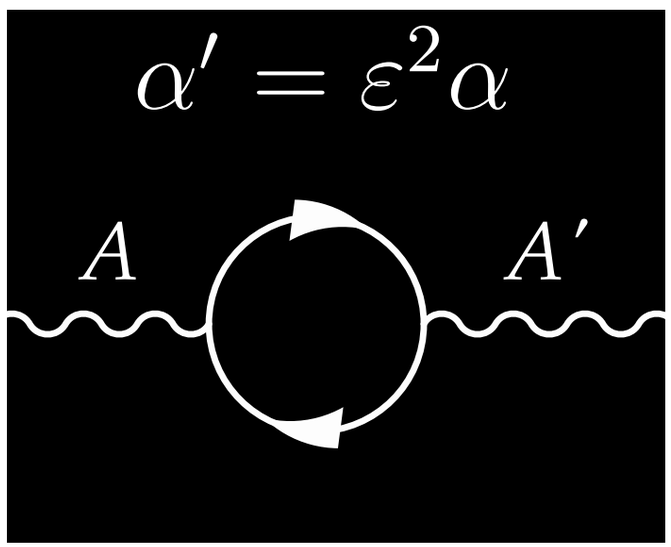
Second supervisor:
Johannes Albrecht (TUDO)

Industrial supervisor:
Francesco Sambo (VERIZON)

Additional supervision:
Martino Borsato (UHEI)
Diego Martinez Santos (USC)

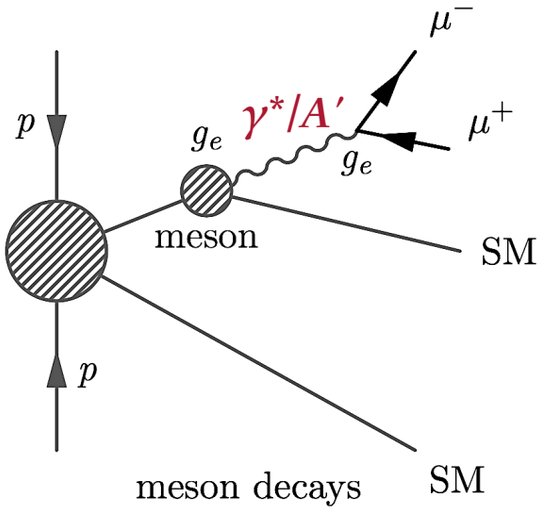
RTA for Dark Photons search in LHCb

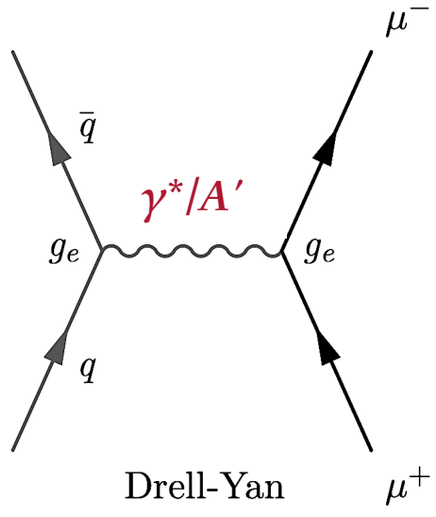
- Dark photons A': well-motivated hypothetical particles
  - Connected to dark matter
  - Searched by several experiments in large range of masses $m(A')$ and coupling ε^2

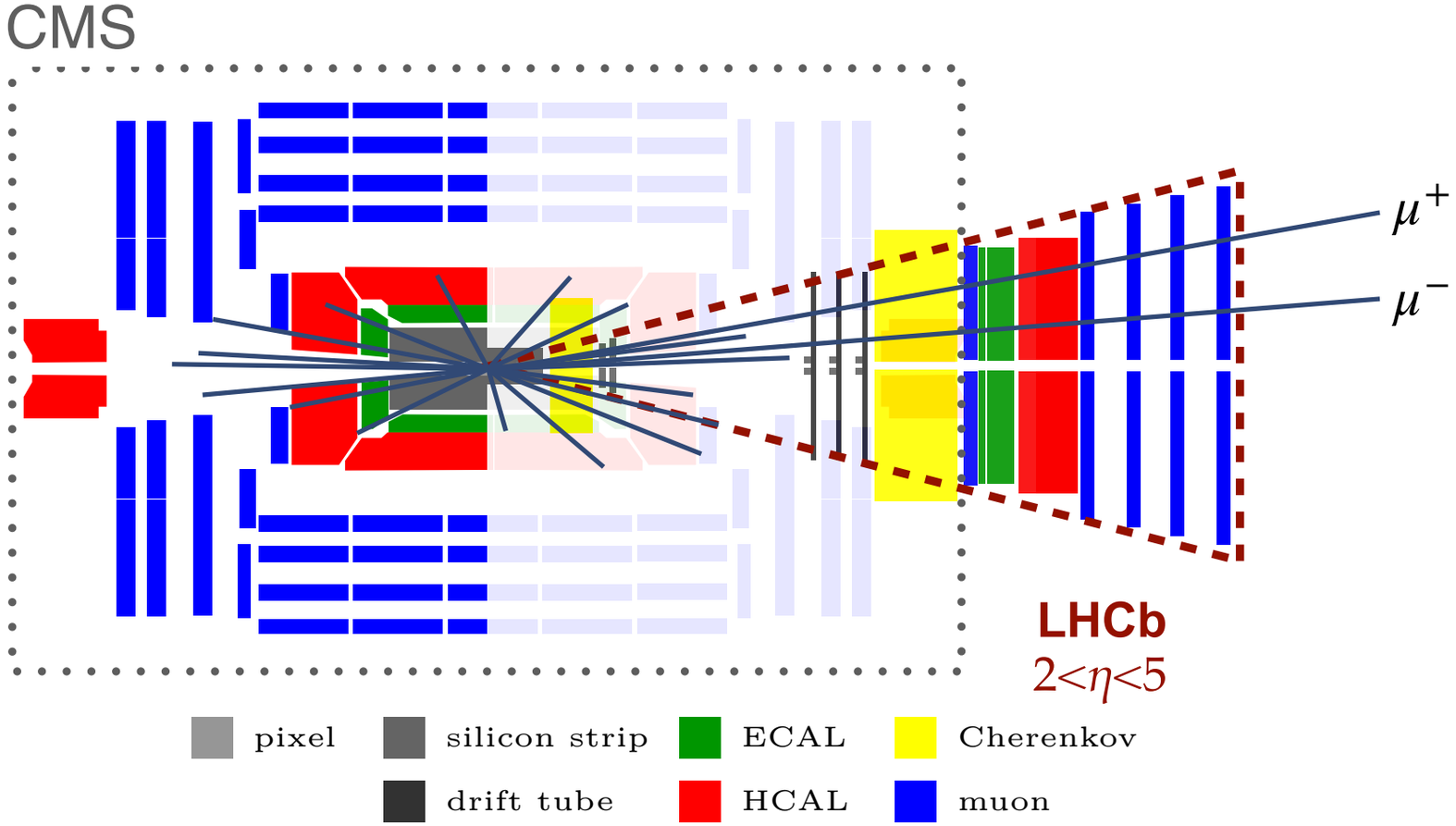


- World-leading search for $A' \to \mu^+\mu^-$ at LHCb
  - An RTA success story!

Dark photons at the LHC

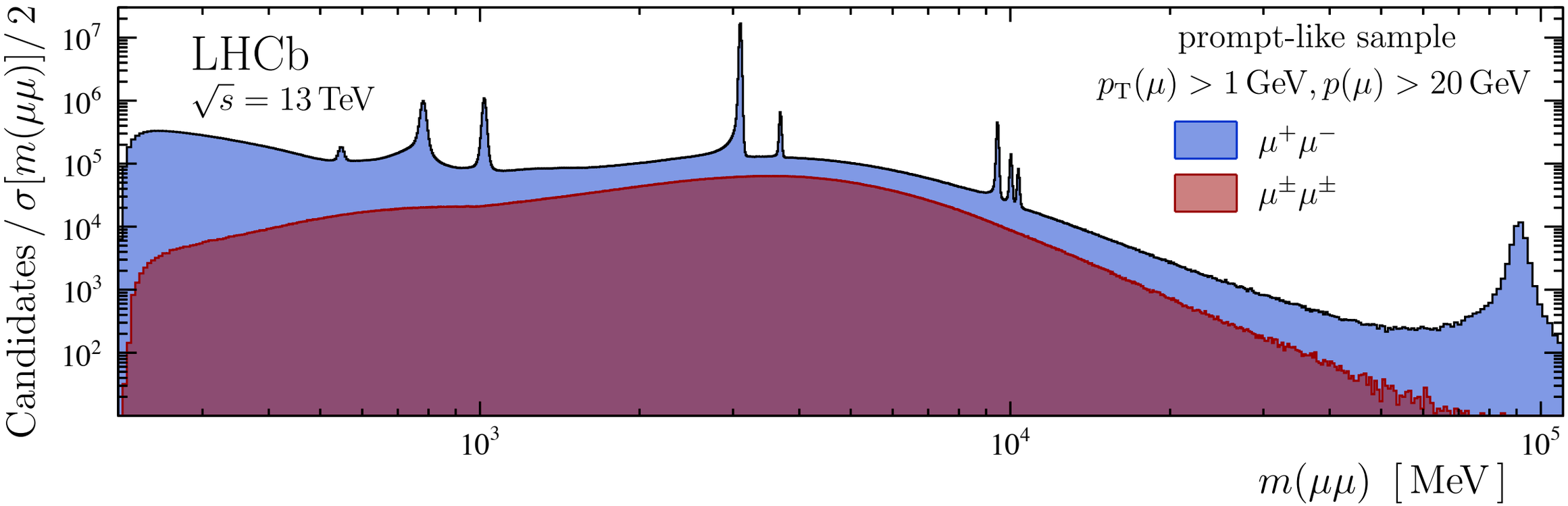




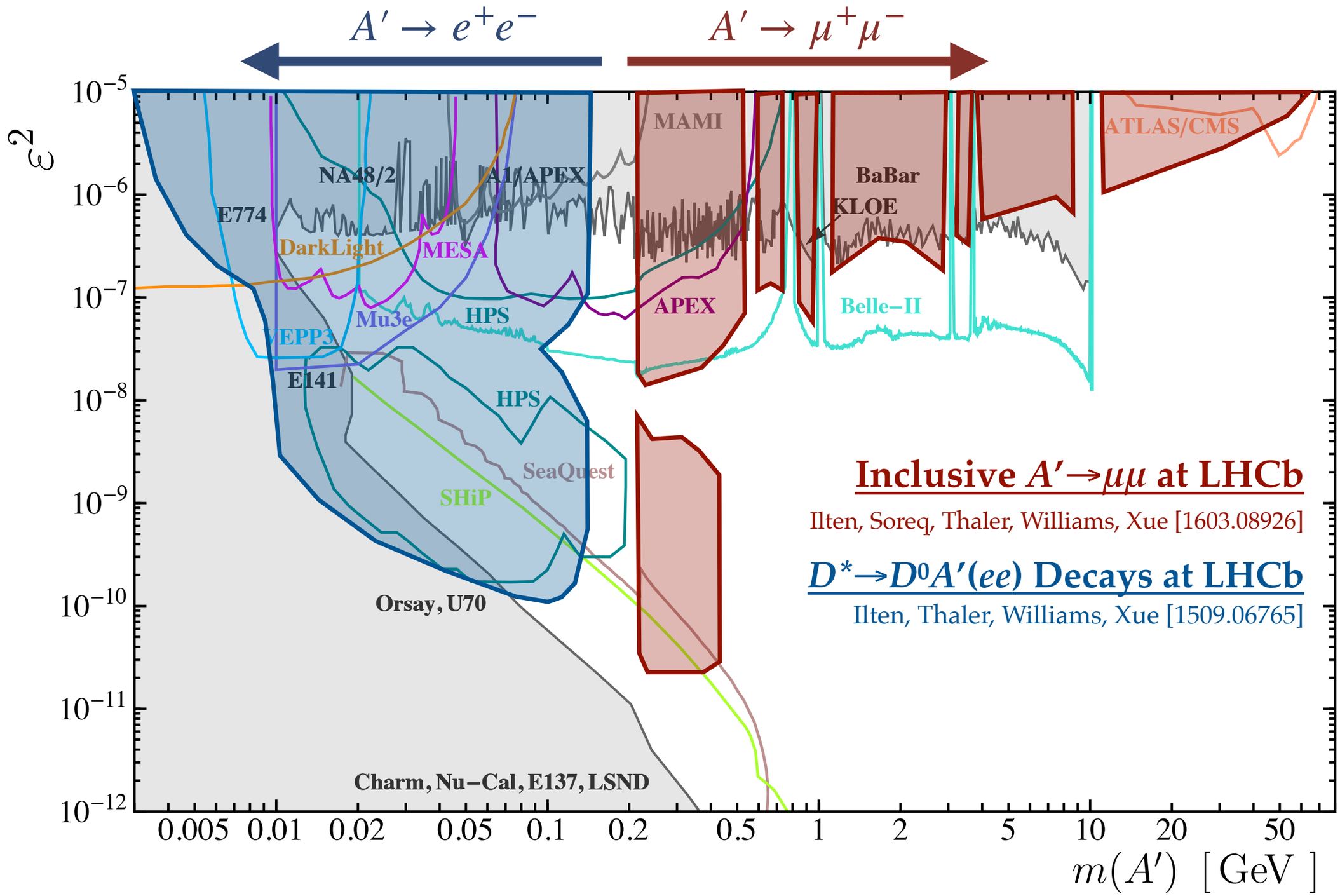


RTA for $A' \to \mu\mu$

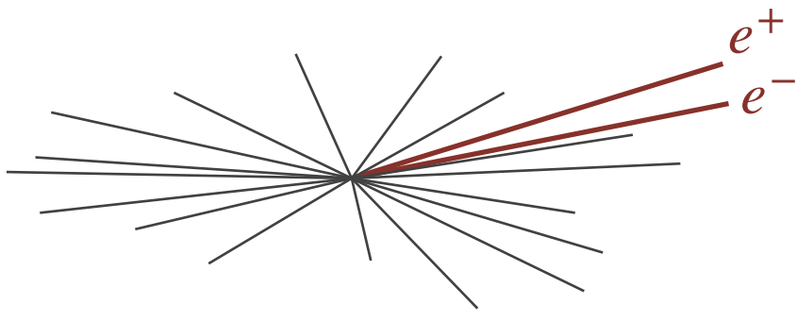
Prompt dimuon spectrum out of the trigger (2016)



Dark photon searches



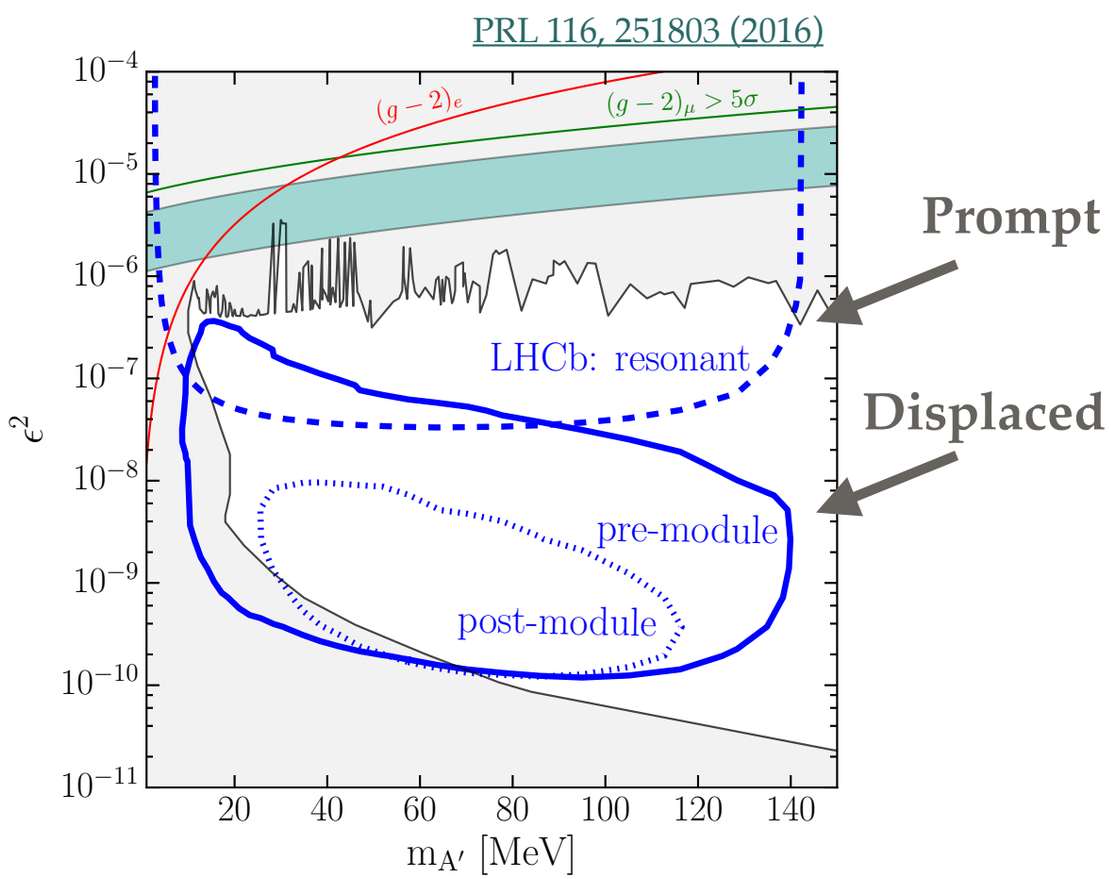
Dark photons in electrons



- Search for $A' \to e^+e^-$ with $m(A') < 200MeV$
  - Low-momentum prompt (displaced) dielectrons
    - Events discarded by
- Only possible with full RTA approach
  - Overwhelming rates at LHC collisions
  - Reconstruct low momentum electron tracks
  - Low-momentum electron identification with ML combining info from tracking, calorimeter and RICH
- Can we do precise enough RTA in the trigger GPUs to write to disk all $A' \to ee$ candidates?

- Expect **700 kHz** of $D^* \to D^0\gamma$ in LHCb (Run 3)
  → proposed in PRL 116, 251803 (2016)
  - High chance that a few γ mix with A'
  - Can use D^0 to help with real-time selection
  - Improved $m(A')$ resolution thanks to constraints on D^* and D^0 masses

Ilten, Thaler, Williams, Xue
PRL 116, 251803 (2016)



Secondments

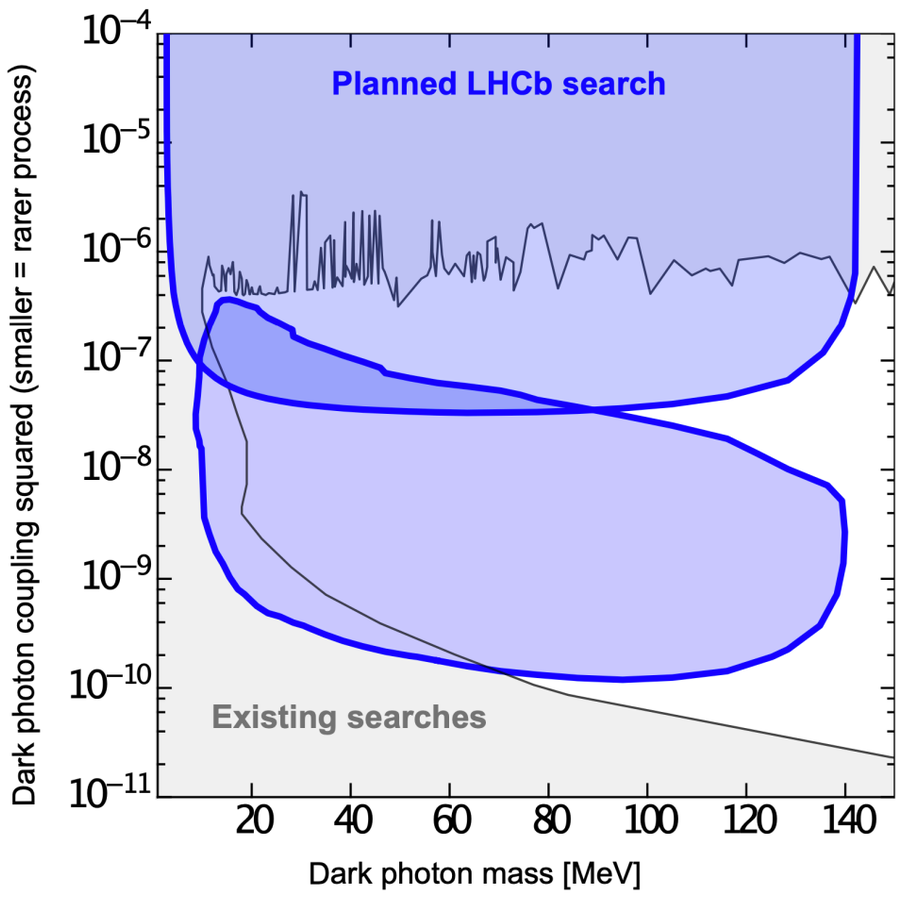
- Optimisation of highly parallel architectures
  - **Secondment** in USC, 2 months, Diego Martinez Santos
- Development of advanced ML for electron identification
  - **Secondment** in TUDO, 3 months, Johannes Albrecht
  - Collaboration on lepton-flavour violation searches $X \to e\mu$
- Potential additional development
  - A tool to efficiently retrieve online low-momentum $\gamma \to e^+e^-$
  - Provide photon with tracks, can do displaced vertices
  - Can be used in other analyses (e.g. $B \to \mu\nu\gamma$ or $\tau \to \mu\gamma$)
- **Secondment** at VERIZON, 4 months, Francesco Sambo
  - Training in ML models based on data streams
  - Training in Amazon Web Services for massively parallel ML training

Project description

https://docs.google.com/document/d/1GFByLMsadvwdN9Y_liELThmoF7VlMNmVJxclMRmNvJs/edit#

Real-time analysis for Dark Photons search in LHCb and smart vehicles

Description: The PhD student in this project will develop an advanced RTA-based analysis to efficiently select decays involving di-electron vertices with low invariant mass. They will use these advances to search for light dark photons with the LHCb detector focusing on a range of extremely low coupling so far unexplored by other experiments. The upgraded LHCb detector, which is planned to start data-taking in 2022, will allow for the first time to search for this kind of signature. It is the novel real-time detector readout in Run-3 that gives the possibility to use real-time analysis to separate dark photon candidates from the overwhelming background online. This challenging task will depend critically on the performance that can be achieved on modern computing architectures. The PhD student in this project will be trained in the usage of highly parallel architectures for the LHCb online reconstruction and will profit from collaboration with experts in the University of Santiago de Compostela on the use of GPUs. Through an internship with VERIZON, the PhD student will be trained in ML models development based on streams of data, and in the Amazon Web Services infrastructure for massively parallel training of large-scale ML models. The acquired ML processing skills will feed back into the main research project, allowing the development of advanced ML algorithms to optimise the electron classification and make it fast enough to be run in real time. This work will benefit from collaboration with the Dortmund experts and PhD students. These advances will also allow the PhD student to develop a tool to efficiently retrieve online low momentum photons through their conversion in di-electron pairs, a challenging task that requires an RTA-based approach.



Caption: Blue lines: constraints on dark photon models that can be obtained with advanced real-time analysis techniques at the LHCb experiment. Adapted from Phys. Rev. Lett. 116, 251803 (2016).

Project description in Annex A

ESR11	UHEI	UHEI	8	36	RTA to search for Dark Photons in LHCb and for smart vehicles
SC	**Main supervisor: Hansmann-Menzemer** (UHEI), [15]. Professor. Expertise: tracking algorithms and software in LHCb. Co-spokesperson of research training "Particle Physics beyond the SM" (DFG). EPS Young Researcher award (2007), ERC StG 2010 **Second supervisor: Albrecht** (TUDO) [25]. Emmy Noether group leader and lecturer. See ESR8. **Industrial supervisor: Sambo** (VERIZON). See ESR13. **Additional supervision: Borsato** (UHEI). Expertise: Dark sectors, trigger and software for LHCb.**Martinez-Santos** (USC). See ESR9.				

Fellow ESR11	**Host** UHEI	**Ph.D.** Yes	**Start (mo.)** 8	**Duration (mo.)** 36	**Deliverables** 3.1,3.3, 4.3, 3.2,6.1, 6.4, 6.7, 6.3
Work Package: WP3,4,5,6		**Doctoral programme:** UHEI		**RTA for Dark Photons search in LHCb and smart vehicles**	
Objectives: ESR11 will develop an advanced fully RTA-based analysis to efficiently select decays involving displaced di-electron vertices with low invariant mass. ESR11 will use these advances to search for light dark photons with the LHCb detector focusing in a range of extremely low coupling so far unexplored by other experiments. The upgraded LHCb detector, which is planned to start data-taking in 2021, will allow for the first time to search for this kind of signature. It is the novel real-time detector readout in Run-3 that gives the possibility to use RTA to separate dark photon candidates from the overwhelming background online. The reconstruction of tracks and displaced vertices has to be carried out online even for low-momentum tracks. This challenging task will depend critically on the performance that can be achieved on modern computing architectures. ESR11 will be trained in the usage of highly parallel architectures for the LHCb online reconstruction and will profit from a secondment in USC on use of GPUs. At VERIZON, ESR11 will be trained in the continuous online learning of ML models based on streams of labelled data, and in both the Apache Spark and the Amazon Web Services infrastructures for massively parallel computations. ESR11 will develop an online learning tool to continuously process real-time GPS data from Fleetmatics customers, providing customers with smart insights, improving customer experience, and thus increasing engagement with VERIZON products. The acquired ML and online processing skills will feed back into the main research project. ESR11 will develop advanced ML algorithms to optimise the electron classification and make it fast enough to be run in real time. This work will benefit from a secondment in TUDO under Albrecht's supervision, who will host both ESR11 and ESR8 and train them on how to design an online analysis of decays involving electrons with the help of his StG team. These advances will also allow ESR11 to develop a tool to efficiently retrieve online low momentum photons through their conversion in di-electron pairs, a challenging task that requires an RTA-based approach.					
Expected Results: 1. Development and testing of algorithms for RTA of electrons (LHCb conference paper). 2. Application to dark photon search with Run 3 data (LHCb peer-reviewed paper). 3. Use of algorithms and implementation for online learning tool of GPS data, cross-talk with HEP (VERIZON). ESR11 will receive a PhD in Experimental HEP from Heidelberg University.					
Secondments: TUDO, 3 months, Albrecht. Design of LFV physics analysis. USC, 2 months, Martinez Santos. Use of GPU in LHCb online reconstruction. VERIZON, 4 months, Sambo, development of an online learning tool for GPS data processing.					

Current constraints on dark photons