Future plans at DAFNE
Fundamental Physics at the strangeness frontier:
Kaon scattering experiments

Johann Zmeskal

LNF - FFF meeting

January 13, 2021

KAON-NUCLEON SCATTERING - KNscat

GOAL

Measuring the particle resulting from the scattering processes on various targets (starting with hydrogen, deuterium, helium-3 and helium-4) with low momenta.

DETECTOR

Measuring scattering processes at low energy represents a big experimental challenge. Therefore, we will develop in the framework of the

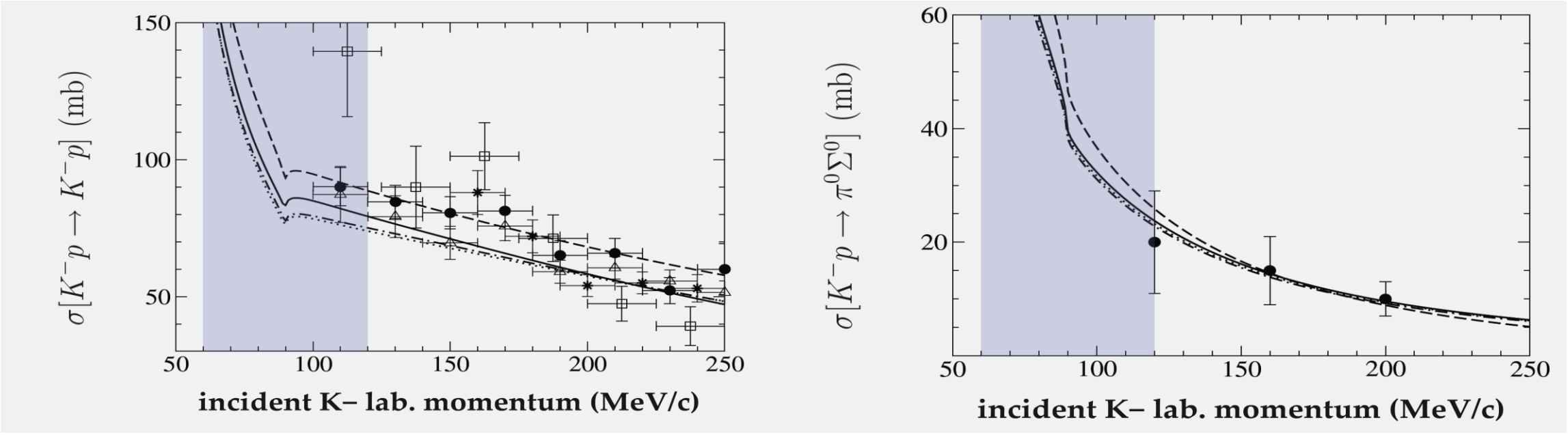
EU programme Horizon 2020, project STRONG2020,

an active Time Projection Chamber (TPC), which will allow to study the kaon interaction directly in the TPC, without additional material.
Scintillator tiles will surround the TPC for charged particle tracking.

In addition to study inelastic channels it is necessary to the detect neutrons as well as gammas ⟹ a new detector concept is under study.

KNscat: KAON-NUCLEON SCATTERING

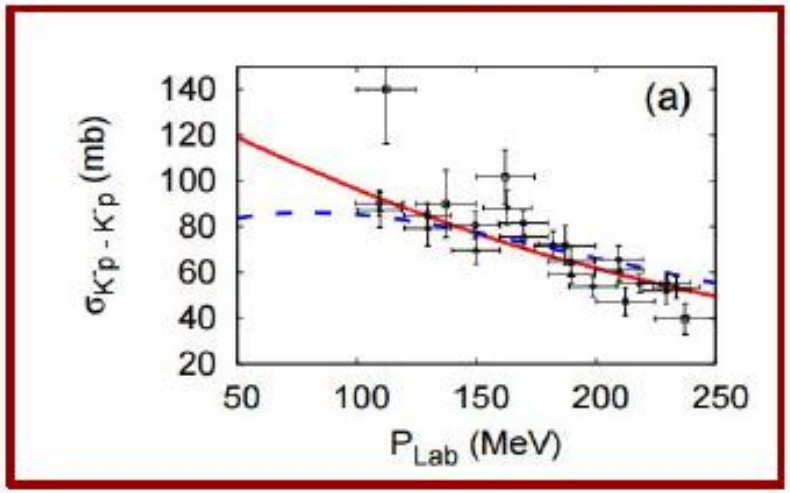
- The present knowledge of total and differential cross sections of low energy kaon-nucleon reactions is very limited.
- Below 150 MeV/c there is a “desert” - the experimental data are very scarce and with large errors and practically no data exist below 100 MeV/c.
- Kaon-nucleon scattering data are fundamental to validate theories: chiral symmetries; lattice calculations; potential models etc.

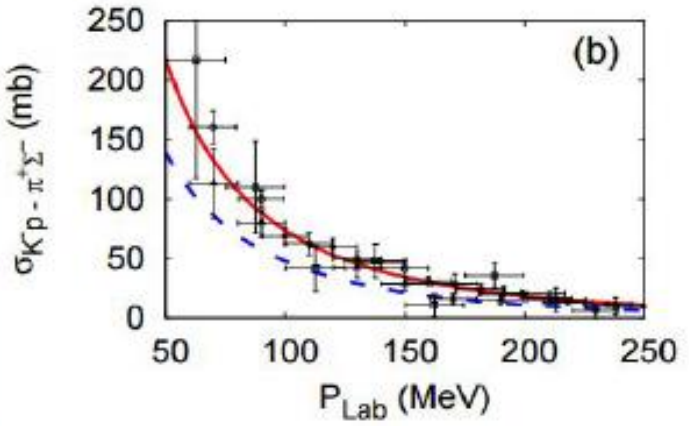


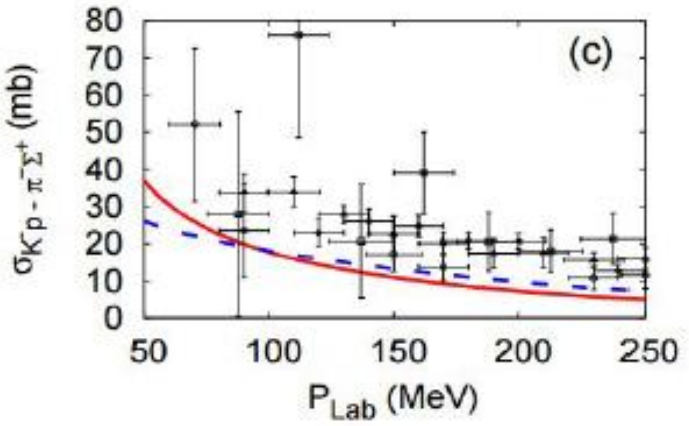
K^-N elastic and inelastic scatterings for p_K < 100 MeV/c

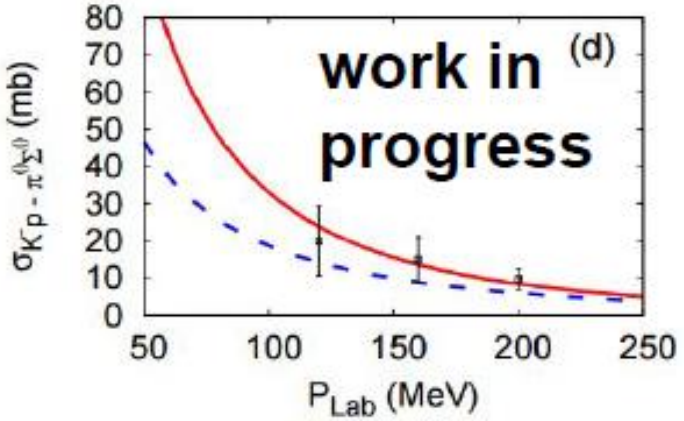
The parameters of the models are constrained by the existing scattering data

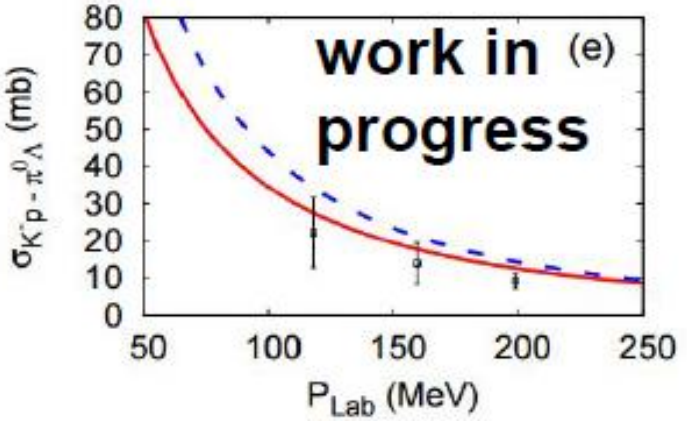
Phen. [Y. Ikeda and T. Sato, Phys. Rev. C76, 035203 (2007)]
Chiral [S. Ohnishi, Y. Ikeda, T. Hyodo, W. Weise, Phys.Rev. C93 (2016) no.2, 025207]











KNscat – elastic scattering

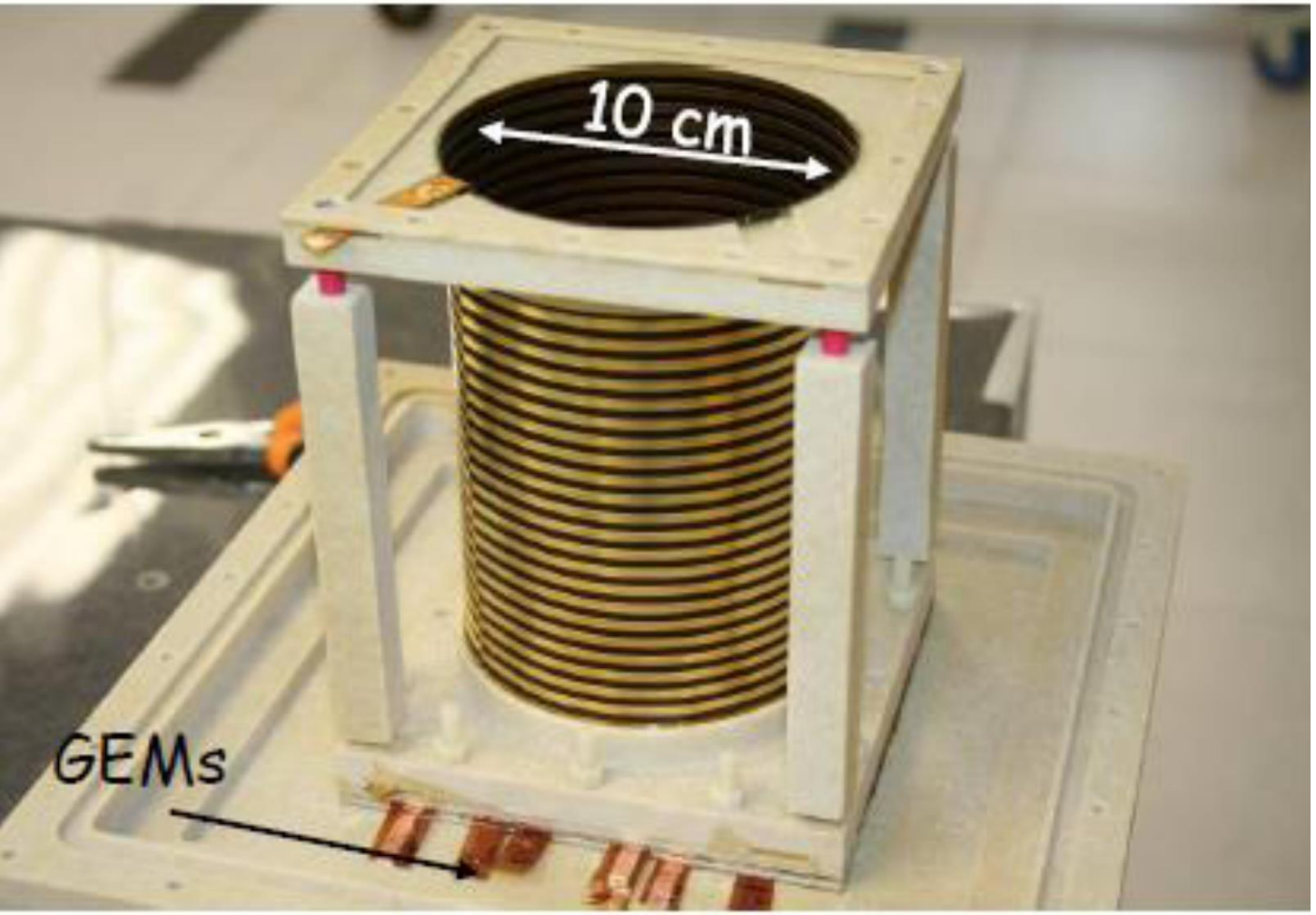
for: H2 – D2 – He – Ar

Main detector components:

- ❑ kaon monitor
- ❑ active TPC
- ❑ charged kaon detector

ACTIVE TPC PROTOTYPE DEVELOPED AT LNF

within EU-FP7 HadronPhysics3

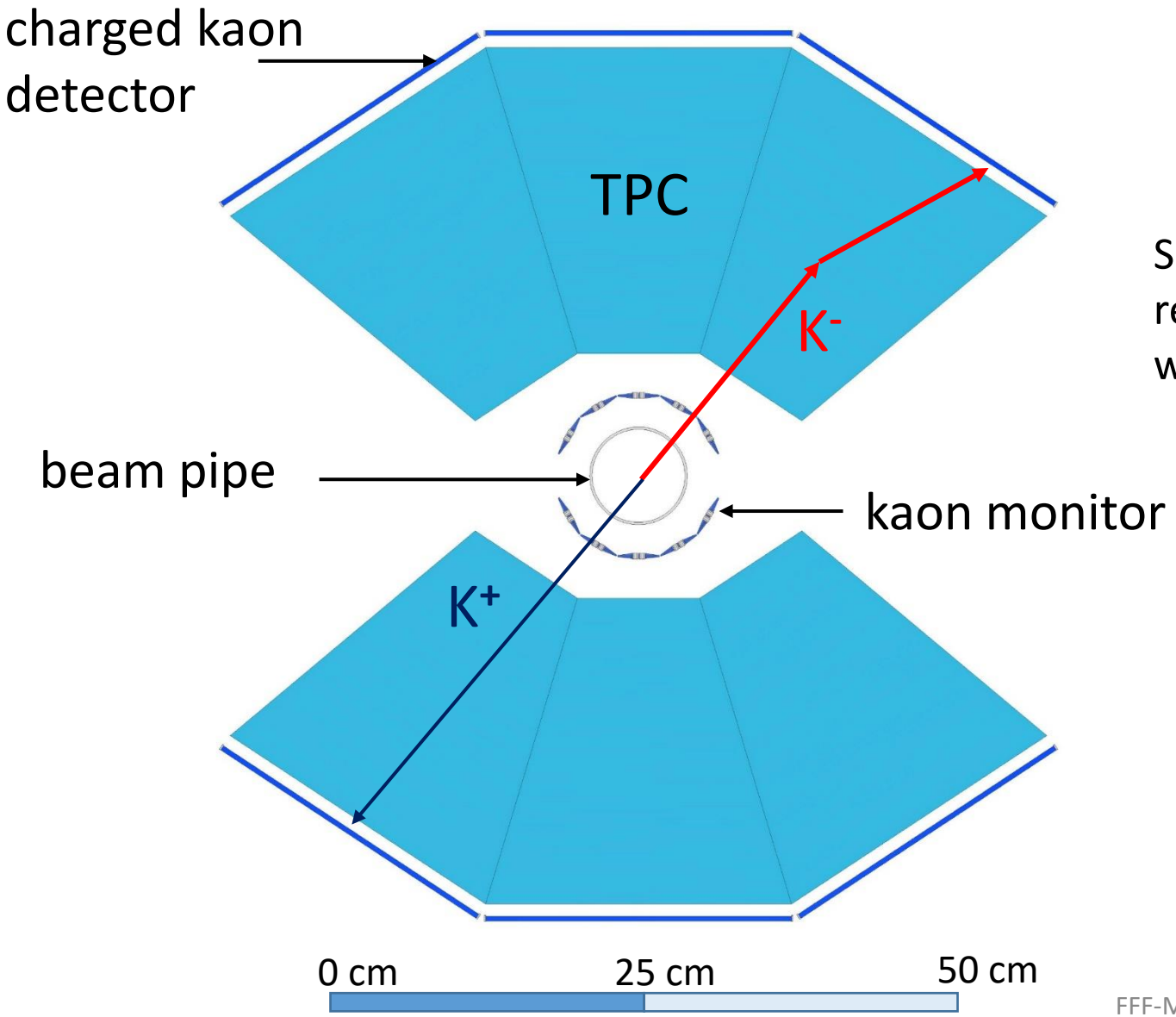


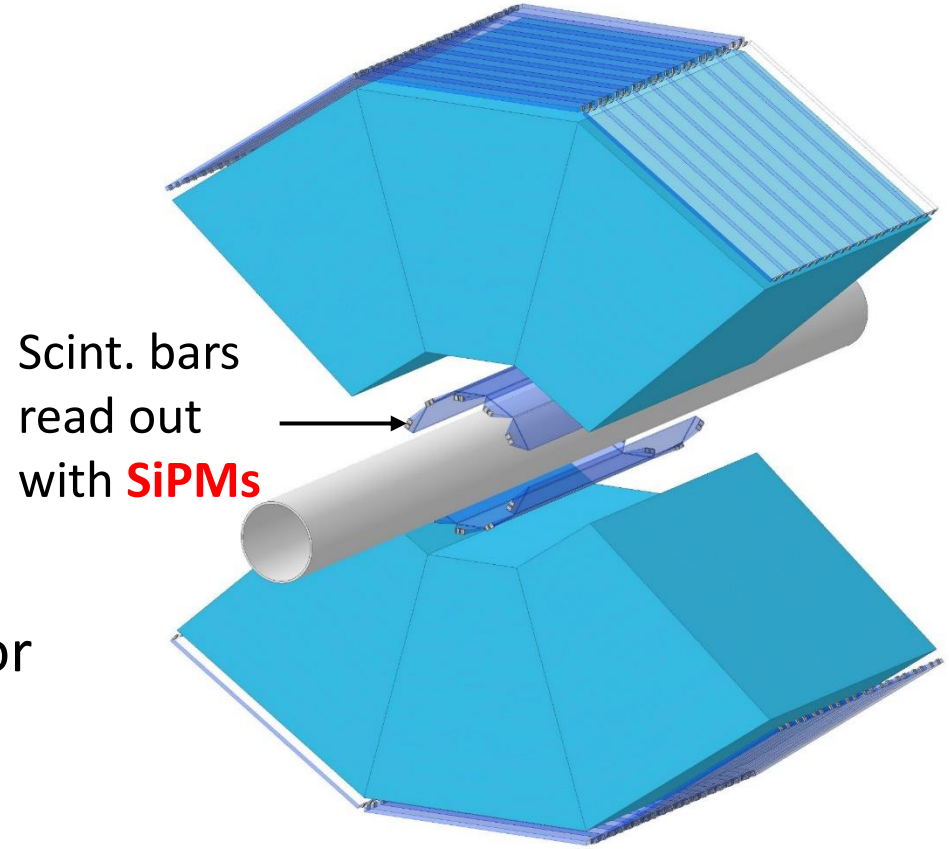
Performances of an Active Target GEM-Based TPC
Modern Instrumentation 4 (2015) 32-41

First tests of GEM based TPC with pure hydrogen
Diploma thesis, Univ. Vienna (2015)

Development of an active target TPC
within Horizon 2020 research and innovation programme: STRONG2020

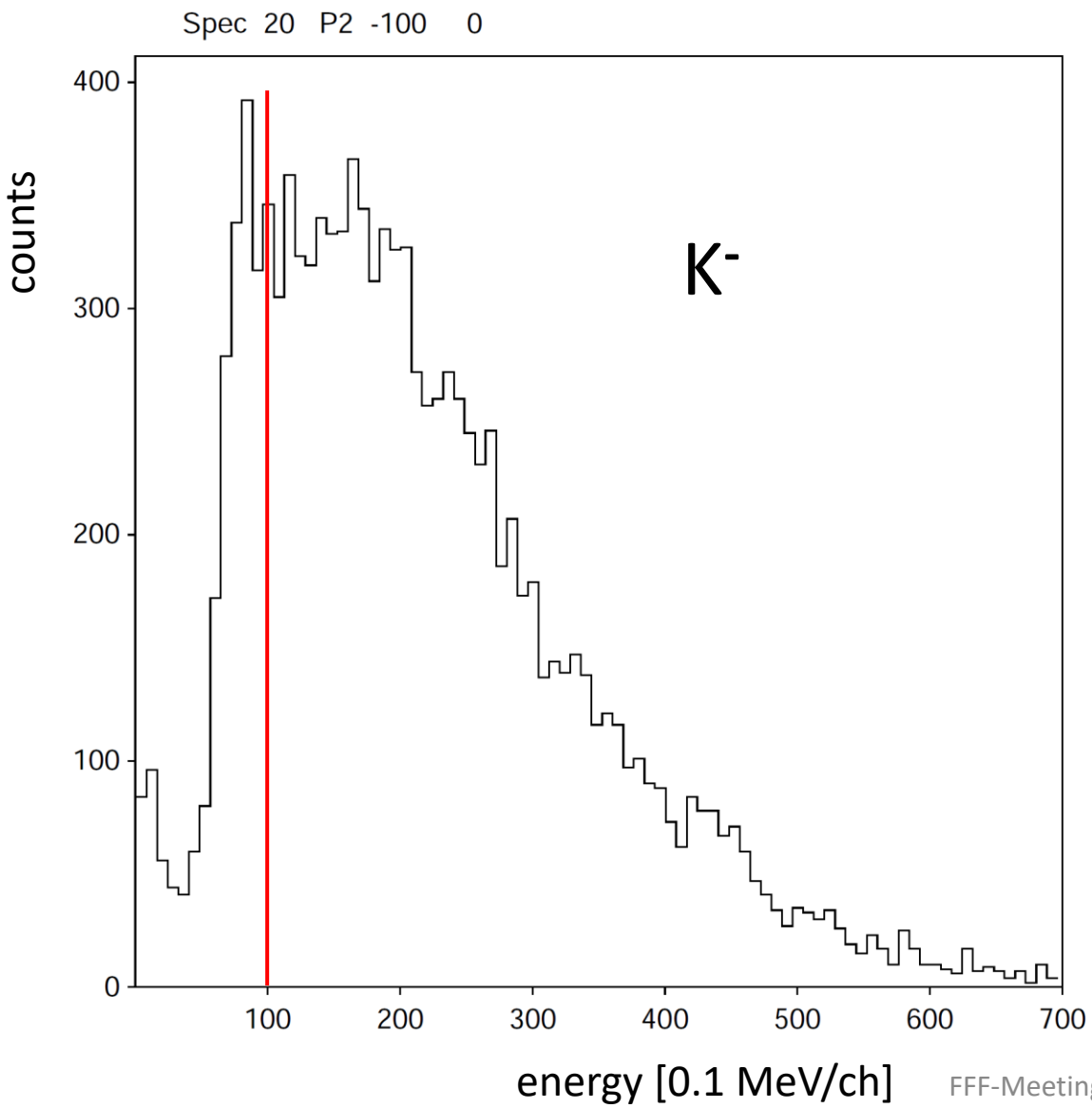
KNcat: elastic scattering, layout

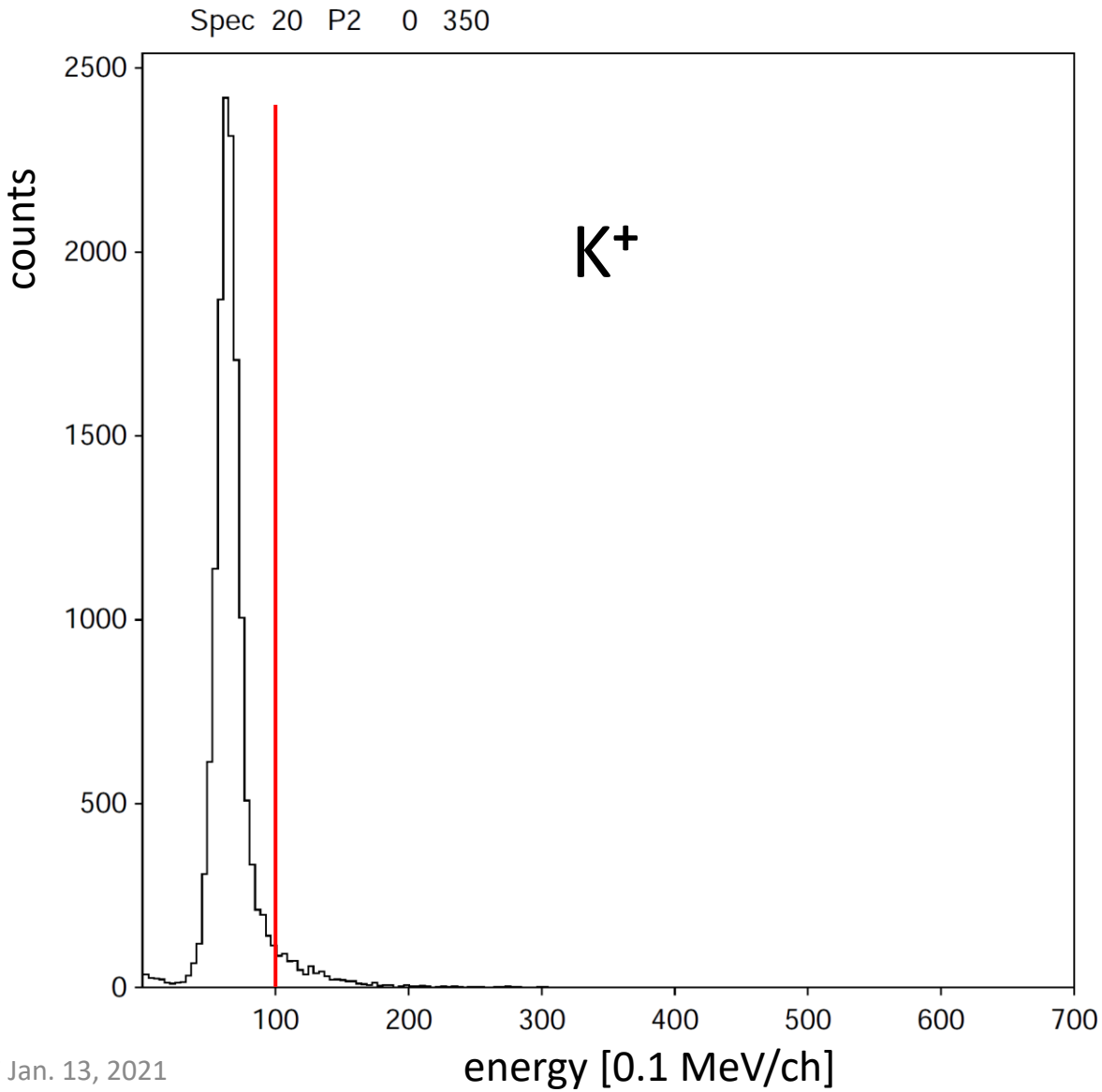




TPC prototyping ongoing at:
Sendai Univ., Japan
SMI, Austria (EU-STRONG2020)

Charged kaon detector - energy distribution

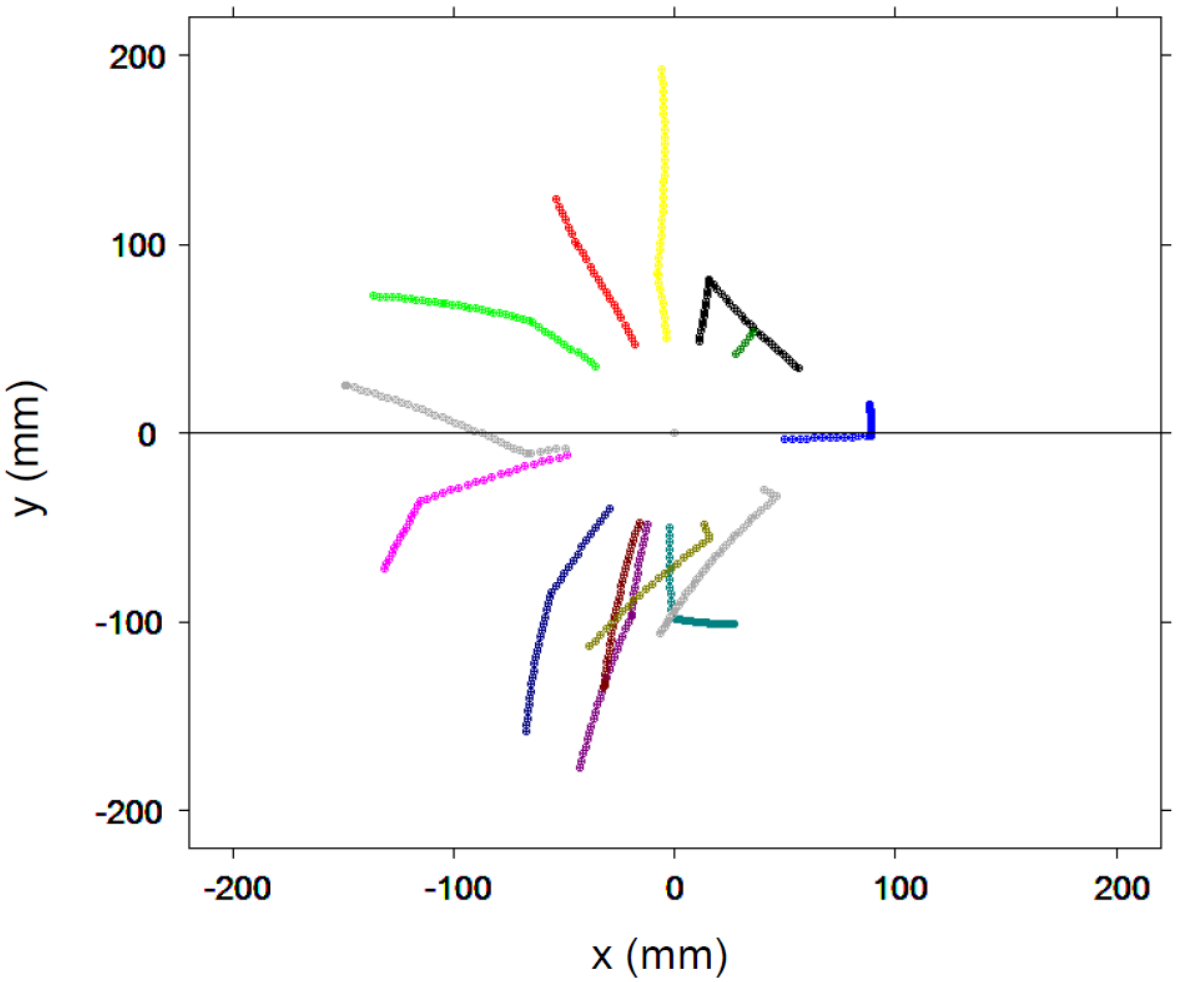




Elastic scattering of K^- in a H_2 gas target

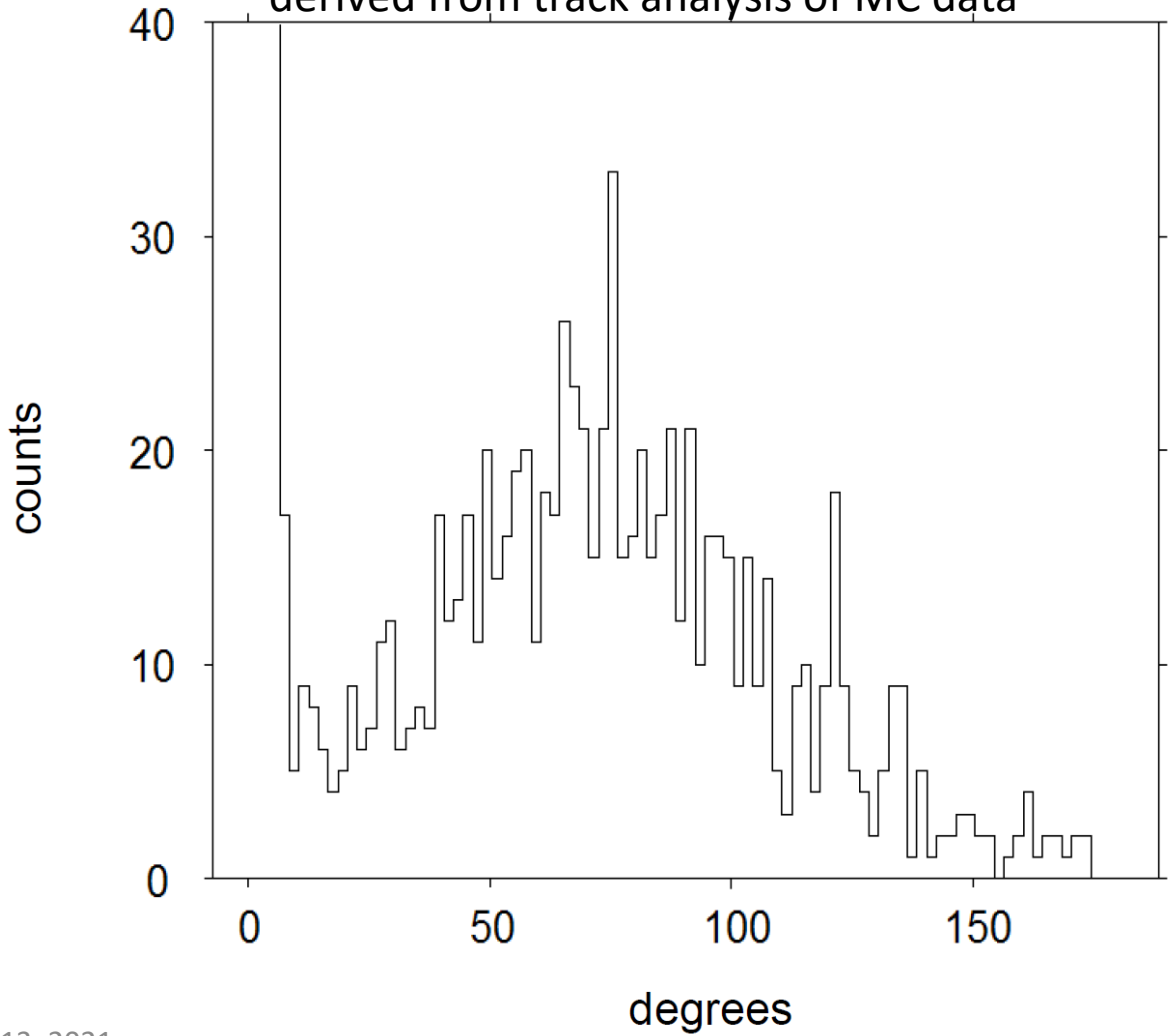
MC simulation with Geant-4

Scattered tracks of K^-



K^- scattering angles

derived from track analysis of MC data



Expected scattered events in H2 gas

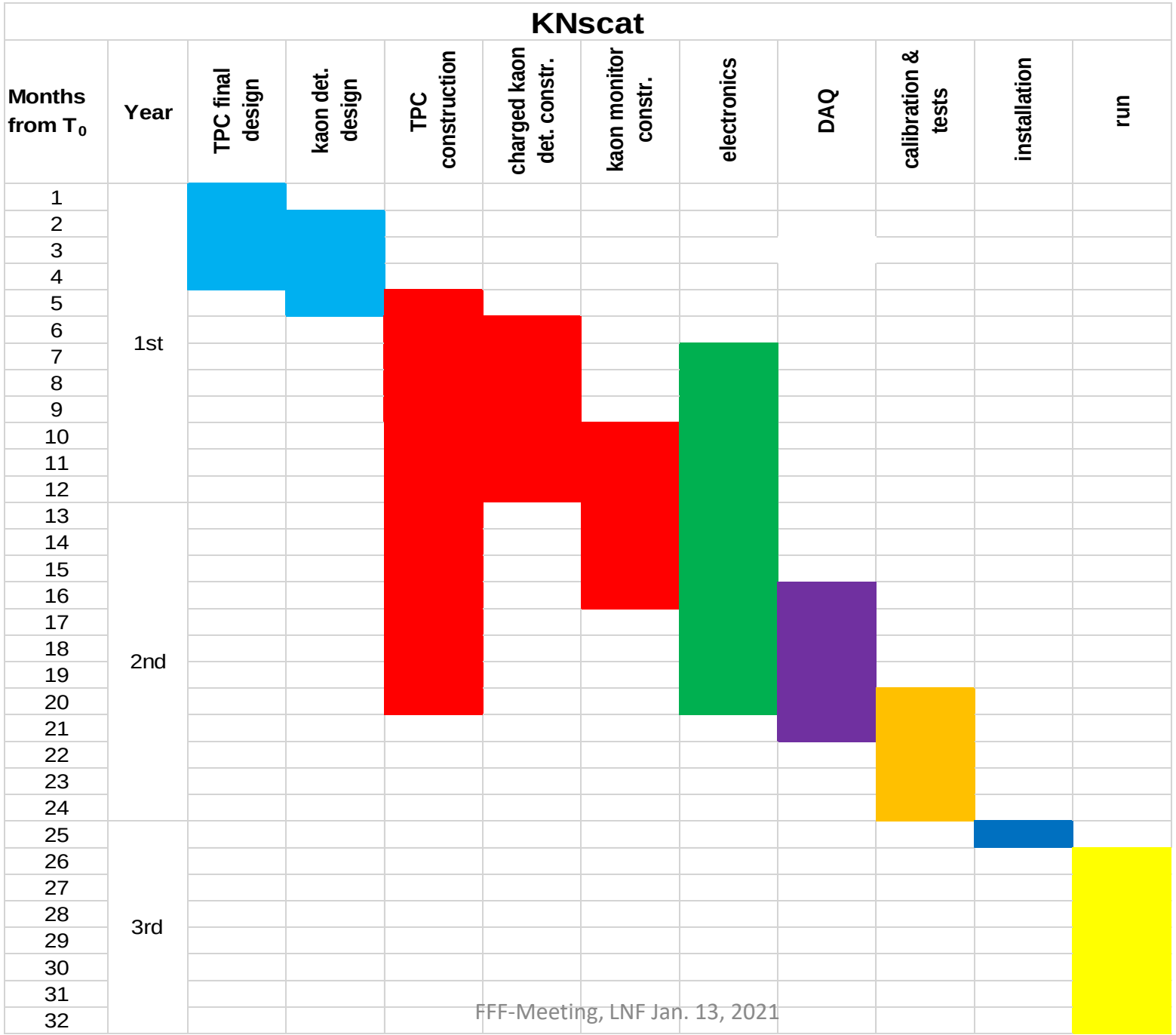
- integrated luminosity 12 $pb^{-1} \rightarrow$ 500(kaon-pairs/s)
- scattering angle > 10° $\rightarrow$ $N_{events/sec} \sim 1x10^{-3}$

➢ **$N_{events/30\ days} \sim 2.5 \times 10^{3}$**

International collaboration

• LNF – INFN	Italy
• SMI – OeAW	Austria
• Univ. Zagreb	Croatia
• Jagiellonian Univ.	Poland
• TUM Munich	Germany
• IFIN-HH, Bucharest	Romania
• INFN and Politecnico di Milano	Italy
• INFN Trieste	Italy
• Univ. Mainz	Germany
• Sendai Univ.	Japan
• RIKEN	Japan

Time frame

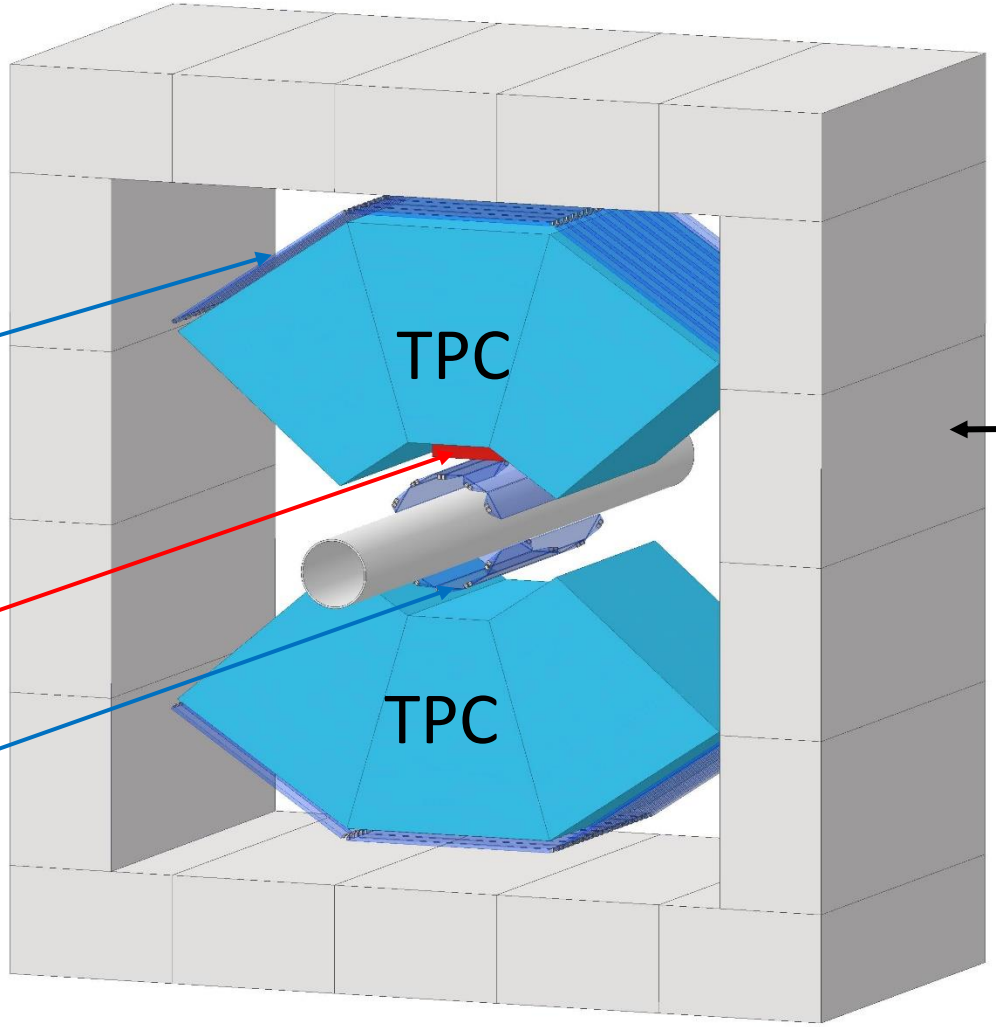

KNscat
Months from T_0
Year
TPC final design
kaon det. design
TPC construction
charged kaon det. constr.
kaon monitor constr.
electronics
DAQ
calibration & tests
installation
run
1st
2nd
3rd

KNscat – inelastic scattering

➢ detection of neutrons and gammas

$K^- p$ reaction	Subsequent decay modes	Finally produced particles
$\Sigma^+ \pi^-$	$\Sigma^+ \rightarrow \pi^0 p$; $\pi^0 \rightarrow 2\gamma$	$\pi^- 2\gamma p$
	$\Sigma^+ \rightarrow \pi^+ n$	$\pi^- \pi^+ n$
$\Sigma^- \pi^+$	$\Sigma^- \rightarrow \pi^- n$	$\pi^- \pi^+ n$
$\Sigma^0 \pi^0$	$\Sigma^0 \rightarrow \Lambda \gamma$; $\Lambda \rightarrow \pi^- p$	$\pi^- 3\gamma p$
	$\Sigma^0 \rightarrow \Lambda \gamma$; $\Lambda \rightarrow \pi^0 n$; $\pi^0 \rightarrow 2\gamma$	$5\gamma n$
$\Lambda \pi^0$	$\Lambda \rightarrow \pi^0 n$; $\pi^0 \rightarrow 2\gamma$	$2\gamma n$
	$\Lambda \rightarrow \pi^- p$	$\pi^- 2\gamma p$

KNscat – inelastic scattering, layout



Charged kaon detector

Cryogenic target:
Solid H2, D2, Ar
Liquid He

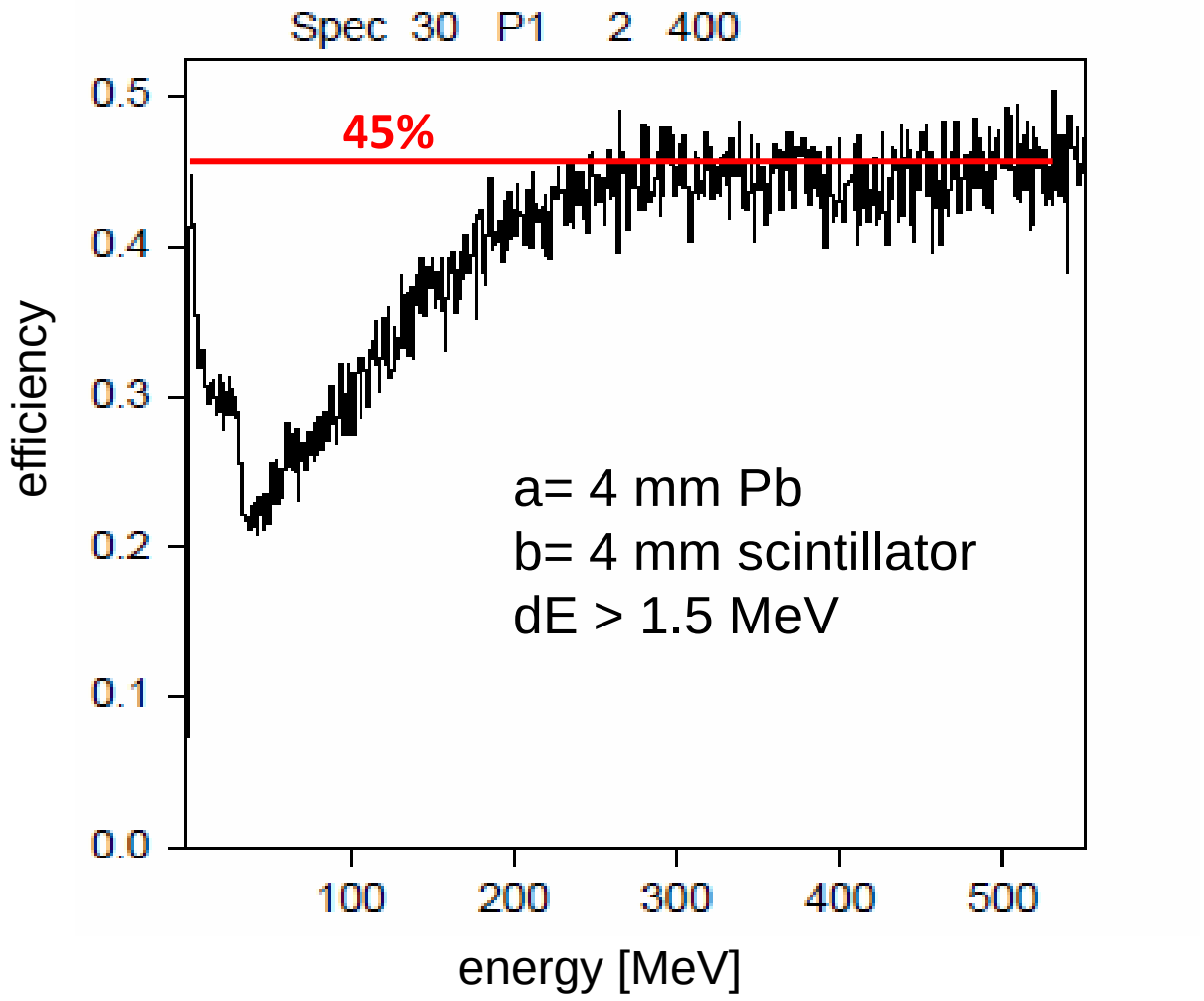
Kaon monitor

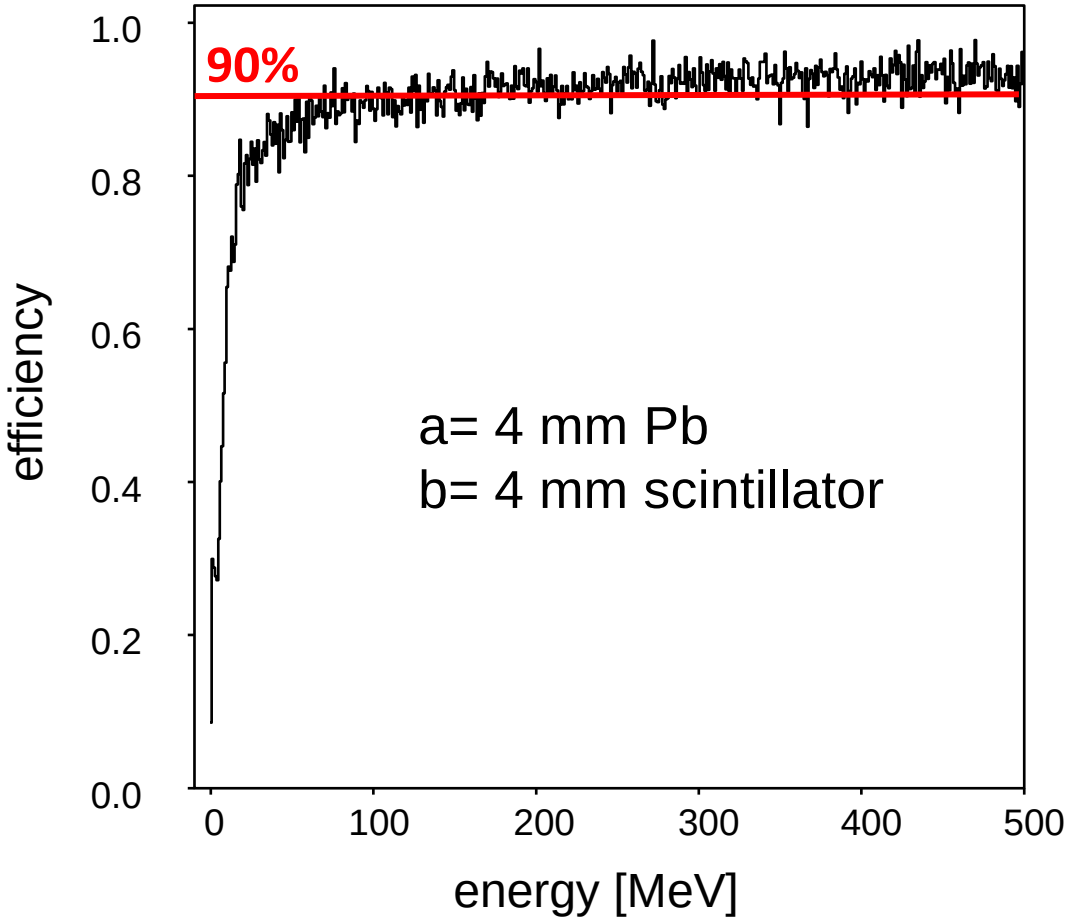
“Sandwich” type calorimeter
32 layers Pb – liq. Scintillator, thickness 25 cm

0 cm 25 cm 50 cm

Monte Carlo Study of a sandwich-calorimeter

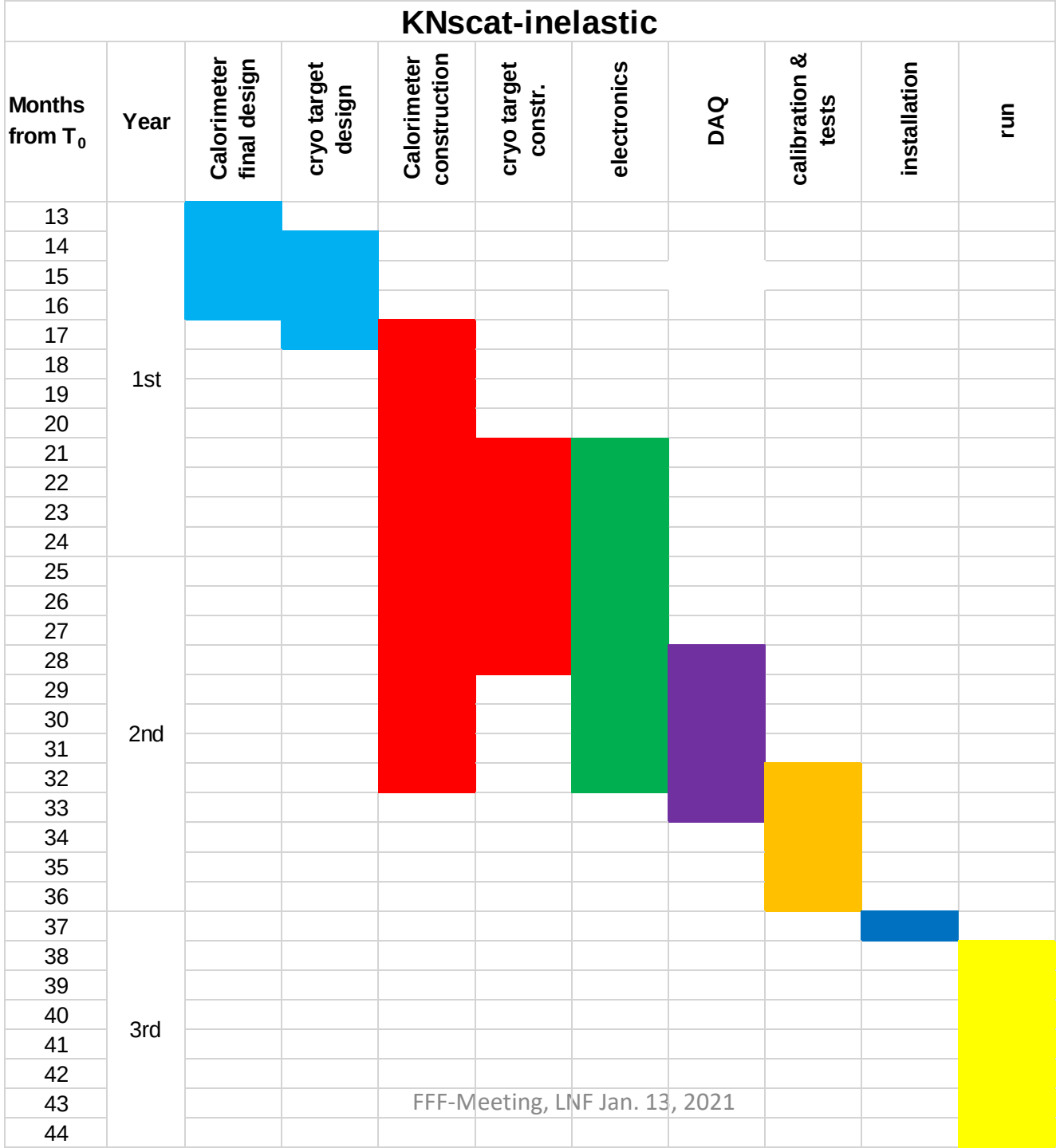
- neutron detection efficiency
  for 32 Pb sheets (thickness=a) in-between liq. scintillator (thickness=b)





Time frame

KNscat-inelastic



CONCLUSION

DAΦNE is worldwide the only machine for mono-energetic low energy kaons with high luminosity, ideally suited to perform measurements to study kaonic atoms and kaon-nuclei,

- with the goal to understand processes going from chiral symmetry breaking to neutron stars EOS which cannot be obtained otherwise!

A strong international community (EU-STRONG2020) is putting forward a programme to perform these experiments, with support from National and European funding agencies!

Thanks for your attention!